ПЕРМСКИЙ
ГОСУДАРСТВЕННЫЙ
НАЦИОНАЛЬНЫЙ
ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

А. Ф. Корлякова

ENGLISH FOR BEGINNERS

READER

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МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ

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НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ»

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Данный практикум предназначен для студентов бакалавриата и магистратуры начинающих изучать английский язык и поэтому тексты достаточно короткие и легкие для понимания, с простыми грамматическими структурами. Практикум содержит аутентичные тексты, связанные различными областями радиофизики, электроники, телекоммуникаций, компьютерных технологий. Каждый текст сопровождается лексико-грамматическими упражнениями, направленными на расширение потенциального словаря и развития навыков чтения.

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Издается по решению ученого совета факультета современных иностранных языков и литератур Пермского государственного национального исследовательского университета

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AI SUPERCHARGES BATTLE OF WEB SEARCH TITANS

by Joseph Boyle and Laurence Benhamou

AI could change the way search engines answer questions. A new generation of AI chatbots has unleashed a titanic battle between Microsoft and Google for the eyeballs of billions of web users, and the dollars they bring.

Microsoft has gone all-in with a multibillion-dollar investment in OpenAI, the firm behind the world's most buzzy bot ChatGPT, hoping to revolutionise its unloved Bing search engine.

Google has owned the search market for two decades and is not ceding any ground – it hit back this week with an in-house bot of its own, called Bard.

And the AI gold rush is not limited to Silicon Valley search giants, Chinese firm Baidu announcing its own bot this week.

But what exactly is the fight about?

Big tech firms have spent years ripping unimaginable amounts of data from the internet and churning it into so-called large language models that they use to train algorithms.

This is how voice recognition tools like Amazon's Alexa, Apple's Siri or Google Assistant work.

Google and Facebook owner Meta have poured their efforts into tools that can translate hundreds of languages, screen for harmful content, or target users with personalized ads.

Yet the fundamentals of search have remained largely unchanged.

You punch a few words into Google and it spits back a mix of useful links and often less useful ads.

But if AI has its way, these familiar pages of blue links could soon be just another dusty corner of internet history.

'Relegated to history'

"A tool like ChatGPT can create search engines that give a structured answer to questions instead of simply a list of documents like Google does at the moment," said Thierry Poibeau of French research institute CNRS.

What that means in practice is that future search engines will not produce lists of links–instead they will give the user coherent and full answers using multiple sources.

Neeva, a search engine that markets itself as privacy friendly, is already pushing this kind of experience.

Neeva founder Sridhar Ramaswamy, a former Google executive, told AFP that smaller companies were much better placed to innovate.

"We use large language models to look at all of the pages that are going to result for a query and show you a summary, and then show you a very rich visual experience," he said.

Like many analysts, Ramaswamy was highly critical of his former firm's obsession with ads, which he claimed was ruining the experience of users.

Industry analyst Rob Enderle said Google's search business risked being torpedoed by innovations in AI.

"Google still largely lives off the fact their search engine is the most widely used," he said.

But these changes could "relegate them to history".

However, there is still a long way to go before AI chatbots successfully wed themselves to search engines.

Racist bots

"Tools like chatGPT provide the illusion of an all-knowing being answering your questions, but that's not true," said Claude de Loupy of French AI text firm Syllabs.

Social media is overflowing with comical examples of ChatGPT's failings, not least its lack of ability in basic maths.

It has also been accused of bias after it refused to generate a poem praising Donald Trump but was more than happy to pen a paean to his successor as US president, Joe Biden.

There are questions about the sources the bots are trained on, the people who are employed in often terrible conditions to program them, copyright issues around pictures and the ultimate question of how firms will monetise their new toys.

However, OpenAI has largely managed to clear up one vital aspect that has plagued such bots–it is very difficult to get ChatGPT to say offensive things.

Microsoft got burnt in 2016 when its teenage AI chatbot Tay was immediately jumped on by Twitter users who got it to spout racist comments.

Meta was similarly embarrassed last year when it launched an AI tool called Galactica.

It was intended to help academics to write papers but had to be withdrawn after it invented citations and could be asked to write racist tracts.

Glossary

1. Artificial intelligence (AI): The simulation of human intelligence processes by computer systems.

2. Chatbot: A computer program designed to simulate conversation with human users, especially over the internet.

3. Bing: Microsoft's search engine.

4. Large language models: AI models that are trained on vast amounts of text data to understand and generate human language.

5. Voice recognition tools: AI-powered tools that can recognize and respond to human speech.

6. Personalized ads: Advertisements that are targeted to individual users based on their interests, behaviors, and demographics.

7. Neeva: A privacy-friendly search engine that provides structured answers to user queries using large language models.

8. Racist bots: Chatbots or other AI tools that exhibit bias or discrimination towards certain groups of people.

9. Copyright issues: Legal issues related to the ownership and use of intellectual property, such as images or text generated by AI tools.

10. Monetization: The process of making money from a product or service, often through advertising or other revenue streams.

Task 1

Find words and expressions meaning the following:

1. to allow someone else to have or own something, especially unwillingly or because you are forced to do so:
2. thing in an unfair way, because of allowing personal opinions to influence your judgment
3. song, film, or piece of writing that praises someone or something very enthusiastically**:**
4. to aim an attack at particular object, person
5. a picture, a short film, a song that tries to persuade people to buy something
6. it is clear and carefully considered
7. to combine two things , ideas
8. to change something into money
9. feeling ashamed or shy
10. to be taken back

Task 2

Answer the following questions:

1. What is the battle between Microsoft and Google about?
2. What is OpenAI and why did Microsoft invest in it?
3. What is Bard and who created it?
4. What other company announced its own bot this week?
5. How do voice recognition tools like Alexa and Siri work?
6. What have Google and Meta focused their efforts on?
7. How could AI change the way search engines answer questions?
8. What is Neeva and how does it differ from traditional search engines?
9. What are some criticisms of ChatGPT and AI chatbots in general?
10. What is one vital aspect that OpenAI has managed to clear up with ChatGPT?

Task 3

Say whether the following statements are true, false, or not mentioned:

1. Microsoft and Google are competing to develop AI chatbots and integrate them into their search engines.
2. Microsoft invested in OpenAI to enhance its Bing search engine using ChatGPT bot.
3. Google has developed its own AI chatbot called Bard to rival Microsoft's ChatGPT, but it is unclear who created it.
4. Baidu, a Chinese company, has also announced its own bot to compete in the AI chatbot market.
5. AI could change the way search engines answer questions by providing structured answers instead of just a list of links.
6. Neeva is the only search engine that offers a structured answer to questions using multiple sources.
7. Smaller companies are better placed to innovate and offer a more personalized and privacy-friendly search experience.
8. There are concerns about the sources bots are trained on, the working conditions of programmers, copyright issues around pictures, and how firms will monetize their new toys.
9. Offensive language and bias are still significant challenges for AI chatbots.
10. Microsoft and Meta have faced backlash after their AI chatbots spouted racist comments or generated offensive content.

STUDY SHOWS HOW LARGE LANGUAGE MODELS LIKE GPT-3 CAN LEARN A NEW TASK FROM JUST A FEW EXAMPLES
by Adam Zewe, Massachusetts Institute of Technology

MIT researchers found that massive neural network models that are similar to large language models are capable of containing smaller linear models inside their hidden layers, which the large models could train to complete a new task using simple learning algorithms. Credit: Jose-Luis Olivares, MIT

Large language models like OpenAI's GPT-3 are massive neural networks that can generate human-like text, from poetry to programming code. Trained using troves of internet data, these machine-learning models take a small bit of input text and then predict the text that is likely to come next.

But that's not all these models can do. Researchers are exploring a curious phenomenon known as in-context learning, in which a large language model learns to accomplish a task after seeing only a few examples–despite the fact that it wasn't trained for that task. For instance, someone could feed the model several example sentences and their sentiments (positive or negative), then prompt it with a new sentence, and the model can give the correct sentiment.

Typically, a machine-learning model like GPT-3 would need to be retrained with new data for this new task. During this training process, the model updates its parameters as it processes new information to learn the task. But with in-context learning, the model's parameters aren't updated, so it seems like the model learns a new task without learning anything at all.

Scientists from MIT, Google Research, and Stanford University are striving to unravel this mystery. They studied models that are very similar to large language models to see how they can learn without updating parameters.

The researchers' theoretical results show that these massive neural network models are capable of containing smaller, simpler linear models buried inside them. The large model could then implement a simple learning algorithm to train this smaller, linear model to complete a new task, using only information already contained within the larger model. Its parameters remain fixed.

An important step toward understanding the mechanisms behind in-context learning, this research opens the door to more exploration around the learning algorithms these large models can implement, says Ekin Akyürek, a computer science graduate student and lead author of a paper exploring this phenomenon. With a better understanding of in-context learning, researchers could enable models to complete new tasks without the need for costly retraining.

"Usually, if you want to fine-tune these models, you need to collect domain-specific data and do some complex engineering. But now we can just feed it an input, five examples, and it accomplishes what we want. So in-context learning is a pretty exciting phenomenon," Akyürek says.

The paper is published on the *arXiv* preprint server.

Joining Akyürek on the paper are Dale Schuurmans, a research scientist at Google Brain and professor of computing science at the University of Alberta; as well as senior authors Jacob Andreas, the X Consortium Assistant Professor in the MIT Department of Electrical Engineering and Computer Science and a member of the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL); Tengyu Ma, an assistant professor of computer science and statistics at Stanford; and Danny Zhou, principal scientist and research director at Google Brain. The research will be presented at the International Conference on Learning Representations.

A model within a model

In the machine-learning research community, many scientists have come to believe that large language models can perform in-context learning because of how they are trained, Akyürek says.

For instance, GPT-3 has hundreds of billions of parameters and was trained by reading huge swaths of text on the internet, from Wikipedia articles to Reddit posts. So, when someone shows the model examples of a new task, it has likely already seen something very similar because its training dataset included text from billions of websites. It repeats patterns it has seen during training, rather than learning to perform new tasks.

Akyürek hypothesized that in-context learners aren't just matching previously seen patterns, but instead are actually learning to perform new tasks. He and others had experimented by giving these models prompts using synthetic data, which they could not have seen anywhere before, and found that the models could still learn from just a few examples. Akyürek and his colleagues thought that perhaps these neural network models have smaller machine-learning models inside them that the models can train to complete a new task.

"That could explain almost all of the learning phenomena that we have seen with these large models," he says.

To test this hypothesis, the researchers used a neural network model called a transformer, which has the same architecture as GPT-3, but had been specifically trained for in-context learning.

By exploring this transformer's architecture, they theoretically proved that it can write a linear model within its hidden states. A neural network is composed of many layers of interconnected nodes that process data. The hidden states are the layers between the input and output layers.

Their mathematical evaluations show that this linear model is written somewhere in the earliest layers of the transformer. The transformer can then update the linear model by implementing simple learning algorithms.

In essence, the model simulates and trains a smaller version of itself.

Probing hidden layers

The researchers explored this hypothesis using probing experiments, where they looked in the transformer's hidden layers to try and recover a certain quantity.

"In this case, we tried to recover the actual solution to the linear model, and we could show that the parameter is written in the hidden states. This means the linear model is in there somewhere," he says.

Building off this theoretical work, the researchers may be able to enable a transformer to perform in-context learning by adding just two layers to the neural network. There are still many technical details to work out before that would be possible, Akyürek cautions, but it could help engineers create models that can complete new tasks without the need for retraining with new data.

"The paper sheds light on one of the most remarkable properties of modern large language models–their ability to learn from data given in their inputs, without explicit training. Using the simplified case of linear regression, the authors show theoretically how models can implement standard learning algorithms while reading their input, and empirically which learning algorithms best match their observed behavior," says Mike Lewis, a research scientist at Facebook AI Research who was not involved with this work. "These results are a stepping stone to understanding how models can learn more complex tasks, and will help researchers design better training methods for language models to further improve their performance."

Moving forward, Akyürek plans to continue exploring in-context learning with functions that are more complex than the linear models they studied in this work. They could also apply these experiments to large language models to see whether their behaviors are also described by simple learning algorithms. In addition, he wants to dig deeper into the types of pretraining data that can enable in-context learning.

"With this work, people can now visualize how these models can learn from exemplars. So, my hope is that it changes some people's views about in-context learning," Akyürek says. "These models are not as dumb as people think. They don't just memorize these tasks. They can learn new tasks, and we have shown how that can be done."

Glossary

1. Neural network models: computer models that simulate the function of the human brain, used in machine learning.

2. Large language models: massive neural networks that can generate human-like text, trained using troves of internet data.

3. In-context learning: a phenomenon where a large language model learns to accomplish a new task after seeing only a few examples, without updating its parameters.

4. Learning algorithms: mathematical formulas and processes used by machine learning models to learn from data and improve their performance.

5. Fine-tuning: the process of adjusting the parameters of a machine learning model to improve its performance on a specific task.

6. ArXiv preprint server: an online repository of scientific papers that have not yet been peer-reviewed or published in academic journals.

7. International Conference on Learning Representations: an academic conference focused on research in machine learning and artificial intelligence.

8. Parameters: the internal settings of a machine learning model that determine how it processes input data and makes predictions.

9. Swaths of text: large amounts of written or digital content, often used as training data for machine learning models.

10. Training dataset: the set of data used to train a machine learning model, which is used to adjust its parameters and improve its performance.

11. Neural network models: computer models that simulate the function of the human brain, used in machine learning.

12. Large language models: massive neural networks that can generate human-like text, trained using troves of internet data.

13. In-context learning: a phenomenon where a large language model learns to accomplish a new task after seeing only a few examples, without updating its parameters.

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18. Parameters: the internal settings of a machine learning model that determine how it processes input data and makes predictions.

19. Swaths of text: large amounts of written or digital content, often used as training data for machine learning models.

20. Training dataset: the set of data used to train a machine learning model, which is used to adjust its parameters and improve its performance.

21. Probing experiments: experiments where researchers look into the hidden layers of a neural network model to recover certain quantities or information.

22. Hidden states: the layers between the input and output layers of a neural network model that process data.

23. Linear model: a type of mathematical model used to describe a linear relationship between two or more variables.

24. Transformer: a type of neural network model with the same architecture as GPT-3, specifically trained for in-context learning.

25. Empirical: based on observation or experience rather than theory or pure logic.

26. Pretraining data: data used to train a machine learning model before fine-tuning it on a specific task.

Task 1

Find words and expressions meaning the following:

1. treasure
2. to carry out, to complete
3. to solve
4. trying
5. put into practice
6. obvious, accurate, direct
7. launch pad

Task 2

Answer the following questions:

1. What are large language models capable of generating?

2. How are large language models trained?

3. What is in-context learning?

4. What is the difference between in-context learning and traditional machine learning?

5. Who conducted the research on in-context learning?

6. What did the researchers discover about massive neural network models?

7. How could a better understanding of in-context learning benefit machine learning research?

8. What do large language models do during training?

9. What did Akyürek hypothesize about in-context learners?

10. How did the researchers test their hypothesis about in-context learners?

11. What are hidden states in a neural network?

12. How did the researchers recover the solution to the linear model from the transformer's hidden layers?

13. What could adding two layers to a neural network enable it to do?

14. What are some future directions for research on in-context learning?

Task 3

Say whether the following statements are true, false or not given:

1. Large language models are only trained to repeat patterns they have seen before. False, they are also capable of in-context learning.

2. Akyürek hypothesized that in-context learners are only matching previously seen patterns. False, they are actually learning to perform new tasks.

3. The researchers tested their hypothesis about in-context learners by conducting experiments on human subjects. False, they explored the architecture of a neural network model called a transformer and theoretically proved that it can write a linear model within its hidden states.

4. Hidden states in a neural network are the input and output layers of the network. False, they are the layers between the input and output layers that process data.

5. The researchers recovered the solution to the linear model from the transformer's hidden layers by using probing experiments. True.

6. Large language models are only capable of learning from explicit training with new data. False, they can also learn from data given in their inputs without explicit training.

7. The researchers proved that a linear model is written in the output layers of the transformer. False, the linear model is written somewhere in the earliest layers of the transformer.

8. Akyürek plans to continue exploring in-context learning with more complex functions than the linear models studied in this work. True.

9. The researchers conducted probing experiments on human subjects to test their hypothesis about in-context learners. False, they conducted probing experiments on a neural network model called a transformer.

10. The ability of large language models to learn from exemplars has changed some people's views about in-context learning. True.

A DEEP BELIEF NEURAL NETWORK BASED ON SILICON MEMRISTIVE SYNAPSES

by Ingrid Fadelli, Tech Xplore

Memristors measured in a probe station. Credit: Technion Spokesperson Department.

While artificial intelligence (AI) models are becoming increasingly advanced, training and running these models on conventional computer hardware is very energy consuming. Engineers worldwide have thus been trying to create alternative, brain-inspired hardware that could better support the high computational load of AI systems.

Researchers at Technion–Israel Institute of Technology and the Peng Cheng Laboratory have recently created a new neuromorphic computing system supporting deep belief neural networks (DBNs), a generative and graphical class of deep learning models. This system, outlined in *Nature Electronics*, is based on silicon-based memristors, energy-efficient devices that can both store and process information.

Memristors are electrical components that can switch or regulate the flow of electrical current in a circuit, while also remembering the charge that passed through it. As their capabilities and structure resemble those of synapses in the human brain more closely than conventional memories and processing units, they could be better suited for running AI models.

"We, as part of a large scientific community, have been working on neuromorphic computing for quite some time now," Shahar Kvatinsky, one of the researchers who carried out the study, told TechXplore. "Usually, memristors are used to perform analog computations. It is known that there are two main limitations in the neuromorphic field–one is the memristive technology that is still not widely available. The second is the high cost of converters that are required to convert the analog computation to the digital data and vice versa."

When developing their neuromorphic computing system, Kvatinsky and his colleagues set out to overcome these two crucial limitations of memristor-based systems. As memristors are not widely available, they decided to instead use a commercially available Flash technology developed by Tower Semiconductor, engineering it to behave like a memristor. In addition, they specifically tested their system with a newly designed DBN, as this particular model does not require data conversions (i.e., its input and output data are binary and inherently digital.

"DBNs are an old machine learning theoretical concept," Kvatinsky explained. "Our idea was to use binary (i.e., either with a value of 0 or 1) neurons (input/output). There are several unique properties (compared to deep neural networks), including that the training of such a network relies on calculating the accumulated desired model update and updating it only when reaching a certain threshold."

The artificial synapses created by the researchers were fabricated using commercial complementary-metal-oxide-semiconductor (CMOS) processes. These memristive, silicon-based synapses have numerous advantageous features, including analog tunability, high endurance, long retention time, predictable cycling degradation, and moderate variability across different devices.

Kvatinsky and his colleagues demonstrated their system by training a type of DBN, known as a restricted Boltzmann machine, on a pattern recognition task. To train this model (a 19x 8 memristive restricted Boltzmann machine), they used two 12 x 8 arrays of the memristors they engineered.

"The simplicity of DBN makes them attractive for hardware implementation," Kvatinsky said. "We showed that even though DBN are simple to implement (due to their binary nature), we can reach high accuracy (>97% accurate recognition of handwritten digits) when using Y-Flash based memristors."

The architecture introduced by this team of researchers offers a new viable solution for running restricted Boltzmann machines and other DBNs. In the future, it could inspire the development of similar neuromorphic systems, collectively helping to run AI systems more energy-efficiently.

"We now plan to scale up this architecture, explore additional memristive technologies and explore more neural network architectures."

Glossary

1. Artificial intelligence (AI): the simulation of human intelligence in machines.

2. Computational load: the amount of processing power required to run a particular task or system.

3. Neuromorphic computing: a type of computing that mimics the structure and function of the human brain.

4. Deep belief neural networks (DBNs): a type of deep learning model that uses graphical structures to represent data.

5. Memristors: electrical components that can store and process information, and are designed to mimic the function of synapses in the human brain.

6. Synapses: connections between neurons in the human brain that allow for the transmission of signals.

7. Analog computations: calculations that use continuous values rather than discrete values.

8. Digital data: data that is represented using discrete values, such as binary digits.

9. Complementary-metal-oxide-semiconductor (CMOS): a type of technology used to fabricate electronic devices.

10. Restricted Boltzmann machine: a type of deep learning model used for pattern recognition tasks.

11. Y-Flash: a commercially available Flash technology developed by Tower Semiconductor, used in the neuromorphic computing system described in the article.

12. Accuracy: the degree to which a model or system produces correct results.

13. Energy-efficient: using less energy to perform a task.

14. Architecture: the design and structure of a system or model.

Task 1

Find words or expressions that mean the following:

1. What is the problem with training and running AI models on conventional computer hardware?

2. What have engineers been trying to create to better support the high computational load of AI systems?

3. What is a memristor?

4. How do memristors resemble synapses in the human brain?

5. What is the main limitation of memristive technology in the neuromorphic field?

6. How did the researchers overcome the limitation of memristor-based systems?

7. What is a DBN?

8. Why did the researchers specifically test their system with a newly designed DBN?

9. What are some advantageous features of the artificial synapses created by the researchers?

10. What did the researchers demonstrate with their system?

Task 2

Say whether the following statements are true or false:

1. Training and running AI models on conventional computer hardware is energy efficient.

2. Engineers have not been trying to create alternative, brain-inspired hardware to better support the high computational load of AI systems.

3. Memristors are electrical components that can store and process information.

4. Memristors do not resemble synapses in the human brain.

5. Memristive technology is widely available in the neuromorphic field.

6. The researchers used memristors for their neuromorphic computing system.

7. DBN stands for Deep Brain Network.

8. The researchers specifically tested their system with a newly designed DBN because it requires data conversions.

9. The artificial synapses created by the researchers have numerous advantageous features.

10. The researchers did not demonstrate their system by training a type of DBN.

STACK OVERFLOW IS THE SITE THAT ANSWERS ALL QUESTIONS FOR PROGRAMMERS AND CODERS. THEY HAVE TEMPORARILY BLOCKED USERS FROM POSTING RESPONSES CREATED *by the AI chatbot ChatGPT*

Site mods stated that the ban was temporary and that they would make a final decision in the future after consulting the community. The mods said that ChatGPT makes it too easy to generate answers and flood the site, which can appear correct at first glance but are often incorrect upon closer examination.

"The primary problem is that while the answers which ChatGPT produces have a high rate of being incorrect, they typically look like they might be good and the answers are very easy to produce," wrote the mods (emphasis theirs). "As such, we need the volume of these posts to reduce […] So, for now, the use of ChatGPT to create posts here on Stack Overflow is not permitted. If a user is believed to have used ChatGPT after this temporary policy is posted, sanctions will be imposed to prevent users from continuing to post such content, even if the posts would otherwise be acceptable."

ChatGPT, an experimental chatbot developed by OpenAI, is based on GPT-3.5's autocomplete text generator. The bot's web demo was published last week and has been enthusiastically received by users worldwide. The bot's interface allows users to ask questions. It returns impressive, fluid results for various queries, including generating TV scripts, poems, and songs.

Many users have appreciated ChatGPT's abilities, but others have noticed its inability to respond reasonably. ChatGPT can create a biography about a public figure. It may even insert incorrect biographical information with confidence. It can also explain how to program software to perform a particular function.

This is just one of many known flaws in AI text generation models. Also called large language models (LLMs), it is one of many. These systems are trained by analyzing patterns in large reams of text pulled from the internet. These systems look for statistical patterns in the data and use them to predict which words will be next in any given sentence. They lack the hard-coded rules governing how specific systems work worldwide, which leads to their propensity for creating "fluent bullshit."

It's difficult to know with certainty how much of these systems' output is fake, given their enormous scale. Stack Overflow has decided that there is too much risk of misleading its users.

Stack Overflow's decision to make this announcement is especially noteworthy, as AI experts are currently discussing the possible danger posed by large language models. Yann LeCun (chief AI scientist at Facebook parent Meta) has stated, for instance, that LLMs can produce wrong output, such as misinformation, but they don't make it easier to share this text, which is what causes harm. Others argue that the cost of these systems generating text at a low rate increases the likelihood that it will be shared later.

There has been no evidence to show LLMs have any harmful effects in the real world. Recent events at StackOverflow prove that these systems can create new problems. In announcing the ban of ChatGPT, the mods noted that ChatGPT's "volume (thousands!) of AI-generated answers" and that answers often require detailed reading by someone with some subject matter expertise to determine if the answer is terrible to have effectively overwhelmed our volunteer-based quality curation infrastructure.

This could lead to a repeat of the same pattern on other platforms. AI content will drown out real users who have valid but inaccurate data. The exact nature of each platform and its moderation capabilities will determine how this might play out. It remains to be seen if these issues can be addressed with tools such as improved spam filters.

Stack Overflow has received a wide range of positive responses to its policy announcement on its discussion boards and on related forums like Hacker News, where users added the caveat that it might be difficult for Stack Overflow mods to identify AI-generated answers.

One user said that they felt the bot's answers to questions regarding coding problems often needed to be corrected. The scary thing was how incorrect and confident it was, said one user. The text was very well written, but it contained many errors.

Glossary

1. Flood: an overwhelming amount or quantity of something.

2. Chatbot: a computer program designed to simulate conversation with human users, especially over the internet.

3. Autocomplete: a feature in software that suggests the completion of a word or phrase as it is being typed.

4. Query: a question or request for information.

5. Large language model: a type of artificial intelligence system that uses statistical patterns to generate text.

6. Fluent bullshit: text generated by AI systems that sounds plausible but is actually false or misleading.

7. Misinformation: false or inaccurate information that is spread intentionally or unintentionally.

8. Curation infrastructure: the systems and processes used to manage and maintain content on a website or platform.

9. Spam filters: software tools that identify and remove unwanted or unsolicited messages or content.

10. Policy announcement: a statement or declaration of a new policy or rule.

11. Subject matter expertise: specialized knowledge and understanding of a particular topic or subject area.

Task 1

Find words that mean the following:

1. frightening
2. an official oder that prevents something from happening
3. mistake
4. value
5. when first looking

Task 2

Answer the following questions:

1. Why did Stack Overflow ban the use of ChatGPT to create posts?
2. Is the ban on ChatGPT permanent?
3. What is ChatGPT?
4. What are some of the flaws in AI text generation models?
5. What is Yann LeCun's view on the possible danger posed by large language models?
6. Has there been any evidence to show that LLMs have harmful effects in the real world?
7. How did users respond to Stack Overflow's policy announcement on its discussion boards and related forums?
8. What is the caveat added by users on Hacker News regarding the ban on ChatGPT?
9. What kind of questions can ChatGPT answer?
10. What is the primary problem with the answers generated by ChatGPT?

Task 3

Say whether the following statemenrts true, false or not mentioned:

1. Stack Overflow banned the use of ChatGPT because it was causing technical issues on the site.

2. The ban on ChatGPT is permanent, and there will be no further consultation with the community.

3. ChatGPT is an experimental chatbot developed by OpenAI that is based on GPT-3.5's autocomplete text generator.

4. AI text generation models are flawless and always produce accurate output.

5. Yann LeCun has stated that large language models can produce wrong output, such as misinformation, but they don't make it easier to share this text, which is what causes harm.

6. There has been no evidence to show that LLMs have any harmful effects in the real world.

7. Users responded positively to Stack Overflow's policy announcement on its discussion boards and related forums.

8. Users added the caveat that it might be difficult for Stack Overflow mods to identify AI-generated answers.

9. ChatGPT can answer various queries, including generating TV scripts, poems, and songs, as well as explain how to program software to perform a particular function.

10. The primary problem with the answers generated by ChatGPT is that they have a high rate of being incorrect, but they typically look like they might be good and are very easy to produce.

TEXT-TO-IMAGE AI: POWERFUL, EASY-TO-USE TECHNOLOGY FOR MAKING ART – AND FAKES

by Hany Farid,University of California, BerkeleyDec 5, 2022 6:00 PM

Type “Teddy bears working on new AI research on the moon in the 1980s” into any of the recently released text-to-image artificial intelligence image generators, and after just a few seconds the sophisticated software will produce an eerily pertinent image.

Seemingly bound by only your imagination, this latest trend in synthetic media has delighted many, inspired others and struck fear in some.

Google, research firm OpenAI and AI vendor Stability AI have each developed a text-to-image image generator powerful enough that some observers are questioning whether in the future people will be able to trust the photographic record.

As a computer scientist who specializes in image forensics, I have been thinking a lot about this technology: what it is capable of, how each of the tools have been rolled out to the public, and what lessons can be learned as this technology continues its ballistic trajectory.

Adversarial approach

Although their digital precursor dates back to 1997, the first synthetic images splashed onto the scene just five years ago. In their original incarnation, so-called generative adversarial networks (GANs) were the most common technique for synthesizing images of people, cats, landscapes and anything else.

A GAN consists of two main parts: generator and discriminator. Each is a type of large neural network, which is a set of interconnected processors roughly analogous to neurons.

Tasked with synthesizing an image of a person, the generator starts with a random assortment of pixels and passes this image to the discriminator, which determines if it can distinguish the generated image from real faces. If it can, the discriminator provides feedback to the generator, which modifies some pixels and tries again. These two systems are pitted against each other in an adversarial loop. Eventually the discriminator is incapable of distinguishing the generated image from real images.

Just as people were starting to grapple with the consequences of GAN-generated deepfakes – including videos that show someone doing or saying something they didn’t – a new player emerged on the scene: text-to-image deepfakes.

In this latest incarnation, a model is trained on a massive set of images, each captioned with a short text description. The model progressively corrupts each image until only visual noise remains, and then trains a neural network to reverse this corruption. Repeating this process hundreds of millions of times, the model learns how to convert pure noise into a coherent image from any caption.

While GANs are only capable of creating an image of a general category, text-to-image synthesis engines are more powerful. They are capable of creating nearly any image, including images that include an interplay between people and objects with specific and complex interactions, for instance "The president of the United States burning classified documents while sitting around a bonfire on the beach during sunset."

OpenAI's text-to-image image generator, DALL-E, took the internet by storm when it was unveiled on Jan. 5, 2021. A beta version of the tool was made available to 1 million users on July 20, 2022. Users around the world have found seemingly endless ways to prompt DALL-E, yielding delightful, bizarre and fantastical imagery.

A wide range of people, from computer scientists to legal scholars and regulators, however, have pondered the potential misuses of the technology. Deep fakes have already been used to create nonconsensual pornography, commit small- and large-scale fraud, and fuel disinformation campaigns. These even more powerful image generators could add jet fuel to these misuses.

Three image generators, three different approaches

Aware of the potential abuses, Google declined to release its text-to-image technology. OpenAI took a more open, and yet still cautious, approach when it initially released its technology to only a few thousand users (myself included). They also placed guardrails on allowable text prompts, including no nudity, hate, violence or identifiable persons. Over time, OpenAI has expanded access, lowered some guardrails and added more features, including the ability to semantically modify and edit real photographs.

Stability AI took yet a different approach, opting for a full release of their Stable Diffusion with no guardrails on what can be synthesized. In response to concerns of potential abuse, the company's founder, Emad Mostaque, said "Ultimately, it's peoples' responsibility as to whether they are ethical, moral and legal in how they operate this technology."

Nevertheless, the second version of Stable Diffusion removed the ability to render images of NSFW content and children because some users had created child abuse images. In responding to calls of censorship, Mostaque pointed out that because Stable Diffusion is open source, users are free to add these features back at their discretion.

The genie is out of the bottle

Regardless of what you think of Google's or OpenAI's approach, Synthesis AI made their decisions largely irrelevant. Shortly after Synthesis AI's open-source announcement, OpenAI lowered their guardrails on generating images of recognizable people. When it comes to this type of shared technology, society is at the mercy of the lowest common denominator – in this case, Synthesis AI.

Synthesis AI boasts that its open approach wrestles powerful AI technology away from the few, placing it in the hands of the many. I suspect that few would be so quick to celebrate an infectious disease researcher publishing the formula for a deadly airborne virus created from kitchen ingredients, while arguing that this information should be widely available. Image synthesis does not, of course, pose the same direct threat, but the continued erosion of trust has serious consequences ranging from people's confidence in election outcomes to how society responds to a global pandemic and climate change.

Moving forward, I believe that technologists will need to consider both the upsides and downsides of their technologies and build mitigation strategies before predictable harms occur. I and other researchers will have to continue to develop forensic techniques to distinguish real images from fakes. Regulators are going to have to start taking more seriously how these technologies are being weaponized against individuals, societies and democracies.

And everyone is going to have to learn how to become more discerning and critical about how they consume information online.

Glossary

1. Text-to-image: a technology that generates images based on textual input.

2. Synthetic media: media that is artificially created, such as images or videos.

3. Trust: confidence in the accuracy and authenticity of a record or piece of media.

4. Image forensics: the study of techniques and methods for analyzing the authenticity of images.

5. Generative adversarial network (GAN): a type of neural network used for synthesizing images.

6. Generator: the part of a GAN that creates new images.

7. Discriminator: the part of a GAN that determines if an image is real or fake.

8. Deepfakes: manipulated or synthesized media that appears real but is actually fake.

9. Neural network: a set of interconnected processors used for machine learning and artificial intelligence.

10. Model: a mathematical representation of a system or process used for prediction or analysis.

11. Corruption: intentional alteration or distortion of data or media.

12. Interplay: interaction between different elements or entities in a system or process.

13. DALL-E: OpenAI's text-to-image image generator.

14. Misuses: negative or harmful ways in which a technology can be used.

15. Guardrails: Restrictions placed on allowable text prompts when using text-to-image technology.

16. NSFW content: Content that is not safe for work, typically containing nudity, violence, or sexual themes.

17. Open source: A type of software where the source code is publicly available for anyone to use or modify.

18. Lowest common denominator: The least restrictive or cautious approach taken when it comes to shared technology.

19. Erosion of trust: A loss of confidence in the accuracy and authenticity of information or media.

20. Mitigation strategies: Plans or actions taken to prevent or reduce potential harms caused by a technology.

21. Regulators: Government agencies or organizations responsible for overseeing and enforcing laws related to technology and media.

22. Weaponized: Used in a harmful or malicious way against individuals, societies, or democracies.

Task 1

Answer the questions:

1. What is the latest trend in synthetic media?
2. Which companies have developed text-to-image image generators?
3. What are some concerns about text-to-image image generators?
4. What is a GAN? How does a GAN work?

5. What are deepfakes?

6. What is the difference between GANs and text-to-image synthesis engines?

7. What is DALL-E? When was DALL-E unveiled to the public?

8. What are some potential misuses of text-to-image image generators?

9. What is the article discussing?

10. Why did Google decline to release its text-to-image technology?

11. What guardrails did OpenAI place on its text-to-image technology?

12. What approach did Stability AI take with its Stable Diffusion technology?

13. Why did Stability AI remove the ability to render images of NSFW content and children in the second version of Stable Diffusion?

14. What is Synthesis AI? . How did Synthesis AI's open-source announcement affect OpenAI's approach to generating images of recognizable people?

15. What is the potential consequence of the continued erosion of trust in photographic records?

16. What do technologists need to consider when developing new technologies?

17. What do regulators need to do in response to the potential weaponization of synthetic media?

Task 2

Say whether the following statements are true or fale:

1. Teddy bears working on new AI research on the moon in the 1980s is not a valid text prompt for any of the recently released text-to-image artificial intelligence image generators.

2. Google, OpenAI, and Stability AI have each developed a text-to-image image generator.

3. Text-to-image synthesis engines are less powerful than GANs in creating an image of a specific category.

4. Some observers are questioning whether people will be able to trust the photographic record in the future.

5. OpenAI's DALL-E has not been made available to any users yet.

6. The first synthetic images using generative adversarial networks (GANs) were introduced five years ago.

7. Text-to-image deepfakes are a new player in the scene.

8. Deep fakes have only been used for nonconsensual pornography.

9. OpenAI's text-to-image image generator, DALL-E, was unveiled on Jan. 5, 2021.

10. The article suggests that regulators have not yet started taking seriously how these technologies are being weaponized against individuals, societies, and democracies.

11. Google declined to release its text-to-image technology due to potential abuses.

12. OpenAI's text-to-image technology has no guardrails on allowable text prompts.

13. OpenAI initially released its text-to-image technology to only a few thousand users and placed guardrails on allowable text prompts.

14. Stability AI opted for a full release of their Stable Diffusion with no guardrails on what can be synthesized.

15. Stability AI's Stable Diffusion allows users to render images of NSFW content and children.

16. Synthesis AI's open-source announcement made the decisions of Google and OpenAI largely irrelevant.

17. The erosion of trust in photographic records has serious consequences ranging from people's confidence in election outcomes to how society responds to global issues.

18. Technologists will need to consider both the upsides and downsides of their technologies and build mitigation strategies before predictable harms occur.

19. Regulators need to start taking more seriously how these technologies are being weaponized against individuals, societies, and democracies.

BRAIN-INSPIRED COMPUTING SYSTEM BASED ON SKYRMIONS 'READS' HANDWRITING

By Riken

This neuromorphic computing device uses skyrmions to perform image-recognition tasks. Credit: RIKEN Center for Emergent Matter Science

A computing device that uses tiny magnetic swirls to process data has been trained to recognize handwritten numbers. Developed by RIKEN researchers, the device shows that miniature magnetic whirlpools could be useful for realizing low-energy computing systems inspired by the brain.

Our brains contain complex networks of neurons that transmit and process electrical signals. Artificial neural networks mimic this behavior, and are particularly adept at tasks such as pattern recognition.

But artificial neural networks consume a lot of power when run on conventional silicon chips. So researchers are developing alternative platforms that are specially designed for brain-inspired computing, an approach known as neuromorphic computing.

The new neuromorphic device created by researchers including Tomoyuki Yokouchi of the RIKEN Center for Emergent Matter Science, relies on a type of artificial neural network known as the reservoir computing model. One feature of this model is its short-term memory–its output depends on both past and present inputs to the system.

That's where tiny magnetic whirlpools known as skyrmions come in. These magnetic patterns have an in-built memory effect, because their structure and behavior reflect previous exposure to magnetic fields.

Skyrmions can also run on low energies. "Another advantage of using skyrmions is energy saving, because skyrmions can be controlled using very small current densities," says Yokouchi.

The team's device contains a series of bars covered in a platinum–cobalt–iridium film, which can host skyrmions a few micrometers wide.

To put data into the device, the researchers encoded information into a magnetic field that, when applied to the skyrmions, generates a voltage. This output voltage depends on the number and size of the skyrmions present.

The researchers trained the device using more than 13,000 images of handwritten digits from 0 to 9. They converted the images into magnetic input signals, and tuned the device so that the output voltage signals accurately represented the correct digit.

The team then tested the device using another 5,000 images, and found that it could recognize the numbers with about 95% accuracy–outperforming rival neuromorphic devices.

"Our work indicates that energy-saving neuromorphic computing can be realized using skyrmions," says Yokouchi.

The findings are published in the journal *Science Advances*.

The team hopes to develop a similar device that uses an electrical current for its input, rather than a magnetic field, which should improve its performance and further reduce its energy consumption. "If we succeed, we may be able to demonstrate more complex tasks such as speech recognition and motion tracking," Yokouchi says.

Glossary

1. Neuromorphic computing: An approach to computing that is inspired by the structure and function of the human brain.

2. Magnetic swirls: Tiny magnetic patterns called skyrmions that are used in neuromorphic computing to process data.

3. Artificial neural networks: Computing systems that mimic the behavior of neurons in the human brain, particularly in tasks such as pattern recognition.

4. Reservoir computing model: A type of artificial neural network that relies on short-term memory to process data.

5. Energy-saving computing: The use of low-energy platforms for computing, such as neuromorphic devices, to reduce power consumption.

6. Magnetic field: A field created by magnets that can be used to encode information into skyrmions in neuromorphic devices.

7. Voltage output: The electrical signal generated by a neuromorphic device in response to input data.

8. Handwritten digits: Numbers written by hand that are used to train and test neuromorphic devices in image recognition tasks.

9. Speech recognition: The ability of a computing system to recognize and interpret human speech.

10. Motion tracking: The ability of a computing system to track and analyze human movement.

Task 1

Find words and expressions meaning the following

1. something that moves quickly with a twisting, circular movement

2. water that moves in a powerful, circular current, sucking into its center anything that floats near it

3. skilled
4. traditional and ordinary
5. use

Task 2

Answer the following questions:

1. What is the new computing device developed by RIKEN researchers using to process data?

2. What is the benefit of using artificial neural networks for computing?

3. Why are alternative platforms being developed for brain-inspired computing?

4. What is the name of the artificial neural network model used by the new neuromorphic device?

5. What is the advantage of using skyrmions in the new neuromorphic device?

6. How did the researchers put information into the device?

7. How accurate was the device in recognizing handwritten digits from 0 to 9?

8. What is the potential for developing a similar device that uses an electrical current for input?

Task 3

Say whether the following statements are true, false, or not mentioned:

1. The new computing device developed by RIKEN researchers uses artificial neurons to process data.

2. Artificial neural networks are not energy-efficient when run on conventional silicon chips.

3. Skyrmions used in the new neuromorphic device have an in-built memory effect.

4. The researchers used more than 5,000 images of handwritten digits to train the device.

5. The team hopes to develop a similar device that uses a magnetic field for its input.

NEW ELECTRODE DESIGN FOR LITHIUM-ION BATTERIES THAT IMPROVES PERFORMANCE

by National Research Council of Science & Technology

Electrode (anode) with a grooved, patterned bilayer structure. Credit: Korea Institute of Machinery and Materials (KIMM)

Korea Institute of Machinery & Materials (KIMM) has announced the development of the design and process technology for the world's first battery electrode that significantly improves the performance and stability of batteries used in electronic devices such as smartphones, laptops, and electric vehicles.

A joint research team led by principal researcher Seungmin Hyun of the Department of Nano-Mechanics at KIMM, an institution under the jurisdiction of the Ministry of Science and ICT, and Professor Hoo-jeong Lee of Sungkyunkwan University have developed a new battery technology that uses an electrode (anode) structure that enhances the reliability and performance of traditional lithium-ion batteries.

The results of their research achievement were published in the journal *Advanced Functional Materials*.

In order to develop a design and process technology that maintains high performance and reliability even when the electrode of the lithium-ion battery is thick, the KIMM-SKKU joint research team formed a bi-layered anode. Additionally, the anode is designed with grooves allowing small materials with improved ion conductivity and electrical conductivity to be placed between high-capacity materials.

In general, lithium-ion battery electrodes are manufactured by coating and drying a slurry so that it can be evenly distributed over the entire electrode. As such, it is the uniformity of the slurry that determines the performance of battery. The thicker the electrode, the lower the energy density and uniformity, making it difficult to maintain performance in a high-power environment.

A bi-layer electrode battery in pouch form. Credit: Korea Institute of Machinery and Materials (KIMM)

However, with the anode structure of this newly developed battery, uniform reaction stability can be achieved while maintaining high energy density throughout the electrode, even if the electrode is thick. This is particularly helpful in improving the performance and lifespan of batteries.

Principal researcher Seungmin Hyun stated that this achievement is an efficient method to improve the performance and lifespan of batteries by applying a new design to traditional lithium-ion battery materials and processes. He added that the team will continue to make efforts to apply this new technology to electric vehicles and soft robots that require high energy density in high-power environments, as well as to electronic devices such as commercial smartphones and laptops.

Glossary

1. Battery electrode: A component of a battery that conducts electricity between the positive and negative terminals.

2. Lithium-ion battery: A type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging.

3. Performance: The ability of a battery to deliver energy efficiently and reliably.

4. Stability: The ability of a battery to maintain its performance over time and under different conditions.

5. Anode: The electrode of a battery where oxidation (loss of electrons) occurs during discharge.

6. Ion conductivity: The ability of a material to conduct ions (charged particles) through it.

7. Electrical conductivity: The ability of a material to conduct electricity through it.

8. Energy density: The amount of energy stored per unit volume or mass of a battery.

9. Pouch form: A flat, flexible packaging format for batteries.

10. Soft robots: Robots made of soft materials that can change shape and adapt to their environment.

Task 1

Find words and expressions meaning the following:

1. strengthen, intensify
2. support, keep
3. suspension, solution
4. transport, car
5. thickness

Task 2

Answer the following questions:

1. What Institute has announced the development for the world's first battery electrode that significantly improves the performance and stability of batteries?

2. What is the name of the journal where the results of their research were published?

3. What is the new battery technology using to enhance the reliability and performance of traditional lithium-ion batteries?

4. How did the KIMM-SKKU joint research team form a bi-layered anode to maintain high performance and reliability even when the electrode of the lithium-ion battery is thick?

5. How are lithium-ion battery electrodes usually manufactured?

6. What determines the performance of a battery in terms of uniformity?

7. What happens to the energy density and uniformity as the electrode of a lithium-ion battery becomes thicker?

8. What benefit does the anode structure of this newly developed battery provide?

9. What are some potential applications for this new technology?

Task 3

Say whether the stalemates are true or false:

1. KIMM has developed a battery electrode that improves the performance and stability of electronic devices.

2. The thicker the electrode, the higher the energy density and uniformity.

3. The new battery technology uses a cathode structure that enhances the reliability and performance of traditional lithium-ion batteries.

4. The bi-layered anode was formed with grooves allowing small materials with improved ion conductivity and electrical conductivity to be placed between high-capacity materials.

5. Lithium-ion battery electrodes are usually manufactured by melting and cooling a slurry.

6. The uniformity of the slurry determines the performance of a battery.

7. As the electrode of a lithium-ion battery becomes thicker, the energy density and uniformity increase.

8. The anode structure of the newly developed battery provides uniform reaction stability while maintaining high energy density throughout the electrode, even if the electrode is thick.

9. The new technology can only be applied to electric vehicles and soft robots, not commercial smartphones and laptops.

SCALABLE METHOD TO MANUFACTURE THIN FILM TRANSISTORS ACHIEVES ULTRA-CLEAN INTERFACE

by Hayley Hanway, University of Michigan

Microchip containing thin film transistors having record sub-threshold slope, made using the in situ atomic layer deposition process. Credit: Silvia Cardarelli, Michigan ECE

Prof. Becky Peterson at the University of Michigan leads a team that has developed a scalable, manufacturable method for developing thin film transistors (TFTs) that operate at the lowest possible voltage. This is particularly important for TFT integration with today's silicon complementary metal-oxide semiconductors (CMOS), which are used in the vast majority of integrated circuits.

"We're essentially developing a less complicated device that operates at lower voltage," said ECE Ph.D. student Tonglin (Tanya) Newsom, who is first author on the paper. "With this steep sub-threshold swing device, we could significantly lower the energy dissipation of our circuitry, meaning there's less energy loss. This could help everyone who uses electronic devices."

TFTs enable the operation of modern displays, acting as switches that control the light at each individual pixel. Switching efficiently between the on and off states allows for lower voltage operation, and results in a more energy-efficient system. One of the key manufacturing challenges to achieving a highly efficient switch is the requirement of a super clean interface between the different material layers within the TFT. A clean interface means electrons can flow in the channel to turn the pixel "on" or "off" without getting trapped.

"The key technology that we were trying to develop is an ultra-clean interface between the semiconductor and the gate insulator, so the switching process between the on and off states would be very sharp," Peterson said. "We were able to achieve switching at the fastest rate possible, according to fundamental physical limits at room temperature."

To do this, Peterson's group partnered with Mechanical Engineering Professor Neil Dasgupta, with whom they developed an atomic layer deposition technology for zinc tin oxide, which is a wide bandgap semiconductor that can be used for electronic and energy devices, such as TFTs, versatile sensors, and solar cells. Peterson's team took this technology one step further by directly integrating the atomic layer deposition processes for two different key parts of the transistor–the gate capacitor and the semiconductor channel.

"We get the best results by depositing the two layers back-to-back within the same tool, without breaking vacuum," Peterson said. "This approach demonstrates a straightforward method to achieve optimal TFT performance."

Peterson's team focused on amorphous oxide semiconductors, which are a category of materials that are commercialized in displays and enable us to individually control pixels. They're important for achieving low power operation, high pixel density screens, touch screens, and haptic displays, which generate tactile effects–such as vibrations–for a variety of applications, including wearables and AR/VR devices.

"I truly hope more people will become interested in doing this kind of fundamental science and engineering," Newsom said "because this work is not just about discovering new possibilities–it's about improving technology to help the world."

The research, "59.9 mV·dec-1 Subthreshold Swing Achieved in Zinc Tin Oxide TFTs With In Situ Atomic Layer Deposited Al2O3 Gate Insulator," was selected as an Editor's Pick in *IEEE Electron Device Letters*.

Glossary

1. Thin film transistors (TFTs): switches that control the light at each individual pixel in modern displays.

2. Silicon complementary metal-oxide semiconductors (CMOS): used in the vast majority of integrated circuits.

3. Voltage: the measure of electrical potential difference between two points.

4. Energy dissipation: the amount of energy lost during the operation of electronic devices.

5. Sub-threshold swing device: a device that operates at lower voltage and with less energy loss.

6. Electron flow: the movement of electrons through a channel to turn a pixel "on" or "off".

7. Semiconductor: a material that has electrical conductivity between that of a conductor and an insulator.

8. Gate insulator: a layer that separates the semiconductor from the gate capacitor in a TFT.

9. Atomic layer deposition: a process for depositing thin films of materials onto a substrate.

10. Zinc tin oxide: a wide bandgap semiconductor used for electronic and energy devices.

11. Amorphous oxide semiconductors: a category of materials used in displays to individually control pixels.

12. Pixel density screens: screens with a high number of pixels per inch.

13. Touch screens: screens that can detect touch and respond accordingly.

14. Haptic displays: displays that generate tactile effects, such as vibrations, for a variety of applications, including wearables and AR/VR devices.

Task 1

Find words and expressions meaning the following

1. disappearing
2. multifunctional
3. additional
4. method
5. thickness, concentration
6. tactile

Task 2

Answer the following questions:

1. What is the focus of Prof. Becky Peterson's team at the University of Michigan?

2. Why is it important to develop TFTs that operate at the lowest possible voltage?

3. What are TFTs used for?

4. What is one of the key manufacturing challenges to achieving a highly efficient switch in TFTs?

5. What is the ultra-clean interface between the semiconductor and the gate insulator that Prof. Peterson's team was trying to develop?

6. What is amorphous oxide semiconductor?

7. What are some applications of amorphous oxide semiconductors?

8. What is the title of the research paper?

9. What is Tonglin (Tanya) Newsom's role in the research?

10. Why does Tonglin (Tanya) Newsom hope more people will become interested in doing this kind of fundamental science and engineering?

Task 3

Say whether the following statements are true or false:

1. Prof. Becky Peterson's team is working on developing a method for developing thin film transistors that operate at the highest possible voltage.

2. Developing TFTs that operate at the lowest possible voltage can result in a more energy-efficient system.

3. TFTs are used to control the light at each individual pixel in modern displays.

4. The requirement of a super clean interface is not a key manufacturing challenge to achieving a highly efficient switch in TFTs.

5. Prof. Peterson's team was trying to develop an ultra-clean interface between the semiconductor and the gate insulator that allows for a sharp switching process between the on and off states.

6. Amorphous oxide semiconductor is not important for achieving low power operation, high pixel density screens, touch screens, and haptic displays.

7. The research paper is titled "59.9 mV·dec-1 Subthreshold Swing Achieved in Zinc Tin Oxide TFTs With In Situ Atomic Layer Deposited Al2O3 Gate Insulator."

8. Tonglin (Tanya) Newsom is not involved in the research on developing thin film transistors.

9. Tonglin (Tanya) Newsom hopes more people will become interested in doing this kind of fundamental science and engineering because it is only about discovering new possibilities.

10. The research paper was not selected as an Editor's Pick in IEEE Electron Device Letters.

STACKING LEDS INSTEAD OF PLACING THEM SIDE BY SIDE COULD ENABLE FULLY IMMERSIVE VIRTUAL REALITY DISPLAYS

by Jennifer Chu, Massachusetts Institute of Technology

Vertically stacked, full-colour μLEDs enabled by 2DLT. Credit: *Nature* (2023). DOI: 10.1038/s41586-022-05612-1

Take apart your laptop screen, and at its heart you'll find a plate patterned with pixels of red, green, and blue LEDs, arranged end to end like a meticulous Lite Brite display. When electrically powered, the LEDs together can produce every shade in the rainbow to generate full-color displays. Over the years, the size of individual pixels has shrunk, enabling many more of them to be packed into devices to produce sharper, higher-resolution digital displays.

But much like computer transistors, LEDs are reaching a limit to how small they can be while also performing effectively. This limit is especially noticeable in close-range displays such as augmented and virtual reality devices, where limited pixel density results in a "screen door effect" such that users perceive stripes in the space between pixels.

Now, MIT engineers have developed a new way to make sharper, defect-free displays. Instead of replacing red, green, and blue light-emitting diodes side by side in a horizontal patchwork, the team has invented a way to stack the diodes to create vertical, multicolored pixels.

Each stacked pixel can generate the full commercial range of colors and measures about 4 microns wide. The microscopic pixels, or "micro-LEDs," can be packed to a density of 5,000 pixels per inch.

"This is the smallest micro-LED pixel, and the highest pixel density reported in the journals," says Jeehwan Kim, associate professor of mechanical engineering at MIT. "We show that vertical pixellation is the way to go for higher-resolution displays in a smaller footprint."

"For virtual reality, right now there is a limit to how real they can look," adds Jiho Shin, a postdoc in Kim's research group. "With our vertical micro-LEDs, you could have a completely immersive experience and wouldn't be able to distinguish virtual from reality."

The team's results are published in the journal *Nature*. Kim and Shin's co-authors include members of Kim's lab, researchers around MIT, and collaborators from Georgia Tech Europe, Sejong University, and multiple universities in the U.S, France, and Korea.

Placing pixels

Today's digital displays are lit through organic light-emitting diodes (OLEDs)–plastic diodes that emit light in response to an electric current. OLEDs are the leading digital display technology, but the diodes can degrade over time, resulting in permanent burn-in effects on screens. The technology is also reaching a limit to the size the diodes can be shrunk, limiting their sharpness and resolution.

For next-generation display technology, researchers are exploring inorganic micro-LEDs–diodes that are one-hundredth the size of conventional LEDs and are made from inorganic, single-crystalline semiconducting materials. Micro-LEDs could perform better, require less energy, and last longer than OLEDs.

But micro-LED fabrication requires extreme accuracy, as microscopic pixels of red, green, and blue need to first be grown separately on wafers, then precisely placed on a plate, in exact alignment with each other in order to properly reflect and produce various colors and shades. Achieving such microscopic precision is a difficult task, and entire devices need to be scrapped if pixels are found to be out of place.

"This pick-and-place fabrication is very likely to misalign pixels in a very small scale," Kim says. "If you have a misalignment, you have to throw that material away, otherwise it could ruin a display."

Color stack

The MIT team has come up with a potentially less wasteful way to fabricate micro-LEDs that doesn't require precise, pixel-by-pixel alignment. The technique is an entirely different, vertical LED approach, in contrast to the conventional, horizontal pixel arrangement.

Kim's group specializes in developing techniques to fabricate pure, ultrathin, high-performance membranes, with a view toward engineering smaller, thinner, more flexible and functional electronics. The team previously developed a method to grow and peel away perfect, two-dimensional, single-crystalline material from wafers of silicon and other surfaces–an approach they call 2D material-based layer transfer, or 2DLT.

In the current study, the researchers employed this same approach to grow ultrathin membranes of red, green, and blue LEDs. They then peeled the entire LED membranes away from their base wafers, and stacked them together to make a layer cake of red, green, and blue membranes. They could then carve the cake into patterns of tiny, vertical pixels, each as small as 4 microns wide.

"In conventional displays, each R, G, and B pixel is arranged laterally, which limits how small you can create each pixel," Shin notes. "Because we are stacking all three pixels vertically, in theory we could reduce the pixel area by a third."

As a demonstration, the team fabricated a vertical LED pixel, and showed that by altering the voltage applied to each of the pixel's red, green, and blue membranes, they could produce various colors in a single pixel.

"If you have a higher current to red, and weaker to blue, the pixel would appear pink, and so on," Shin says. "We're able to create all the mixed colors, and our display can cover close to the commercial color space that's available."

The team plans to improve the operation of the vertical pixels. So far, they have shown they can stimulate an individual structure to produce the full spectrum of colors. They will work toward making an array of many vertical micro-LED pixels.

"You need a system to control 25 million LEDs separately," Shin says. "Here, we've only partially demonstrated that. The active matrix operation is something we'll need to further develop."

"For now, we have shown to the community that we can grow, peel, and stack ultrathin LEDs," Kim says. "This is the ultimate solution for small displays like smart watches and virtual reality devices, where you would want highly densified pixels to make lively, vivid images."

Glossary

1. Pixels: the individual units that make up a digital display, consisting of red, green, and blue light-emitting diodes (LEDs).

2. LEDs: light-emitting diodes, which emit light in response to an electric current.

3. Pixel density: the number of pixels per inch in a digital display.

4. Screen door effect: a visual artifact caused by limited pixel density, resulting in visible stripes between pixels.

5. Micro-LEDs: one-hundredth the size of conventional LEDs, made from inorganic, single-crystalline semiconducting materials.

6. Inorganic: not containing carbon or derived from living matter.

7. Single-crystalline: consisting of a single crystal lattice structure, which results in higher performance and efficiency.

8. Fabrication: the process of manufacturing or constructing something.

9. Wafers: thin slices of semiconductor material used in the production of microchips and other electronic devices.

10. Alignment: the precise positioning of objects in relation to each other.

11. Pick-and-place fabrication: a technique for assembling electronic components by manually placing them onto a substrate.

12. Vertical LED approach: a technique for fabricating micro-LEDs that stacks the diodes vertically instead of horizontally.

13. Ultrathin: extremely thin, often on the nanoscale.

14. Flexible electronics: electronic devices that can be bent or shaped without breaking or losing functionality.

15. Two-dimensional material-based layer transfer (2DLT): a method developed by the researchers to grow and peel away perfect, two-dimensional, single-crystalline material from wafers of silicon and other surfaces.

16. Ultrathin membranes: extremely thin layers of material, in this case, red, green, and blue LEDs.

17. Vertical pixels: pixels that are stacked vertically instead of arranged laterally, allowing for smaller pixel sizes.

18. Commercial color space: the range of colors that are available for use in commercial displays.

19. Active matrix operation: a system for controlling individual pixels in a display.

20. Smart watches: wearable electronic devices that can perform various functions beyond timekeeping.

21. Virtual reality devices: electronic devices that simulate a virtual environment and allow users to interact with it.

Task 1

Find words and expressions meaning the following

1. to arrange things in an ordered pile
2. a way of doing something
3. position
4. able to be bought or used
5. to notice or understand the difference between two things
6. become smaller

Task 2

Answer the following questions:

1. Is there the current limit to how small LEDs can be while still performing effectively?

2. What is the "screen door effect"?

3. What have MIT engineers developed to make sharper, defect-free displays?

4. What is the highest pixel density reported in journals?

5. Where is the leading digital display technology currently used?

6. What are micro-LEDs and how are they different from conventional LEDs?

7. Why is micro-LED fabrication a difficult task?

8. What is the MIT team's approach to fabricating micro-LEDs?

9. What approach did the MIT team use to grow ultrathin membranes of LEDs?

10. How did the team stack the LED membranes together to create vertical pixels?

11. What is the potential benefit of stacking all three pixels vertically?

Task 3

Say whether the following statements are true, false, or not mentioned:

1. The size of individual pixels in digital displays has been increasing over the years.

2. The "screen door effect" is caused by limited pixel density in close-range displays.

3. MIT engineers have developed a new way to make sharper, defect-free displays.

4. The team replaced red, green, and blue light-emitting diodes side by side in a horizontal patchwork.

5. The microscopic pixels can be packed to a density of 500 pixels per inch.

6. OLEDs are the leading digital display technology, but they can degrade over time.

7. Micro-LEDs are made from organic, single-crystalline semiconducting materials.

8. The team developed a method called 2D material-based layer transfer to grow and peel away LED membranes.

9. The team stacked the red, green, and blue LED membranes laterally to reduce the pixel area.

10. By altering the voltage applied to each membrane, the team was able to produce various colors in a single pixel.

STUDY UNVEILS A LARGE TUNABLE DRAG RESPONSE BETWEEN A NORMAL CONDUCTOR AND A SUPERCONDUCTOR
by Ingrid Fadelli, Phys.org

Giant drag effect is discovered between a graphene layer and an interfacial superconductor, which can be attributed to a unique interaction between normal electrons and dynamical fluctuations of superconducting phases mediated by static Coulomb fields. Credit: Tao et al.

The Coloumb drag is a phenomenon that affects two electronic circuits, whereby a charge current in one circuit induces a responsive current in a neighboring circuit solely through so-called Coloumb interactions. These are electrostatic interactions between electric charges that follow Coulomb's law, the key physics theory describing classical electrodynamics.

Typically, this phenomenon was investigated using neighboring circuits made of conducting materials, or electrical conductors. These are essentially materials through which electricity can flow easily.

Researchers at the University of Science and Technology of China have recently explored what happens when one circuit is based on a conductor and a neighboring other on a superconductor (i.e., materials that offer no resistance whatsoever to electrical current). Their findings, published in *Nature Physics*, show that in these instances the drag response is significantly larger than that previously observed in studies using two normal conductors.

"Drag experiment between two electrically isolated conductors has been an effective approach to detecting elementary excitations and revealing interlayer phase coherence," Changgan Zeng, one of the researchers who carried out the study, told Phys.org. "Replacing one of the conductors with a superconductor may open opportunities for examining superconductivity and fluctuation effects as well as exploring new techniques for manipulating superconductor circuits."

The first drag experiments using conductors and superconductors were conducted in the 1990s. The devices used at the time, however, were based on conventional metal-superconductor double films, such as $Au/Ti\text{-}AlO_{X.}$

The drag responses observed in these experiments were rather weak and uncontrolled. Moreover, researchers were unable to clarify the microscopic origin of the drag effect they observed.

"Thanks to newly emerging two-dimensional (2D) materials, we were able to revisit the problem, since the electronic properties there are highly tunable and an ultra-small interlayer separation is also archivable," said Lin Li, who designed and supervised this work together with Zeng.

"Our experimental group at USTC led by Prof. Zeng has long experience in fabricating devices and investigating transport properties of 2D materials. We naturally designed the unique Graphene-$LaAlO_3/SrTiO_3$ heterostructure for studying drag effect in the ultimate 2D limit."

The heterostructure that Zeng and his colleagues used in their experiments was fabricated using a lanthanum aluminate (LAO) layer as a natural insulating spacer between the conductor graphene and a 2D electron gas that formed at the interface between LAO and a strontium titanate (STO) layer, which becomes a superconductor at low temperatures.

The researchers then tuned multiple parameters of their system, including its temperature, magnetic field and gate voltages. As they did this, they observed a sizable and tunable drag signal in the superconducting transition regime of the LAO/STO interface.

"The optimal passive-to-active ratio (PAR) is much higher than the typical drag signal between two normal conductors as well as that between Au/Ti and SC AlO_x obtained in the existing studies," Li said. "The giant values and anomalous temperature and carrier dependence of the PAR indicate that a new drag mechanism is hidden behind our observations."

Dr. Hong-Yi Xie, a theoretical physicist at the Beijing Academy of Quantum Information Sciences who recently moved to the University of Oklahoma, used modern quantum many-body theory to explain the team's observations. More specifically, he developed a theoretical description of what happens when a Coulomb-coupled normal conductor is paired with a superconductor.

"Eventually, we revealed that the observed drag phenomenon can be attributed to the dynamic coupling between the quantum fluctuations of the SC phases of a Josephson-junction-array superconductor and the charge densities in the normal conductor, which we termed the Josephson-Colulomb (JC) drag effect," Zeng said. "The unveiled JC drag effect creates a new category in drag physics and manifests the unique role of quantum fluctuations in dominating the interlayer processes."

The recent work by this team of researchers shows that the drag response between a normal conductor and a superconductor can be much larger than that between two normal conductors. This finding could have significant implications both for physics research and technology development.

The JC drag unveiled by the researchers could prove to be particularly promising for the creation of new electronics. Specifically, it could contribute to the creation of components based on superconductors that could work as current or voltage transformers.

"In our next works, we would first like to carry out drags experiments between two 2D superconductors," Zeng added. "Moreover, we are planning to investigate emergent interlayer coupling between broader 2D systems that exhibit various quantum phases by parameter tuning, i.e., 2D topological semimetal/insulator and 2D ferromagnet. We aim to discover novel many-body effects due to strong interlayer coupling between various elementary excitations."

Glossary

1. Coloumb drag: a phenomenon where a charge current in one circuit induces a responsive current in a neighboring circuit solely through electrostatic interactions between electric charges that follow Coulomb's law.

2. Conducting materials: materials through which electricity can flow easily.

3. Superconductors: materials that offer no resistance whatsoever to electrical current.

4. Nature Physics: an academic journal focused on research in physics.

5. Elementary excitations: the smallest possible disturbances or fluctuations in a physical system.

6. Interlayer phase coherence: the degree to which the layers of a material are in phase with each other.

7. Two-dimensional (2D) materials: materials that are only a few atoms thick and have unique electronic properties.

8. Graphene-LaAlO3/SrTiO3 heterostructure: a layered material consisting of graphene, lanthanum aluminate, and strontium titanate, used to study the Coloumb drag effect in the ultimate 2D limit.

9. Lanthanum aluminate (LAO) layer: a natural insulating spacer used in the Graphene-LaAlO3/SrTiO3 heterostructure.

10. Strontium titanate (STO) layer: a layer that becomes a superconductor at low temperatures, used in the Graphene-LaAlO3/SrTiO3 heterostructure.

11. Magnetic field: a field created by a magnet or a moving electric charge that affects other magnets or moving electric charges in its vicinity.

12. Gate voltages: voltages applied to the gate of a transistor to control its conductivity.

13. Passive-to-active ratio (PAR): the ratio between the passive and active components of a signal or system.

14. Quantum many-body theory: a theoretical framework used to describe the behavior of many interacting particles in quantum mechanics.

15. Theoretical physicist: a physicist who uses mathematical models and theories to explain physical phenomena.

16. Josephson-junction-array superconductor – A type of superconductor made up of an array of Josephson junctions.

17. Josephson-Colulomb (JC) drag effect – The dynamic coupling between the quantum fluctuations of the superconducting phases of a Josephson-junction-array superconductor and the charge densities in a normal conductor.

18. Normal conductor – A material that conducts electricity with some resistance.

19. Interlayer processes – Processes that occur between adjacent layers of a material.

20. Current or voltage transformers – Devices that convert electrical current or voltage from one level to another.

21. 2D superconductors – Superconductors that have thicknesses of only a few atoms or molecules.

22. Emergent interlayer coupling – The emergence of strong coupling between adjacent layers of a material due to the presence of certain quantum phases.

23. 2D topological semimetal/insulator – A type of 2D material that exhibits both metallic and insulating behavior due to its topology.

24. 2D ferromagnet – A type of 2D material that exhibits ferromagnetic behavior due to its thickness.

25. Many-body effects – Effects that arise from the interactions between many particles in a physical system.

Task 1

Find words and expressions meaning the following:

1. influence
2. doing something as a reaction to something or someone in a quick or positive way
3. only and not involving anything or anybody
4. to examine something carefully
5. showing something that was not previously known
6. a change, or a process of changing
7. relation, connection, pairing

Task 2

Answer the following questions:

1. What is the Coulomb drag phenomenon?

2. What are electrical conductors?

3. What did the researchers at the University of Science and Technology of China investigate?

4. What did the researchers find in their study?

5. When were the first drag experiments using conductors and superconductors carried out?

6. What was the problem with the devices used in the first drag experiments?

7. What does the study suggest about exploring new techniques for manipulating superconductor circuits?

8. What is the Josephson-Coulomb drag effect?

9. What did the researchers find in their recent work?

10. What could be the implications of the researchers' findings for technology development?

11. What are some of the 2D systems that the researchers plan to investigate in their future work?

12. What is the unique role of quantum fluctuations in the JC drag effect?

13. What is the significance of the JC drag effect in drag physics?

14. What is a normal conductor?

Task 3

Say whether the following statements are true or false

1. The Josephson-Coulomb drag effect is the dynamic coupling between the quantum fluctuations of the SC phases of a Josephson-junction-array superconductor and the charge densities in the normal conductor.

2. The researchers found that the drag response between a normal conductor and a superconductor can be much smaller than that between two normal conductors.

3. The researchers' findings could contribute to the creation of components based on superconductors that could work as current or voltage transformers.

4. The researchers plan to investigate emergent interlayer coupling between broader 3D systems that exhibit various quantum phases, such as 3D topological semimetal/insulator and 3D ferromagnet.

5. Quantum fluctuations do not play a unique role in the JC drag effect.

6. The JC drag effect is caused by the coupling between quantum fluctuations of the SC phases and charge densities in a normal conductor.

7. The drag response between a normal conductor and a superconductor can be smaller than that between two normal conductors.

8. The JC drag effect could be useful for creating components based on superconductors that function as current or voltage transformers.

9. The researchers plan to investigate interlayer coupling between 3D systems that exhibit various quantum phases.

10. Quantum fluctuations do not play a significant role in the JC drag effect.

HIGH-SPEED, HIGH-CAPACITY POWER AMPLIFIER FOR NEXT-GENERATION NETWORKS

by NEC Corporation

Newly developed D band power amplifier. Credit: NEC Corporation

NEC Corporation has developed a power amplifier that will serve as a key device for mobile access and fronthaul/backhaul wireless communication equipment to enable high-speed, high-capacity communications for 5G Advanced and 6G networks. This power amplifier uses GaAs technology that can be mass-produced and has achieved the world's highest output power of 10 mW in the 150 GHz band. Capitalizing on this, NEC aims to fast-track both equipment development and social implementation.

5G Advanced and 6G are expected to deliver 100 Gbps-class high-speed, high-capacity communications, equivalent to 10 times the speed of current 5G. This can be effectively achieved through the use of the sub-terahertz band (100 to 300 GHz), which can provide a wide bandwidth of 10 GHz or more. In particular, early commercialization of the D band (130 to 174.8 GHz), which is internationally allocated for fixed wireless communications, is expected.

NEC continues to make advancements in technological development by leveraging its knowledge of high-frequency bands cultivated through the development and operation of radio equipment for 5G base stations and PASOLINK, an ultra-compact microwave communication system that connects base stations via wireless communication.

The newly developed power amplifier uses a commercially available 0.1-μm gallium arsenide (GaAs) pseudomorphic high electron mobility transistor (pHEMT) process. Compared to CMOS and silicon germanium (SiGe) used for the sub-terahertz band, GaAs pHEMTs have high operation voltage and lower initial costs for mass production.

In terms of circuit design, this power amplifier eliminates factors that degrade performance in the high-frequency band and uses an impedance matching network configuration suitable for high output power. This has resulted in the achievement of excellent high-frequency characteristics between 110 GHz and 150 GHz as well as the world's highest output power for a GaAs pHEMT.

In addition to the realization of high-performance, low-cost radio communication equipment above 100 GHz, this power amplifier will accelerate the social implementation of 5G Advanced and 6G.

Going forward, NEC will continue developing technologies aimed at achieving high-speed, high-capacity, cost effective wireless communications for 5G Advanced and 6G.

NEC will announce further details regarding this technology at IEEE Topical Conference on RF/Microwave Power Amplifiers for Radio and Wireless Applications (PAWR2023), an international conference scheduled to be held in Las Vegas, Nevada, U.S., starting on January 22, 2023

Glossary

1. Sub-terahertz and terahertz frequency bands – Frequencies above 100GHz that are being explored for next-generation wireless communication networks.

2. Power amplifier – A device used to increase the power of a signal.

3. GaAs technology – A technology that uses gallium arsenide to create semiconductors for electronic devices.

4. Output power – The amount of power that a device can produce.

5. Bandwidth – The range of frequencies that a signal can carry.

6. Impedance matching network – A network used to match the impedance of a source and load to maximize power transfer.

7. CMOS – Complementary metal-oxide-semiconductor, a technology used to create integrated circuits.

8. Silicon germanium – A technology that uses silicon and germanium to create semiconductors for electronic devices.

9. High-frequency characteristics – The performance of a device at high frequencies.

10. Social implementation – The adoption and use of a technology by society.

Task 1

Answer the following questions:.

1. What is the newly developed device by NEC Corporation?

2. What is the purpose of the power amplifier developed by NEC Corporation?

3. What is the technology used in the power amplifier developed by NEC Corporation?

4. What is the output power achieved by the power amplifier developed by NEC Corporation?

5. What advantage does the sub-terahertz range give?

6. What is the D band?

7. What is PASOLINK?

8. What are the advantages of a power amplifier developed by NEC Corporation?

9. What is the purpose of announcing further details regarding the technology at IEEE Topical Conference on RF/Microwave Power Amplifiers for Radio and Wireless Applications (PAWR2023)?

10. What is NEC Corporation's future plan for technology development?

Task 2

Say whether the statements are true, false or not mentioned:

1. NEC Corporation has developed a power amplifier for mobile access and fronthaul/backhaul wireless communication equipment for 5G Advanced and 6G networks

2. The power amplifier developed by NEC uses GaAs technology that cannot be mass-produced

3. The power amplifier developed by NEC has achieved the world's highest output power of 10 mW in the 150 GHz band.

4. NEC aims to fast-track equipment development and social implementation by capitalizing on the high output power of the power amplifier.

5. 5G Advanced and 6G networks are expected to deliver 10 times the speed of current 5G.

6. The sub-terahertz band (100 to 300 GHz) provides a narrow bandwidth of 10 GHz or less.

7. The D band (130 to 174.8 GHz) is allocated for fixed wireless communications and is expected to be commercially available soon.

8. NEC leverages its knowledge of high-frequency bands cultivated through the development and operation of radio equipment for 5G base stations and PASOLINK.

9. The newly developed power amplifier uses a commercially available GaAs pHEMT process, which has lower initial costs for mass production than CMOS and SiGe.

10. NEC will announce further details regarding this technology at an international conference scheduled to be held in Las Vegas, Nevada, U.S. on January 22, 2024.

RESEARCHERS DECIPHER ATOMIC-SCALE IMPERFECTIONS IN LITHIUM-ION BATTERIES

by University of California, Irvine

As lithium-ion batteries have become a ubiquitous part of our lives through their use in consumer electronics, automobiles and electricity storage facilities, researchers have been working to improve their power, efficiency and longevity.

As detailed in a paper published today in *Nature Materials*, scientists at the University of California, Irvine and Brookhaven National Laboratory conducted a detailed examination of high-nickel-content layered cathodes, considered to be components of promise in next-generation batteries. Super-resolution electron microscopy combined with deep machine learning enabled the UCI-led team to decipher minute changes at the interface of materials sandwiched together in lithium-ion batteries.

"We are particularly interested in nickel, as it can help us transition away from cobalt as a cathode material," said co-author Huolin Xin, UCI professor of physics and astronomy. "Cobalt is toxic, so it's dangerous to mine and handle, and it's often extracted under socially repressive conditions in places like the Democratic Republic of Congo."

But for the change to be fully realized, battery developers need to know what goes on inside the cells as they are repeatedly discharged and recharged. The high energy density of nickel-layered lithium-ion batteries has been found to cause rapid chemical and mechanical breakdown of LIBs' component materials.

The team used a transmission electron microscope and atomistic simulations to learn how oxidation phase transitions impact battery materials, causing imperfections in an otherwise fairly uniform surface.

"This project, which relied heavily on some of the world's most powerful microscopy technologies and advanced data science approaches, clears the way for the optimization of high-nickel-content lithium-ion batteries," Xin said. "Knowing how these batteries operate at the atomic scale will help engineers develop LIBs with vastly improved power and life cycles."

Glossary

1. Lithium-ion batteries: rechargeable batteries used in consumer electronics, automobiles, and electricity storage facilities.

2. Power: the amount of energy that can be stored and released by a battery.

3. Efficiency: the ability of a battery to convert stored energy into usable power.

4. Longevity: the lifespan of a battery before it needs to be replaced.

5. High-nickel-content layered cathodes: components of next-generation batteries that contain a high percentage of nickel and are arranged in layers.

6. Super-resolution electron microscopy: a type of microscopy that uses electrons to create highly detailed images.

7. Deep machine learning: a type of artificial intelligence that allows computers to learn and improve on their own.

8. Interface: the boundary between two materials in a battery.

9. Cobalt: a toxic metal used in some cathode materials for lithium-ion batteries.

10. Toxic: harmful to living organisms or the environment.

11. Socially repressive conditions: situations in which human rights are violated or suppressed.

12. Democratic Republic of Congo: a country in Africa known for its cobalt mines.

13. Discharged and recharged: the process of using and recharging a battery.

14. Energy density: the amount of energy stored in a battery per unit of volume or weight.

15. Chemical and mechanical breakdown: the degradation of battery materials due to repeated use and charging.

16. Transmission electron microscope: a type of microscope that uses electrons to transmit images through a thin sample.

17. Atomistic simulations: computer simulations that model atomic-scale interactions between materials.

18. Oxidation phase transitions: chemical reactions that occur when materials in a battery are exposed to oxygen.

19. Imperfections: flaws or defects in a material's surface or structure.

20. Power and life cycles: the ability of a battery to deliver power over its lifespan before needing replacement.

Task 1

Find words meaning the following:

1. widestread

2. trigger

3. influence

4. collaps, failure

5. shortcomings

Task 2

Answer the following questions:

1. What is the focus of the research detailed in the paper published in Nature Materials?

2. Why are scientists interested in nickel as a cathode material?

3. What technology did the research team use to learn how oxidation phase transitions impact battery materials?

4. How will knowing how these batteries operate at the atomic scale help engineers?

5. What is the problem with using cobalt as a cathode material in lithium-ion batteries?

6. What is the potential benefit of using high-nickel-content cathodes in lithium-ion batteries?

7. What microscopy technology did the research team use to examine the interface of materials in lithium-ion batteries?

Task 3

Say whether the following statements true or false:

1. Researchers are working to improve the power, efficiency, and longevity of lithium-ion batteries.

2. The research team examined high-cobalt-content layered cathodes in their study.

3. Scientists are interested in nickel as a cathode material because it is toxic and difficult to mine.

4. The research team used super-resolution electron microscopy to examine the interface of materials in lithium-ion batteries.

5. High energy density in nickel-layered lithium-ion batteries can cause rapid chemical and mechanical breakdown of component materials.

6. Cobalt is often extracted under socially repressive conditions in places like the Democratic Republic of Congo.

7. Knowing how these batteries operate at the atomic scale will not help engineers develop LIBs with improved power and life cycles.

VERTICAL ELECTROCHEMICAL TRANSISTOR PUSHES WEARABLE ELECTRONICS FORWARD

by Megan Fellman, Northwestern University

The vertical electrochemical transistor is based on a new kind of electronic polymer and a vertical, instead of planar, architecture. Credit: Northwestern University

A transdisciplinary Northwestern University research team has developed a revolutionary transistor that is expected be ideal for lightweight, flexible, high-performance bioelectronics.

The electrochemical transistor is compatible with blood and water and can amplify important signals, making it especially useful for biomedical sensing. Such a transistor could enable wearable devices for onsite signal processing, right at the biology-device interface. Potential applications include measuring heartbeat and levels of sodium and potassium in blood as well as eye motion for studying sleep disorders.

"All modern electronics use transistors, which rapidly turn current on and off," said Tobin J. Marks, a co-corresponding author of the study. "Here we use chemistry to enhance the switching. Our electrochemical transistor takes performance to a totally new level. You have all the properties of a conventional transistor but far higher transconductance (a measure of the amplification it can deliver), ultra-stable cycling of the switching properties, a small footprint that can enable high density integration, and easy, low-cost fabrication."

Marks is a world leader in the fields of materials science and organic electronics. He is the Vladimir N. Ipatieff Professor of Catalytic Chemistry in the Weinberg College of Arts and Sciences and professor of materials science and engineering and chemical and biological engineering in the McCormick School of Engineering.

The vertical electrochemical transistor is based on a new kind of electronic polymer and a vertical, instead of planar, architecture. It conducts both electricity and ions and is stable in air. The design and synthesis of new materials and the transistor's fabrication and characterization required the collaborative expertise of chemists, materials scientists and biomedical engineers.

Marks led the research team along with Antonio Facchetti, research professor of chemistry at Weinberg; Wei Huang, now a professor at the University of Electronic Science and Technology of China; and Jonathan Rivnay, professor of biomedical engineering at the McCormick School.

"This exciting new type of transistor allows us to speak the language of both biological systems, which often communicate via ionic signaling, and electronic systems, which communicate with electrons," Rivnay said. "The ability of the transistors to work very efficiently as 'mixed conductors' makes them attractive for bioelectronic diagnostics and therapies."

This study detailing the efficient electrochemical transistor and an accompanying News & Views article were published this week by the journal *Nature*.

"With their vertical architecture, our electrochemical transistors can be stacked one on top of another," Facchetti said. "Thus, we can make very dense electrochemical complementary circuits, which is impossible for the conventional planar electrochemical transistors."

To make more reliable and powerful electronic circuits, two types of transistors are needed: p-type transistors that carry positive charges and n-type transistors that carry negative charges. These types of circuits are called complementary circuits. The challenge researchers have faced in the past is that n-type transistors are difficult to build and are typically unstable.

This is the first work to demonstrate electrochemical transistors with similar and very high performance for both types (p+n) electrochemical transistors. This resulted in the fabrication of very efficient electrochemical complementary circuits.

Glossary

1. Transistor: a device that can amplify or switch electronic signals.

2. Bioelectronics: the field of electronics that focuses on developing devices for biological applications.

3. Electrochemical transistor: a type of transistor that conducts both electricity and ions and is stable in air.

4. Biomedical sensing: the use of electronic devices to measure and monitor biological signals.

5. Wearable devices: electronic devices that can be worn on the body, such as smartwatches or fitness trackers.

6. Transconductance: a measure of the amplification that a transistor can deliver.

7. Density integration: the ability to pack more transistors into a smaller space.

8. Fabrication: the process of manufacturing or constructing something.

9. Ionic signaling: communication between biological systems using ions.

10. Electronic systems: systems that communicate with electrons.

11. Mixed conductors: materials that conduct both electricity and ions.

12. Diagnostics: the process of identifying a disease or condition.

13. Therapies: treatments for a disease or condition.

14. Complementary circuits: circuits that use both p-type and n-type transistors to carry positive and negative charges, respectively.

15. P-type transistors: transistors that carry positive charges.

16. N-type transistors: transistors that carry negative charges.

17. Unstable: not reliable or consistent in performance.

Task 1

Find words in the text that mean the following:

1. to improve
2. to allow through
3. thick
4. the act of producing a product, especially in industrial process
5. good together

Task 2

Say whether the statements are true or false:

1. The new transistor developed by Northwestern University researchers is compatible with blood and water.

2. The transistor has potential applications in measuring heartbeat, levels of sodium and potassium in blood, and eye motion for studying sleep disorders.

3. The electrochemical transistor has all the properties of a conventional transistor except for a smaller footprint.

4. Tobin J. Marks led the research team that developed the new transistor.

5. The vertical electrochemical transistor is based on a new kind of electronic polymer and a vertical architecture.

6. The development of the new transistor required the collaborative expertise of chemists, materials scientists, and biomedical engineers.

7. The ability of the transistors to work efficiently as 'mixed conductors' makes them attractive for bioelectronic diagnostics and therapies.

8. The electrochemical transistors with vertical architecture cannot be stacked one on top of another.

9. N-type transistors are typically stable and easy to build.

10. This is the first work to demonstrate electrochemical transistors with similar and high performance for both types (p+n) electrochemical transistors.

Task 3

Answer the following questions:

1. What is the new type of transistor developed by Northwestern University researchers?

2. What are the potential applications of the new transistor?

3. How does the new transistor differ from conventional transistors?

4. Who led the research team that developed the new transistor?

5. What is the vertical electrochemical transistor based on?

6. What expertise was required to develop the new transistor?

7. What makes the electrochemical transistor attractive for bioelectronic diagnostics and therapies?

8. What advantage do the electrochemical transistors with vertical architecture have over conventional planar electrochemical transistors?

9. Why are n-type transistors difficult to build and typically unstable?

10. What is significant about the new work by Northwestern University researchers?

HIGHSPEED VISIBLE LIGHT COMMUNICATION BASED ON MICRO LEDS

by Compuscript Ltd

The evolution of next-generation cellular networks is aimed at creating faster, more reliable solutions. Both the next-generation 6G network and the metaverse require high transmission speeds. Visible light communication (VLC) is deemed an important ancillary technology to wireless communication.

Light-emitting diode (LED) solid-state lighting technology offers low power consumption and cost, small size, and a long operational lifetime. Moreover, it is environmentally friendly. These advantages contributed to the explosive growth of the LED-lighting market.

Notably, the visible-light band with a spectral range between 380 and 780 nm is not licensed like radio frequencies and can be used without authorization. Hence, LED-based visible light communication (VLC) technology has attracted research attention worldwide, and VLC technology has rapidly developed in the past decade.

The flickering of LEDs cannot be identified by the naked eye, owing to the high frequency of the signal in the VLC system. Thus, by adding relatively inexpensive front-end components, VLC can be easily implemented in existing lighting infrastructures to achieve data communications with speeds in the Gbps range.

Furthermore, compared with the considerable co-channel interference of wireless RF communication, the propagation of visible light is not perturbed by electromagnetic waves, i.e., the electromagnetic interference phenomenon does not occur. Therefore, VLC offers unique advantages in hospitals, airports, nuclear power plants, underground mines, substations, and other scenarios that are sensitive to electromagnetic interference.

Owing to high modulation bandwidths of micro light-emitting diodes (μLEDs), they are ideal light sources for high-speed VLC. Although μLEDs are now widely used in VLC, few studies have provided general descriptions of μLED-based VLC systems from devices to applications.

The authors of this article present an overview of μLEDs for VLC. Methods to improve the modulation bandwidth are discussed in terms of epitaxy optimization, crystal orientation, and active region structure. Moreover, photoluminescent white LEDs based on phosphor or quantum-dot color conversion and μLED-based detectors for VLC are introduced. Finally, the latest high-speed VLC applications and the application prospects of VLC in 6G are introduced.

As the most common type of μLEDs, structural optimization of c-plane μLED devices has been reported and the improvement of the modulation bandwidth has mainly focused on enhancing the carrier recombination process. The specific methods include the formation of metal contacts with low contact resistance by thermal annealing, the growth of ultra-thin QW devices, etc., which can significantly improve the modulation bandwidth of μLED devices.

Furthermore, C-plane LEDs are affected by a strong quantum confinement Stark effect (QCSE), which limits the modulation bandwidth. One approach to overcome the QCSE is to fabricate nonpolar or semipolar structures. The modulation bandwidth of μLEDs with different crystal orientations is shown. The bandwidth of μLEDs grown on the nonpolar faces is the highest, followed by the semi-polar plane and c-plane. Therefore, manufacturing non-polar or semi-polar μLED is also a method to improve the modulation bandwidth.

Due to their low power consumption, high brightness, high resolution and color saturation, μLEDs are advantageous for display and lighting applications. Therefore, white-light VLC systems based on μLEDs can achieve both illumination and display functions in addition to high-speed data transmission, which has greater application prospects. The authors of this article have compiled the latest advances in μLED-based white-light VLC systems in recent years to demonstrate that these kind of systems are expected to become an important part of next-generation communication and illumination technologies.

As the research on μLED devices expands, the μLED-based high-speed VLC is garnering increasing interest. This review summarizes the advantages and challenges of μLEDs in VLC systems. Methods to improve the modulation bandwidth of μLEDs were introduced. In addition to conventional c-polar epitaxial structure optimization and semi/nonpolar GaN epitaxial growth, μLEDs using microstructures or InGaN QDs as active regions can also improve the radiative recombination rate.

μLEDs are considered bright solid-state lighting sources compared with different classes of WLEDs for VLC. Similarly, μLEDs can also be used as detectors in VLC systems. Finally, the prospects of VLC in 6G and the latest high-speed VLC applications were introduced. Given the high-speed transmission advantages, μLED-based VLC is expected to become an ancillary technology for 6G and cooperate with other communication technology to benefit our daily lives.

This work provides new ideas for the device design of high-bandwidth μLEDs, reveals more potential uses of μLED-based high-speed VLC systems, and provides a new technical path for the promotion of VLC in next-generation communication technologies.

Glossary

1. Next-generation cellular networks: Advanced mobile communication networks designed to provide faster and more reliable solutions than current networks.

2. 6G network: The next generation of mobile networks after the current 5G network.

3. Metaverse: A virtual world where users can interact with a computer-generated environment and other users.

4. Transmission speeds: The rate at which data is transmitted over a network or communication system.

5. Visible light communication (VLC): A technology that uses visible light to transmit data wirelessly.

6. Light-emitting diode (LED): A semiconductor device that emits light when an electric current is passed through it.

7. Solid-state lighting technology: Lighting technology that uses solid-state components, such as LEDs, instead of traditional light bulbs.

8. Low power consumption: The amount of power used by a device or system is low, resulting in energy efficiency.

9. Spectral range: The range of frequencies or wavelengths of electromagnetic radiation in a given system.

10. Radio frequencies: The range of frequencies used for wireless communication.

11. Authorization: Permission or clearance granted to use a certain resource or technology.

12. Flickering: Rapid changes in light intensity or brightness.

13. Front-end components: Components that are located at the beginning of a system or process.

14. Gbps range: Gigabits per second range, referring to data transmission speeds.

15. Co-channel interference: Interference caused by multiple signals transmitting on the same frequency channel.

16. Electromagnetic waves: Waves consisting of oscillating electric and magnetic fields, such as those used in wireless communication.

17. Electromagnetic interference: Interference caused by electromagnetic waves disrupting other electronic devices or systems.

18. Modulation bandwidth: The range of frequencies that can be transmitted through a signal.

19. Epitaxy optimization: The process of improving the crystal structure of semiconductor materials for better performance in electronic devices.

20. Crystal orientation: The direction in which the crystal lattice of a material is oriented.

21. Active region structure: The part of a semiconductor device that generates light or electrical signals.

22. Photoluminescent: Emitting light as a result of exposure to light.

23. Quantum-dot color conversion: A technology that converts the wavelength of light emitted by a device by using quantum dots.

24. Detectors: Devices used to detect and measure electromagnetic radiation.

25. Structural optimization: The process of improving the design or structure of a device for better performance.

26. Carrier recombination process: The process by which electrons and holes combine to emit light in a semiconductor device.

27. Quantum confinement Stark effect (QCSE): A phenomenon that limits the modulation bandwidth in c-plane LEDs.

28. Nonpolar or semipolar structures: Crystal orientations that are not parallel to the polar axis of a crystal lattice.

29. High resolution: The ability of a device to display or capture fine details.

30. Color saturation: The intensity or purity of colors displayed by a device.

31. Display and lighting applications: The use of a device for both display and illumination purposes.

32. Energy efficiency: The ability of a device or system to perform its function while using minimal energy.

Task 1

Find words in the text that mean the following:

1. advance

2. get together

3. because of

4. improving

5. intrude, intervene

6. disturb

7. distributuon

Task 2

Answer the questions:

1. What is the aim of next-generation cellular networks?

2. What are the two technologies that require high transmission speeds?

3. What is visible light communication (VLC)?

4. What are the advantages of LED solid-state lighting technology?

5. Can LED-based VLC technology be used without authorization?

6. Why is VLC technology ideal for scenarios that are sensitive to electromagnetic interference?

7. What are micro light-emitting diodes (μLEDs)?

8. How can the modulation bandwidth of μLEDs be improved?

9. What are the advantages of white-light VLC systems based on μLEDs?

10. What is the focus of the review on μLEDs in VLC systems?

11. What are some methods to improve the modulation bandwidth of μLEDs?

12. What are some potential uses of μLED-based high-speed VLC systems?

Task 3

Say whether the following statements true, false or not given:

1. The article suggests that VLC is the only ancillary technology to wireless communication for 6G and the metaverse.

2. The visible-light band with a spectral range between 380 and 780 nm is not licensed like radio frequencies and can be used without authorization. Hence, LED-based visible light communication (VLC) technology has attracted research attention worldwide, and VLC technology has rapidly developed in the past decade.

3. The flickering of LEDs in a VLC system can be identified by the naked eye.

4. Compared with the considerable co-channel interference of wireless RF communication, the propagation of visible light is not perturbed by electromagnetic waves, i.e., the electromagnetic interference phenomenon does not occur. Therefore, VLC offers unique advantages in hospitals, airports, nuclear power plants, underground mines, substations, and other scenarios that are sensitive to electromagnetic interference.

5. The article suggests that μLEDs are not ideal light sources for high-speed VLC.

6. The only method to improve the modulation bandwidth of μLEDs is by enhancing the carrier recombination process.

7. C-plane LEDs are affected by a strong quantum confinement Stark effect (QCSE), which limits the modulation bandwidth. One approach to overcome the QCSE is to fabricate nonpolar or semipolar structures.

8. White-light VLC systems based on μLEDs can only achieve high-speed data transmission, but not illumination or display functions.

9. The article highlights the latest advances in μLED-based white-light VLC systems and their potential as an important part of next-generation communication and illumination technologies.

10. The review introduces methods to improve the modulation bandwidth of μLEDs, including conventional c-polar epitaxial structure optimization, semi/nonpolar GaN epitaxial growth, and the use of microstructures or InGaN QDs as active regions.

LITHIUM-SULFUR BATTERIES ARE ONE STEP CLOSER TO POWERING THE FUTURE

by Dominic Lynch, Argonne National Laboratory

Image shows microstructure and elemental mapping (silicon, oxygen and sulfur) of porous sulfur-containing interlayer after 500 charge-discharge cycles in lithium-sulfur cell. Credit: Guiliang Xu/Argonne National Laboratory.

Batteries are everywhere in daily life, from cell phones and smart watches to the increasing number of electric vehicles. Most of these devices use well-known lithium-ion battery technology. And while lithium-ion batteries have come a long way since they were first introduced, they have some familiar drawbacks as well, such as short lifetimes, overheating and supply chain challenges for certain raw materials.

Scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory are researching solutions to these issues by testing new materials in battery construction. One such material is sulfur. Sulfur is extremely abundant and cost effective and can hold more energy than traditional ion-based batteries.

In a new study, researchers advanced sulfur-based battery research by creating a layer within the battery that adds energy storage capacity while nearly eliminating a traditional problem with sulfur batteries that caused corrosion.

A promising battery design pairs a sulfur-containing positive electrode (cathode) with a lithium metal negative electrode (anode). In between those components is the electrolyte, or the substance that allows ions to pass between the two ends of the battery.

Early lithium-sulfur (Li-S) batteries did not perform well because sulfur species (polysulfides) dissolved into the electrolyte, causing its corrosion. This polysulfide shuttling effect negatively impacts battery life and lowers the number of times the battery can be recharged.

To prevent this polysulfide shuttling, previous researchers tried placing a redox-inactive interlayer between the cathode and anode. The term "redox-inactive" means the material does not undergo reactions like those in an electrode. But this protective interlayer is heavy and dense, reducing energy storage capacity per unit weight for the battery. It also does not adequately reduce shuttling. This has proved a major barrier to the commercialization of Li-S batteries.

To address this, researchers developed and tested a porous sulfur-containing interlayer. Tests in the laboratory showed initial capacity about three times higher in Li-S cells with this active, as opposed to inactive, interlayer. More impressively, the cells with the active interlayer maintained high capacity over 700 charge-discharge cycles.

"Previous experiments with cells having the redox-inactive layer only suppressed the shuttling, but in doing so, they sacrificed the energy for a given cell weight because the layer added extra weight," said Guiliang Xu, an Argonne chemist and co-author of the paper. "By contrast, our redox-active layer adds to energy storage capacity and suppresses the shuttle effect."

To further study the redox-active layer, the team conducted experiments at the 17-BM beamline of Argonne's Advanced Photon Source (APS), a DOE Office of Science user facility. The data gathered from exposing cells with this layer to X-ray beams allowed the team to ascertain the interlayer's benefits.

The data confirmed that a redox-active interlayer can reduce shuttling, reduce detrimental reactions within the battery and increase the battery's capacity to hold more charge and last for more cycles. "These results demonstrate that a redox-active interlayer could have a huge impact on Li-S battery development," said Wenqian Xu, a beamline scientist at APS. "We're one step closer to seeing this technology in our everyday lives."

Going forward, the team wants to evaluate the growth potential of the redox-active interlayer technology. "We want to try to make it much thinner, much lighter," Guiliang Xu said.

A paper based on the research appeared in the Aug. 8 issue of *Nature Communications*. Khalil Amine, Tianyi Li, Xiang Liu, Guiliang Xu, Wenqian Xu, Chen Zhao and Xiao-Bing Zuo contributed to the paper.

Glossary

1. Lithium-ion battery technology: A type of rechargeable battery technology widely used in electronic devices and electric vehicles.

2. Short lifetimes: The limited lifespan of a battery before it needs to be replaced or recharged.

3. Overheating: Excessive heat generated by a battery, which can lead to safety hazards and reduced performance.

4. Supply chain challenges: Difficulties in sourcing raw materials required for battery production.

5. Sulfur: A chemical element that is abundant and cost-effective, and has potential as a material for energy storage in batteries.

6. Electrolyte: A substance that allows ions to move between the electrodes of a battery.

7. Polysulfides: Sulfur species that dissolve into the electrolyte and cause corrosion in sulfur-based batteries.

8. Redox-inactive interlayer: A layer placed between the cathode and anode of a battery to prevent polysulfide shuttling, but which reduces energy storage capacity per unit weight.

9. Redox-active interlayer: A porous sulfur-containing layer that adds energy storage capacity and suppresses the shuttle effect in sulfur-based batteries.

10. Charge-discharge cycles: The number of times a battery can be charged and discharged before its performance degrades.

11. Advanced Photon Source (APS): A user facility at Argonne National Laboratory that uses X-ray beams to study materials and processes.

12. Growth potential: The potential for a technology to be developed and improved over time.

Task 1

Find words that mean the following:

1. numerous, plentiful
2. to stop something from happening
3. to keep in good condition
4. to make something become smaller
5. to judge or calculate the quality, importance

Task 2

Answer the questions:

1. What is the focus of research at Argonne National Laboratory related to batteries?
2. What is one material being researched for use in batteries at Argonne National Laboratory?
3. What advantage does sulfur have over traditional ion-based batteries?
4. What is a promising battery design that researchers are working on?
5. What is the main problem that has hindered the commercialization of lithium-sulfur batteries?
6. What did previous researchers try to do to prevent the shuttling effect in lithium-sulfur batteries?

7. What was the problem with the redox-inactive interlayer solution?

8. What did the researchers develop and test to address this problem?

9. What were the results of testing the redox-active interlayer?

10. What is the next step for the research team?

Task 3

Say whether the following statemants true or false:

1. Argonne National Laboratory is researching solutions to issues with lithium-ion batteries.

2. Sulfur is a rare and expensive material being researched for use in batteries.

3. Sulfur can hold more energy than traditional ion-based batteries.

4. A promising battery design pairs a sulfur-containing negative electrode with a lithium metal positive electrode.

5. The polysulfide shuttling effect caused by dissolved sulfur species negatively impacts battery life.

6. Previous researchers tried placing a redox-active interlayer between the cathode and anode to prevent shuttling.

7. The redox-inactive interlayer reduced shuttling but added extra weight to the battery.

8. Researchers developed a porous sulfur-containing interlayer that is redox-inactive to address the weight issue.

9. Tests showed that cells with the active interlayer had lower capacity over 700 charge-discharge cycles.

10. The research team plans to evaluate the growth potential of the redox-active interlayer technology and make it thinner and lighter.

RE-AWAKENING THE WORLD'S FIRST SOLAR CELLS FOR INDOOR PHOTOVOLTAICS APPLICATIONS

by Thamarasee Jeewandara, Tech Xplore

The world's first solid-state photovoltaics were reported in 1883, and were composed of selenium, which eventually led to the development of the present-day photovoltaics, although the wide bandgap of selenium was limiting for applications of sunlight harvesting.

In their present work published in *Science Advances*, Bin Yan and a team of researchers in chemistry, nanotechnology and materials science in China, revisited the concept of the world's oldest photovoltaics material to describe its role in indoor photovoltaics applications. The adsorption spectrum of the material perfectly matched the emission spectra of commonly used indoor light sources. The researchers used selenium modules to produce an output power of 232.6 μW under indoor light illumination to power a radiofrequency identification-based localization tag.

The field of photovoltaics

In 1873, electrical engineer Willoughby Smith first discovered the photoconductivity of selenium, and Charles Fritts constructed the first solid-state solar cells thereafter in 1883 by sandwiching selenium between a metal foil and a thin gold layer. The low preliminary power conversion efficiency of these early discoveries, initiated research in the field of photovoltaics and inspired the emergence of solar cells in 1954, to lay the foundation to the modern photovoltaic industry.

Until recently, scientists had incorporated indoor photovoltaics to convert indoor light into usable electrical power for wireless devices such as sensors, actuators, and communication devices. In this work, Yan et al. showed the unique advantages of using selenium for indoor photovoltaics with its suitably wide bandgap and intrinsic environmental stability. The team also developed selenium modules to produce an output power of 232.6 μW, to power an internet of things wireless device for radiofrequency identification-based localization.

Photovoltaic performances of Se cells measured under AM1.5G and indoor light conditions. (A) Schematic of Se thin-film solar cell architecture. (B) Cross-sectional SEM image of Se cell. (C) PCE statistics of 20 Se cells for 0.5-, 2.5-, and 5-nm Te layers measured under AM1.5G and indoor illumination of 1000 lux. (D) J-V curves of 0.5, 2.5, and 5 nm Te layer Se devices under standard one-sun illumination. (E) EQE curves of 0.5, 2.5, and 5 nm Te layer Se devices. (F) J-V curves of 0.5, 2.5, and 5 nm Te layer Se devices under indoor illumination of 1000 lux. Credit: *Science Advances*, DOI: 10.1126/sciadv.adc9923

Indoor photovoltaics

It is now possible to power the "internet of things" devices by harvesting indoor light via indoor photovoltaics (IPV). The concept is a growing research field, where a variety of technologies including dye-sensitized solar cells and organic photovoltaics and lead-halide perovskite solar cells are explored for their functionality.

Indoor light is typically designed to suit human eye sensitivity, so by design its elements differ from conventional outdoor photovoltaics. When the existing features of selenium were combined with its non-toxicity and excellent stability, Yan et al. deemed the material to be ideal for indoor photovoltaic applications.

Optimizing the experiments for improved outcomes

The research team adopted a superstrate configuration of glass/Fluorine-doped tin oxide with titanium oxide/tellurium/selenium and gold to develop the thin-film selenium solar cells. During the process, they used environmentally-friendly titanium oxide to form the buffer layer, and constructed the non-toxic selenium-based devices to facilitate indoor light applications.

Investigation of the effect of Te on interface quality between Se and TiO2. Comparison of the operational mechanism between (A) indoor condition and (B) one-sun condition. DFT models for (C) delocalized surface defects at the Te-modified Se/TiO2 interface and (D) localized surface defects at the Se/TiO2 interface. (E) XPS spectra of Te 3d recorded during sputtering from the top to the bottom of Te film. a.u., arbitrary unit. AFM images of (F) 0.5 nm and (G) 2.5 nm Te layers. (H) C-V and DLCP characteristics of 0.5 nm Te and 2.5 nm Te devices. Credit: *Science Advances*, DOI: 10.1126/sciadv.adc9923

During the experiments, they studied the selenium solar cells under standard one-sun illumination and measured indoor photovoltaic performances of devices under indoor light at 1000 Lux, with a common LED source of light to simulate the environment of illumination. The outcomes also led to the optimization of the tellurium layer to facilitate significantly different light intensities between indoor light and sunlight.

Indoor light could comparatively only generate a relatively small number of carriers on account of its very weak intensity. The team therefore improved the device to obtain a positive photodoping effect to optimize the selenium solar cells under indoor light conditions. Yan et al. additionally incorporated tellurium at the selenium/titanium oxide interface to provide a strong bond for surface passivation.

Applications of the devices

The devices can be used to investigate a range of indoor lighting conditions typically required to light environments such as the living room, the library, or a bright supermarket. The selenium cells outperformed market-dominating silicon-based cells that are presently an industry standard for indoor photovoltaics, relative to both power conversion efficiency and stability.

Application in powering IoT wireless device. (A) Emission power and integrated power spectra of a 2700 K LED at 1000 lux. (B) J-V curves of 2.5 nm Te device under illumination at 200, 500, and 1000 lux. (C) Evolution of normalized PCEs of unencapsulated Se device under continuous indoor illumination at 1000 lux in an ambient atmosphere. (D) J-V curves of individual large-area (2.25 cm2) Se device and (3 × 2.25 cm2) module under indoor illumination at 1000 lux. Inset: Photographs of individual large-area Se cell and module. (E) Schematic of self-powered RFID-based localization tag enabled by Se module under indoor light illumination. (F) Measured number of signals per minute from a Se module–powered RFID tag. Credit: *Science Advances*, DOI: 10.1126/sciadv.adc9923

Contrastingly, silicon-based cells only exhibited a power conversion efficiency below 10%, with relatively minimal photostability. On account of these observations, the team considered the selenium-based devices to be a more attractive alternative candidate. They also studied the capacity of the selenium device to power the internet of things wireless devices.

Outlook

In this way, Bin Yan and colleagues reinterpreted selenium, the oldest existing photovoltaic material with the emergence of indoor photovoltaic devices, due to its unique capacity to offer a suitable wide bandgap for indoor light harvesting. The material is non-toxic and has intrinsic environmental stability as essential features.

The scientists optimized the material composition to achieve a power conversion efficiency of 15%, suited for 1000 Lux indoor illumination with selenium cells. This outcome surpassed the existing efficiency of commercial silicon cells. The selenium devices performed without degradation, even after 1000 hours of continuous indoor lighting.

The outcomes of the study highlight the scope of using selenium for indoor photovoltaics with added potential to power the internet of things devices as an attractive element in photovoltaics.

Glossary

1. Photovoltaics: The conversion of light into usable electrical power.

2. Solid-state photovoltaics: Photovoltaic materials that are not in liquid or gas form.

3. Selenium: A chemical element used in the production of photovoltaic cells.

4. Output power: The amount of power produced by a device.

5. Bandgap: The energy range that electrons cannot occupy in a material.

6. Indoor photovoltaics: The use of photovoltaic cells to convert indoor light into usable electrical power.

7. Internet of things: The interconnection of everyday objects through the internet.

8. Dye-sensitized solar cells: Photovoltaic cells that use dyes to absorb sunlight and generate electricity.

9. Organic photovoltaics: Photovoltaic cells made from organic materials, such as polymers.

10. Lead-halide perovskite solar cells: Photovoltaic cells made from a class of materials called perovskites.

11. Superstrate configuration: A configuration where the photovoltaic material is on top of a transparent substrate.

12. Buffer layer: A layer between two materials to improve their adhesion and prevent damage.

13. Titanium oxide: A compound used in the production of photovoltaic cells as a buffer layer.

14. Gold: A metal used in the production of photovoltaic cells as an electrode.

15. Fluorine-doped tin oxide: A transparent conductor used as a substrate in photovoltaic cells.

16. XPS spectra: X-ray photoelectron spectroscopy spectra used to analyze the chemical composition of a material.

17. Carriers: Electrons or holes that carry electric charge in a material.

18. Photodoping effect: The process of introducing impurities into a material to improve its electrical properties under light.

19. Surface passivation: The process of reducing surface recombination of carriers in a material to improve its efficiency.

20. Power conversion efficiency: The percentage of light energy that is converted into electrical energy by a photovoltaic device.

21. Photostability: The ability of a material to maintain its performance under light exposure.

22. Non-toxic: Not harmful to human health or the environment.

Task 1

Answer the questions:

1. What were the world's first solid-state photovoltaics made of and when were they reported?

2. Who led the research on indoor photovoltaics using selenium?

3. What is the unique advantage of using selenium for indoor photovoltaics?

4. What was the output power produced by the selenium modules developed by Yan et al. under indoor light illumination?

5. What is the "internet of things" and how can it be powered by indoor photovoltaics?

6. What are some other technologies that are explored for their functionality in indoor photovoltaics?

7. What configuration was adopted by the research team to develop thin-film selenium solar cells?

8. What environmentally-friendly material was used to form the buffer layer in the development of selenium-based devices for indoor light applications?

9. What was the purpose of investigating the effect of Te on the interface quality between Se and TiO2?

10. What type of light was used to simulate indoor lighting conditions in the experiments?

11. Why did the research team incorporate tellurium at the selenium/titanium oxide interface?

12. How did the selenium cells perform compared to silicon-based cells for indoor photovoltaic applications?

13. What is the power conversion efficiency achieved by the selenium devices for 1000 Lux indoor illumination?

14. How long did the selenium devices perform without degradation under continuous indoor lighting?

15. What are some essential features of selenium that make it suitable for indoor photovoltaic applications?

16. What is the added potential of using selenium for indoor photovoltaics?

Task 2

Say whether the following statements true, false or not mentioned:

1. The world's first solid-state photovoltaics were reported in 1883 and were composed of selenium.

2. The research team incorporated tellurium at the selenium/titanium oxide interface to provide a strong bond for surface passivation.

3. The selenium cells outperformed silicon-based cells in terms of power conversion efficiency and stability for indoor photovoltaic applications.

4. TThe power conversion efficiency achieved by the selenium devices for 1000 Lux indoor illumination is 15%.

5. The selenium devices performed without degradation even after 1000 hours of continuous indoor lighting.

6. Selenium has a suitable wide bandgap and intrinsic environmental stability, making it ideal for indoor photovoltaic applications. It is also non-toxic.

7. Selenium has added potential to power internet of things devices as an attractive element in photovoltaics.

8. The low preliminary power conversion efficiency of the early discoveries of photovoltaics led to the emergence of solar cells in 1954.

9. Scientists have incorporated indoor photovoltaics to convert indoor light into usable electrical power for wireless devices such as sensors, actuators, and communication devices.

10. By combining the existing features of selenium with its non-toxicity and excellent stability, Yan et al. deemed the material to be ideal for indoor photovoltaic applications.

11. The selenium solar cells performed better under one-sun illumination than under indoor light at 1000 Lux.

12. The team used silicon-based cells as a benchmark for their experiments on indoor photovoltaics.

13. The tellurium layer was optimized to facilitate similar light intensities between indoor light and sunlight.

14. The selenium devices were only tested for indoor lighting conditions in a living room environment.

15. The selenium devices achieved a power conversion efficiency of 15% for indoor illumination at 1000 Lux.

16. Selenium is non-toxic and has intrinsic environmental stability, making it an ideal material for indoor photovoltaic applications.

17. The selenium devices demonstrated potential to power internet of things wireless devices.

SPRAY-ON SMART SKIN USES AI TO RAPIDLY UNDERSTAND HAND TASKS

by Andrew Myers, Stanford University

Spray-on sensory system which consists of printed, bio-compatible nanomesh directly connected with wireless Bluetooth module and further trained through meta-learning. Credit: Kyun Kyu “Richard” Kim, Bao Group, Stanford U.

A new smart skin developed at Stanford University might foretell a day when people type on invisible keyboards, identify objects by touch alone, or allow users to communicate by hand gestures with apps in immersive environments.

In a just-publish paper in the journal *Nature Electronics* the researchers describe a new type of stretchable biocompatible material that gets sprayed on the back of the hand, like suntan spray. Integrated in the mesh is a tiny electrical network that senses as the skin stretches and bends and, using AI, the researchers can interpret myriad daily tasks from hand motions and gestures. The researchers say it could have applications and implications in fields as far-ranging as gaming, sports, telemedicine, and robotics.

So far, several promising methods, such as measuring muscle electrical activities using wrist bands or wearable gloves, have been actively explored to enable various hand tasks and gesturing. However, these devices are bulky as multiple sensory components are needed to pinpoint movements at every single joint. Moreover, a large amount of data needs to be collected for each user and task in order to train the algorithm. These challenges make it difficult to adopt such devices as daily-use electronics.

This work is the first practical approach that is both lean enough in form and adaptable enough in function to work for essentially any user–even with limited data. Current technologies require multiple sensor components to read each joint of the finger, making them bulky. The new device also takes a leaner approach to software to allow faster learning. Such precision could be key in virtual reality applications to convey finely detailed motions for a more realistic experience.

Credit: *Nature Electronics* (2022). DOI: 10.1038/s41928-022-00888-7

The enabling innovation is a sprayable electrically sensitive mesh network embedded in polyurethane–the same durable-yet-stretchable material used to make skateboard wheels and to protect hardwood floors from damage. The mesh is comprised of millions of nanowires of silver coated with gold that are in contact with each other to form dynamic electrical pathways. This mesh is electrically active, biocompatible, breathable, and stays on unless rubbed in soap and water. It conforms intimately to the wrinkles and folds of each human finger that wears it. Then a lightweight Bluetooth module can be simply attached to the mesh which can wirelessly transfer the signal changes.

"As the fingers bend and twist, the nanowires in the mesh get squeezed together and stretched apart, changing the electrical conductivity of the mesh. These changes can be measured and analyzed to tell us precisely how a hand or a finger or a joint is moving," explained Zhenan Bao, a K.K. Lee Professor of Chemical Engineering and senior author of the study.

The researchers chose a spray-on approach directly on skin so that the mesh is supported without a substrate. This key engineering decision eliminated unwanted motion artifacts and allowed them to use a single trace of conductive mesh to generate multi-joint information of the fingers.

Two-handed QWERTY keyboard typing recognition with nanomesh printed on both hands and real-time recognition of interacting objects. Credit: Kyun Kyu “Richard” Kim, Bao Group, Stanford U.

The spray-on nature of the device allows it to conform to any size or shaped hand, but opens the possibility that the device could be adapted to the face to capture subtle emotional cues. That might enable new approaches to computer animation or lead to new avatar-led virtual meetings with more realistic facial expressions and hand gestures.

Machine learning then takes over. Computers monitor the changing patterns in conductivity and map those changes to specific physical tasks and gestures. Type an X on a keyboard, for instance, and the algorithm learns to recognize that task from the changing patterns in the electrical conductivity. Once the algorithm is suitably trained, the physical keyboard is no longer necessary. The same principles can be used to recognize sign language or even to recognize objects by tracing their exterior surfaces.

And, whereas existing technologies are computationally intensive and require vast amounts of data that must be laboriously labeled by humans–by hand, if you will–the Stanford team has developed a learning scheme that is far more computationally efficient.

"We brought the aspects of human learning that rapidly adapt to tasks with only a handful of trials known as 'meta-learning.' This allows the device to rapidly recognize arbitrary new hand tasks and users with a few quick trials," said Kyun Kyu "Richard" Kim, a post-doctoral scholar in Bao's lab, who is first author of the study.

"Moreover, it's a surprisingly simple approach to this complex challenge that means we can achieve faster computational processing time with less data because our nanomesh captures subtle details in its signals," Kim added. The precision with which the device can map subtle motions of the fingers is one of the leading features of this innovation.

The researchers have built a prototype that recognizes simple objects by touch and can even do predictive two-handed typing on an invisible keyboard. The algorithm was able to type, "No legacy is so rich as honesty" from William Shakespeare and "I am the master of my fate, I am the captain of my soul" from William Ernest Henley's poem "Invictus."

Glossary

1. Smart skin: A new type of technology that can interpret hand motions and gestures through a sprayable electrically sensitive mesh network embedded in polyurethane.

2. Stretchable biocompatible material: A material that can stretch and bend with the skin without causing harm or irritation.

3. AI: Artificial intelligence, a computer system that can learn and adapt to different situations.

4. Immersive environments: Virtual reality or augmented reality experiences that fully immerse the user in a digital world.

5. Wearable gloves: Gloves with sensors that can detect hand movements and gestures.

6. Lean approach: A simplified approach to technology that is adaptable and easy to use.

7. Polyurethane: A durable and stretchable material used in the sprayable mesh network.

8. Nanowires: Extremely small wires that make up the mesh network.

9. Conductivity: The ability of a material to conduct electricity.

10. Motion artifacts: Unwanted movements or distortions in the data collected by a sensor or device.

11. Machine learning: A type of artificial intelligence where computers can learn and adapt based on data input.

12. Avatar-led virtual meetings: Virtual meetings where users are represented by avatars, which can now have more realistic facial expressions and hand gestures thanks to the smart skin technology.

13. Electrical pathways: The routes that electricity takes through the mesh network.

14. Bluetooth module: A small device that allows wireless communication between the smart skin and other devices.

15. K.K. Lee Professor of Chemical Engineering: Zhenan Bao, a senior author of the study who is an expert in chemical engineering.

16. QWERTY keyboard typing recognition: The ability of the smart skin to recognize specific typing patterns on a keyboard.

17. Real-time recognition: The ability of the smart skin to recognize gestures and movements as they happen in real-time.

18. Multi-joint information: Information about the movement of multiple joints in the fingers, captured by the smart skin.

19. Emotional cues: Subtle facial expressions or body language that can convey emotions.

20. Conductive mesh: The mesh network that allows the smart skin to detect and interpret hand movements and gestures.

21. Algorithm: A set of instructions or rules followed by a computer program to solve a problem or complete a task.

22. Sign language: A visual language that uses hand gestures and body language to convey meaning.

23. Meta-learning: A type of machine learning where a computer system can learn how to learn new tasks more efficiently.

24. Computational processing time: The amount of time it takes for a computer system to process data and complete tasks.

25. Nanomesh: A mesh network made up of extremely small wires called nanowires.

26. Prototype: A preliminary version of a product or device used for testing and evaluation.

27. Predictive typing: A feature that predicts the words a user is typing based on previous input and context.

28. Invisible keyboard: A virtual keyboard that does not physically exist but can be used with hand gestures and movements.

29. Leading features: The most notable or important characteristics of a product or technology.

30. Tracing: Following the outline or contours of an object or surface with a sensor or device.

Task 1

Find words that mean the following:

1. to say what is going to happen in future
2. application
3. large, clumsy
4. present, today
5. more efficient
6. prevail
7. although

Task 2

Answer the questions:

1. What is the new type of stretchable material described in the article?
2. How does the mesh network work?
3. What is the advantage of the spray-on approach for the device?
4. What is the potential application of the smart skin technology?
5. How does machine learning help interpret the hand motions and gestures?
6. What is the material used to make the mesh network?
7. What is the advantage of the new device over current technologies for hand motion recognition?
8. What is the advantage of using a single trace of conductive mesh to generate multi-joint information of the fingers?
9. Can the device be adapted to capture facial expressions?
10. What is the potential application of the smart skin technology in virtual meetings?
11. What is the learning scheme used by the Stanford team to recognize hand tasks and users with only a few trials?
12. How does the nanomesh capture subtle details in its signals?
13. What is one of the leading features of this innovation?
14. What is the potential application of the prototype built by the researchers?
15. Can the same principles be used to recognize sign language or objects by tracing their exterior surfaces?

Task 3

Say wherether the following statements are true or false:

1. The smart skin developed at Stanford University can allow users to type on invisible keyboards and identify objects by touch alone.

2. The stretchable biocompatible material is applied to the palm of the hand.

3. Current technologies require multiple sensor components to read each joint of the finger, making them bulky.

4. The new device can only be used by individuals who have provided a large amount of data for each task.

5. The electrically sensitive mesh network is embedded in silicone.

6. The mesh network is comprised of millions of nanowires of silver coated with platinum.

7. The device can be adapted to the face to capture subtle emotional cues.

8. The machine learning algorithm can recognize physical tasks and gestures from changes in electrical conductivity.

9. The physical keyboard is still necessary even after the algorithm is trained.

10. The new device has no potential applications beyond gaming and telemedicine.

11. The device can recognize sign language and objects by tracing their exterior surfaces.

12. Existing technologies require vast amounts of data that must be labeled by humans.

13. The learning scheme developed by the Stanford team is computationally inefficient.

14. The nanomesh captures subtle details in its signals, which results in slower computational processing time.

15. The algorithm was able to type two quotes from William Shakespeare and William Ernest Henley's poem "Invictus."

SCIENTISTS DISCOVER A NOVEL PHOTOPHYSICAL MECHANISM THAT HAS ACHIEVED RECORD-BREAKING EFFICIENCY FOR ORGANIC PHOTOVOLTAICS

Date: December 21, 2022
Source: City University of Hong Kong

Summary:

Organic photovoltaics (OPVs) are a promising, economical, next-generation solar cell technology for scalable clean energy and wearable electronics. But the energy conversion loss due to the recombination of photogenerated charge carriers in OPVs has hindered further enhancement of their power conversion efficiency (PCE). Recently, researchers from City University of Hong Kong (CityU) overcame this obstacle by inventing a novel device-engineering strategy to successfully suppress the energy conversion loss, resulting in record-breaking efficiency.

Organic photovoltaics (OPVs) are a promising, economical, next-generation solar cell technology for scalable clean energy and wearable electronics. But the energy conversion loss due to the recombination of photogenerated charge carriers in OPVs has hindered further enhancement of their power conversion efficiency (PCE). Recently, researchers from City University of Hong Kong (CityU) overcame this obstacle by inventing a novel device-engineering strategy to successfully suppress the energy conversion loss, resulting in record-breaking efficiency.

The best-performing OPVs developed by the CityU team have achieved PCE of over 19%, and the team expects to exceed 20% very soon. The discovery is promising for the commercialisation of OPVs.

OPVs, a solar cell technology based on organic semiconductors, are regarded as a promising candidate for clean energy because of their low material toxicity and vast molecular tunability in photoactive materials. Currently, most high-performance organic photovoltaics adopt a "bulk-heterojunction" (BHJ) structure, consisting of electron donor and acceptor materials intermixed throughout the active layer of the device (see figure 1).

When converting sunlight into electricity in OPVs, energy from sunlight creates excitons (a negatively charged electron and a positively charged hole bound together), which then dissociate into free electrons and holes at the nanoscale donor-acceptor interface, generating charge carriers (photocurrent) and hence electricity.

However, if these charge carriers are not collected by the electrodes and encounter each other again at the donor-acceptor interface, they may recombine to form a so-called low-energy "spin-triplet exciton" (T_1), which consecutively relaxes back to ground state, causing energy loss in the form of heat and hence photocurrent loss. This irreversible process strongly limits the maximum achievable PCE of OPVs.

A research team led by Professor Alex Jen Kwan-yue, Lee Shau Kee Chair Professor of Materials Science and Director of the Hong Kong Institute for Clean Energy at CityU, overcame this obstacle by inventing a novel device-engineering strategy to suppress T_1 formation and minimise the associated recombination loss, which led to the record-breaking efficiency of OPVs.

"We are the first team that managed to modulate T_1 formation through device engineering without changing the properties of the photoactive materials and to reveal the fundamental mechanism," said Professor Jen. "Using this strategy, we have expanded it to 14 other material systems to show the universal applicability of this study." Their findings were published in the scientific journal *Nature Energy,* under the title "Suppressed Recombination Loss in Organic Photovoltaics Adopting a Planar-mixed Heterojunction Architecture."

By replacing the traditional highly intermixed bulk-heterojunction (BHJ) architecture inside the solar cell with a rather de-mixed "planar-mixed heterojunction" (PMHJ) to reduce the donor-acceptor interface inside the active layer of OPVs, the team managed to alleviate the energy conversion loss in OPVs by suppressing the recombination of the charge carriers. This discovery maximized the photocurrent of OPVs, resulting in devices with a high PCE of over 19%.

"Compared to the traditional inter-mixed bulk-heterojunction (BHJ) architecture, our rather de-mixed planar-mixed heterojunction (PMHJ) strategy is capable of suppressing the loss pathway mediated by charge-transfer states at the donor-acceptor interface," Professor Jen explained. "We revealed that having fewer donor-acceptor contacts in planar-mixed heterojunction minimizes the chance of recombination and results in reduced T_1 concentration. This fundamentally changes researchers' previous impression of OPVs – that the more donor-acceptor contacts, the higher the OPV performance."

"The achieved optimum photovoltage-photocurrent trade-off resulting from our strategy enables OPVs with competitive efficiency comparable to that of inorganic photovoltaics," added Dr Francis Lin, postdoc in the Department of Chemistry, who also took part in the study. He explained that organic photovoltaic cells have several advantages over inorganic counterparts, such as being lightweight and flexible, like a thin plastic film, and allowing cost-effective fabrication, using roll-to-roll printing production.

The team believes that its latest discovery provides a comprehensive basis for future organic photovoltaics to reach their full promise and stimulate a new wave of studies on the versatile photophysical processes in organic semiconductors.

They are applying for a patent for the discovery. "We hope to further boost the performance of OPVs following our novel discovery of modulating the photophysical processes. This redefines the maximum potential of OPVs to facilitate their commercialisation," said Professor Jen.

Professor Jen and Dr Lin, at CityU, and Professor Zhang Chunfeng, from Nanjing University, are the corresponding authors of the paper. The first authors include Mr Jiang Kui, PhD student in the Department of Chemistry at CityU, who was involved in the research when he was a research assistant in Professor Jen's group.

The research was supported by various funding sources, including the Lee Shau-Kee Endowed Chair Professorship (Materials Science), CityU, the Innovation and Technology Commission of Hong Kong, the Research Grants Council of Hong Kong, the Guangdong Major Project of Basic and Applied Basic Research, and the Guangdong-Hong Kong-Macao Joint Laboratory of Optoelectronic and Magnetic Functional Materials.

Glossary

1. Organic photovoltaics (OPVs): A type of solar cell technology based on organic semiconductors.

2. Power conversion efficiency (PCE): The efficiency of converting sunlight into electricity in OPVs.

3. Recombination: The process where photogenerated charge carriers encounter each other again at the donor-acceptor interface, resulting in energy loss.

4. Bulk-heterojunction (BHJ) structure: A structure consisting of electron donor and acceptor materials intermixed throughout the active layer of the device.

5. Excitons: Negatively charged electrons and positively charged holes bound together.

6. Planar-mixed heterojunction (PMHJ): A de-mixed structure that reduces the donor-acceptor interface inside the active layer of OPVs.

7. Charge carriers: Electrons and holes generated by the dissociation of excitons.

8. Low-energy "spin-triplet exciton" (T1): A type of exciton that results in energy loss if it relaxes back to ground state.

9. Device-engineering strategy: A strategy to modify the structure of OPVs to enhance their performance.

10. Photocurrent: The flow of electrical current resulting from the generation of charge carriers in OPVs.

11. Universal applicability: The ability of a study's findings to be applied to various material systems.

12. Charge-transfer states: States where an electron is transferred from one molecule to another.

Task 1

Find words that mean the following:

1. something that can be worn that contains computer technjligy
2. transformation
3. interfere, complicate
4. end by force, prevent
5. meet
6. reconnect
7. ease, relieve
8. show

Task 2

Answer the following questions:

1. What are organic photovoltaics (OPVs)?
2. What is the current obstacle that hinders further enhancement of the power conversion efficiency (PCE) of OPVs?
3. How did the research team from City University of Hong Kong overcome the obstacle of energy conversion loss in OPVs?
4. What is the PCE achieved by the best-performing OPVs developed by the CityU team?
5. What is the novel device-engineering strategy used by the CityU team to suppress T1 formation and minimize the associated recombination loss?
6. What are the advantages of organic photovoltaic cells over inorganic counterparts?
7. What is the latest discovery made by the research team from City University of Hong Kong?
8. What is the potential impact of the latest discovery on future studies on organic semiconductors?

Task 3

Say whether the following statements are true, false or not given:

1. Organic photovoltaic cells are heavier than inorganic counterparts.

2. The research team from City University of Hong Kong invented a novel device-engineering strategy to suppress T1 formation and minimise the associated recombination loss.

3. The best-performing OPVs developed by the CityU team have achieved PCE of over 25%.

4. The discovery made by the research team from City University of Hong Kong is not promising for the commercialisation of OPVs.

5. The energy conversion loss due to the recombination of photogenerated charge carriers in OPVs has not hindered further enhancement of their power conversion efficiency (PCE).

6. The research team led by Professor Alex Jen Kwan-yue replaced the traditional highly intermixed bulk-heterojunction (BHJ) architecture inside the solar cell with a rather intermixed "planar-mixed heterojunction" (PMHJ) to reduce the donor-acceptor interface inside the active layer of OPVs.

7. Having fewer donor-acceptor contacts in planar-mixed heterojunction maximizes the photocurrent of OPVs.

8. Organic photovoltaic cells have advantages over inorganic counterparts, such as being lightweight and flexible, like a thin plastic film.

9. The research team's latest discovery does not have any potential for future organic photovoltaics.

10. Inorganic photovoltaics are more cost-effective to fabricate than organic photovoltaics.

NOVEL PREPARATION OF NEXT-GENERATION ANODE DELIVERS BOOST TO LITHIUM-ION BATTERIES

by Tsinghua University Press

Schematic illustration of the LiCPON solid electrolyte and silicon-monoxide-carbon composite anode and consequent structure following battery cycling. Credit: Nano Research, Tsinghua University Press

Performance of lithium-ion batteries will be essential to make the clean transition cheaper and easier, which in turn requires a new generation of materials for anodes in those batteries. One of the best-performing options, a silicon-monoxide-carbon composite, suffers from a series of unwanted chemical reactions. A new preparation technique for this anode material appears to have finally solved the problem.

The hunt for the next generation of materials for anodes in lithium-ion batteries has long suffered from a series of parasitic chemical reactions for many of the proposed replacements for the graphite that is conventionally used. A novel preparation technique for a silicon-monoxide-carbon composite material looks set to finally deliver the efficiency gains desired with none of the unwanted side reactions.

A paper describing the process appeared in the journal *Nano Research*.

Since the late 1990s, most manufacturers of lithium-ion batteries have used graphite as the battery's anode (the negative terminal into which the electrical current enters the battery), replacing coking coal. The switch from coke to graphite, a form of carbon, was made due to its long-term stability over many cycles of recharging and discharging.

But to improve lithium-ion battery performance still further (and in so doing making the transition away from fossil fuels cheaper and more feasible), battery makers will need even better anodes.

One of the widely touted anode material replacements for graphite are silicon-based compounds due to their high specific capacity (rate of discharge) and abundance in the earth's crust. Silicon monoxide in particular has shown great promise for the next generation of high-power lithium-ion batteries.

Despite this promise, silicon monoxide on its own also comes with a set of drawbacks, not least its inherent low conductivity and massive change in size (volume) over the course of cycles of recharging and discharging. These variations in volume of up to 300 percent results in a destruction and shedding of the anode materials, radically reducing performance.

"However, if silicon monoxide is combined in a composite material with carbon–a sort of mash-up between the existing graphite anode material and next-generation silicon-based anode, we could be on to a winner," said Zhengwen Fu, a co-author of the study and an electrochemist with the Shanghai Key Laboratory of

Molecular Catalysis and Innovative Materials at Fudan University. "The composite offers the best of both worlds. But even here, there are many obstacles to be overcome."

The carbon offers the benefit of high electrical conductivity and its aforementioned structural stability, and also experiences a much smaller volume expansion during cycling. Its flexibility and lubricating ability also work to inhibit the volume expansion of the silicon. Overall, the composite anode offers good capacity and high cycling performance.

Unfortunately solving one set of problems has only produced another: silicon-monoxide-carbon composite anodes suffer from relatively poor coulombic efficiency. Coulombic efficiency, sometimes called current efficiency, refers to the ratio of the total electric charge put into a battery compared to the total charge extracted from it. (Coulomb is the term used to describe a unit of electric charge) There will always be less taken out than put in, but the goal is to limit such inevitable losses to a minimum.

Coulombic efficiency is of particular importance to improving the performance and reducing the cost of the colossal amount of batteries we will need to electrify vehicles and for energy storage systems to back up variable sources of renewable energy such as wind and solar.

During the lithium-ion battery's very first cycle using a silicon-monoxide-carbon composite anode, some of the lithium reacts irreversibly with the composite, producing 'degradation products' that form a layer between the surface of the anode and the electrolyte called the solid electrolyte interphase, or SEI. This parasitic 'lithiation' process in turn results in loss of active lithium as well as of coulombic efficiency.

To overcome these challenges, the researchers developed a novel technique for 'pre-lithiation', in which they store extra lithium in the battery in advance to compensate for the lithium consumed by the parasitic reactions during the cycling of the battery. Other researchers had developed their own pre-lithiation techniques, typically involving pure metal lithium, a modified metal lithium or a compound containing lithium.

All of these approaches have their own limitations. For example, the lithium containing compounds tend to release a gas following lithiation during cycling, which reduces the performance of the anode and the energy density of the battery as a whole.

The new pre-lithiation technique, which the researchers call 'solid-state corrosion of lithium', does away with such problems by replacing the liquid electrolyte (the lithium-based medium that allows transport of ions between the anode and its positive counterpart, the cathode, of a battery) with a solid electrolyte composed of carbon-incorporated lithium phosphorus oxynitride, or LiCPON. In this way not only are the various unwanted side reactions associated with metal lithium avoided, but a better interface is produced between anode and electrolyte.

The researchers were able to investigate whether their solid-state corrosion prelithiation process was performing as predicted via optical imaging, electron microscopy and X-ray diffraction–three different methods of viewing the electrochemical reactions in real time. The technique gave a boost to the anode of almost 83 percent over a prelithiation electrode using a liquid electrolyte.

Having proven their concept on 'coin cells'–small-scale batteries intended for laboratory battery research and development, the researchers now want to demonstrate the process with industrial-grade batteries.

Glossary

1. Anode: The negative terminal of a battery where electrical current enters.

2. Efficiency gains: Improvements in the effectiveness and productivity of a process or system.

3. Specific capacity: The rate of discharge of a battery.

4. Composite material: A material made up of two or more different substances that combine to create new properties.

5. Volume expansion: The increase in volume of a material during cycles of recharging and discharging.

6. Coulombic efficiency: The ratio of the total electric charge put into a battery compared to the total charge extracted from it.

7. Current efficiency: Another term for coulombic efficiency.

8. Coulomb: The unit of electric charge.

Task 1

Find words that mean the following:

1. important
2. diadvantage
3. relatedt
4. advantage
5. is not possible to change
6. to research

Task2

Answer the following questions:

1. What is the main challenge in finding new anode materials for lithium-ion batteries?

2. What material is conventionally used as the anode in lithium-ion batteries?

3. Why are silicon-based compounds a promising replacement for graphite as an anode material?

4. What are some drawbacks of using silicon monoxide as an anode material on its own?

5. What is the advantage of combining silicon monoxide with carbon in a composite material?

6. What is coulombic efficiency?

7. Why is coulombic efficiency important for improving battery performance and reducing costs?

8. What is the solid electrolyte interphase (SEI)?

9. What is the goal of reducing degradation products in lithium-ion batteries?

10. What is the significance of the new preparation technique for silicon-monoxide-carbon composite anodes?

11. What is the parasitic 'lithiation' process and why is it a challenge for lithium-ion batteries?

12. What is the new pre-lithiation technique developed by researchers, and how does it differ from existing techniques?

13. How did the researchers investigate whether their solid-state corrosion pre-lithiation process was performing as predicted?

14. What kind of boost did the researchers achieve with their solid-state corrosion prelithiation process compared to a prelithiation electrode using a liquid electrolyte?

15. What is the next step for the researchers after proving their concept on 'coin cells'?

Task 3

Say whether the statements are true or false:

1. The hunt for the next generation of materials for anodes in lithium-ion batteries has not suffered from any parasitic chemical reactions.

2. Graphite has been used as the battery's anode since the late 1990s.

3. Silicon-based compounds are not considered a good replacement for graphite as anode material.

4. Silicon monoxide on its own does not have any drawbacks.

5. A composite material of silicon monoxide and carbon could offer a solution for anode material.

6. Coulombic efficiency refers to the ratio of the total electric charge put into a battery compared to the total charge extracted from it.

7. Coulombic efficiency is not important for improving the performance and reducing the cost of batteries.

8. The silicon-monoxide-carbon composite anodes have excellent coulombic efficiency.

9. Researchers have found a way to improve coulombic efficiency in silicon-monoxide-carbon composite anodes.

10. The researchers plan to demonstrate the solid-state corrosion prelithiation process with consumer-grade batteries.

11. The lithium-ion battery's anode has no effect on the coulombic efficiency of the battery.

12. Pre-lithiation techniques involve adding more lithium to the battery before its first cycle.

13. Lithium-containing compounds are a preferred pre-lithiation technique due to their lack of drawbacks.

14. The solid-state corrosion prelithiation technique replaces the liquid electrolyte with a solid electrolyte composed of LiCPON.

15. The solid-state corrosion prelithiation technique improves the anode's performance by 83 percent.

AT THE EDGE OF GRAPHENE-BASED ELECTRONICS

Date: December 21, 2022
Source: Georgia Institute of Technology
Summary:

Researchers developed a new graphene-based nanoelectronics platform compatible with conventional microelectronics manufacturing, paving the way for a successor to silicon.

A pressing quest in the field of nanoelectronics is the search for a material that could replace silicon. Graphene has seemed promising for decades. But its potential faltered along the way, due to damaging processing methods and the lack of a new electronics paradigm to embrace it. With silicon nearly maxed out in its ability to accommodate faster computing, the next big nanoelectronics platform is needed now more than ever.

Walter de Heer, Regents' Professor in the School of Physics at the Georgia Institute of Technology, has taken a critical step forward in making the case for a successor to silicon. De Heer and his collaborators developed a new nanoelectronics platform based on graphene – a single sheet of carbon atoms. The technology is compatible with conventional microelectronics manufacturing, a necessity for any viable alternative to silicon. In the course of their research, published in *Nature Communications*, the team may have also discovered a new quasiparticle. Their discovery could lead to manufacturing smaller, faster, more efficient, and more sustainable computer chips, and has potential implications for quantum and high-performance computing.

"Graphene's power lies in its flat, two-dimensional structure that is held together by the strongest chemical bonds known," de Heer said. "It was clear from the beginning that graphene can be miniaturized to a far greater extent than silicon – enabling much smaller devices, while operating at higher speeds and producing much less heat. This means that, in principle, more devices can be packed on a single chip of graphene than with silicon."

In 2001, de Heer proposed an alternative form of electronics based on epitaxial graphene, or epigraphene – a layer of graphene that was found to spontaneously form on top of silicon carbide crystal, a semiconductor used in high power electronics. At the time, researchers found that electric currents flow without resistance along epigraphene's edges, and that graphene devices could be seamlessly interconnected without metal wires. This combination allows for a form of electronics that relies on the unique light-like properties of graphene electrons.

"Quantum interference has been observed in carbon nanotubes at low temperatures, and we expect to see similar effects in epigraphene ribbons and networks," de Heer said. "This important feature of graphene is not possible with silicon."

Building the Platform

To create the new nanoelectronics platform, the researchers created a modified form of epigraphene on a silicon carbide crystal substrate. In collaboration with researchers at the Tianjin International Center for Nanoparticles and Nanosystems at the University of Tianjin, China, they produced unique silicon carbide chips from electronics-grade silicon carbide crystals. The graphene itself was grown at de Heer's laboratory at Georgia Tech using patented furnaces.

The researchers used electron beam lithography, a method commonly used in microelectronics, to carve the graphene nanostructures and weld their edges to the silicon carbide chips. This process mechanically stabilizes and seals the graphene's edges, which would otherwise react with oxygen and other gases that might interfere with the motion of the charges along the edge.

Finally, to measure the electronic properties of their graphene platform, the team used a cryogenic apparatus that allows them to record its properties from a near-zero temperature to room temperature.

Observing the Edge State

The electric charges the team observed in the graphene edge state were similar to photons in an optical fiber that can travel over large distances without scattering. They found that the charges traveled for tens of thousands of nanometers along the edge before scattering. Graphene electrons in previous technologies could only travel about 10 nanometers before bumping into small imperfections and scattering in different directions.

"What's special about the electric charges in the edges is that they stay on the edge and keep on going at the same speed, even if the edges are not perfectly straight," said Claire Berger, physics professor at Georgia Tech and director of research at the French National Center for Scientific Research in Grenoble, France.

In metals, electric currents are carried by negatively charged electrons. But contrary to the researchers' expectations, their measurements suggested that the edge currents were not carried by electrons or by holes (a term for positive quasiparticles indicating the absence of an electron). Rather, the currents were carried by a highly unusual quasiparticle that has no charge and no energy, and yet moves without resistance. The components of the hybrid quasiparticle were observed to travel on opposite sides of the graphene's edges, despite being a single object.

The unique properties indicate that the quasiparticle might be one that physicists have been hoping to exploit for decades – the elusive Majorana fermion predicted by Italian theoretical physicist Ettore Majorana in 1937.

"Developing electronics using this new quasiparticle in seamlessly interconnected graphene networks is game changing," de Heer said.

It will likely be another five to 10 years before we have the first graphene-based electronics, according to de Heer. But thanks to the team's new epitaxial graphene platform, technology is closer than ever to crowning graphene as a successor to silicon.

Wirelessly powered electronics developed by KAUST researchers could help to make internet of things technology more environmentally friendly.

Credit: © 2022 KAUST; Heno Hwang

Emerging forms of thin-film device technologies that rely on alternative semiconductor materials, such as printable organics, nanocarbon allotropes and metal oxides, could contribute to a more economically and environmentally sustainable internet of things (IoT), a KAUST-led international team suggests.

Their paper is published in the journal *Nature Electronics*.

The IoT is set to have a major impact on daily life and many industries. It connects and facilitates data exchange between a multitude of smart objects of various shape and size–such as remote-controlled home security systems, self-driving cars equipped with sensors that detect obstacles on the road, and temperature-controlled factory equipment–over the internet and other sensing and communications networks.

This burgeoning hypernetwork is projected to reach trillions of devices by the next decade, boosting the number of sensor nodes deployed in its platforms.

Current approaches used to power sensor nodes rely on battery technology, but batteries need regular replacement, which is costly and environmentally harmful over time. Also, the current global production of lithium for battery materials may not keep up with the increasing energy demand from the swelling number of sensors.

Wirelessly powered sensor nodes could help achieve a sustainable IoT by drawing energy from the environment using so-called energy harvesters, such as photovoltaic cells and radio-frequency (RF) energy harvesters, among other technologies. Large-area electronics could be key in enabling these power sources.

KAUST alumn Kalaivanan Loganathan, with Thomas Anthopoulos and coworkers, assessed the viability of various large-area electronic technologies and their potential to deliver ecofriendly, wirelessly powered IoT sensors.

Large-area electronics have recently emerged as an appealing alternative to conventional silicon-based technologies thanks to significant progress in solution-based processing, which has made devices and circuits easier to print on flexible, large-area substrates. They can be produced at low temperatures and on biodegradable substrates such as paper, which makes them more ecofriendly than their silicon-based counterparts.

Over the years, Anthopoulos' team has developed a range of RF electronic components, including metal-oxide and organic polymer-based semiconductor devices known as Schottky diodes. "These devices are crucial components in wireless energy harvesters and ultimately dictate the performance and cost of the sensor nodes," Loganathan says.

Key contributions from the KAUST team include scalable methods for manufacturing RF diodes to harvest energy reaching the 5G/6G frequency range. "Such technologies provide the needed building blocks toward a more sustainable way to power the billions of sensor nodes in the near future," Anthopoulos says.

The team is investigating the monolithic integration of these low-power devices with antenna and sensors to showcase their true potential, Loganathan adds.

Glossary

1. Nanoelectronics – the branch of electronics that deals with the design and development of very small electronic devices.

2. Silicon – a chemical element commonly used in the production of microelectronics, such as computer chips.

3. Graphene – a single sheet of carbon atoms arranged in a two-dimensional honeycomb lattice structure.

4. Quasiparticle – a collective excitation that behaves like a particle and can be observed in certain materials.

5. Microelectronics – the branch of electronics that deals with the design and development of small electronic devices and integrated circuits.

6. Epitaxial graphene (epigraphene) – a layer of graphene that is formed on top of a substrate material, such as silicon carbide crystal.

7. Quantum interference – the phenomenon where quantum waves interfere with each other and either reinforce or cancel each other out.

8. Electron beam lithography – a method for carving tiny patterns on a material using a focused beam of electrons.

9. Cryogenic apparatus – a device used to cool materials to very low temperatures, typically below 100 Kelvin (-173°C).

10. Edge state – the state of electric charges that flow along the edges of certain materials, such as graphene.

11. Majorana fermion – an elusive quasiparticle predicted by Ettore Majorana in 1937 that physicists hope to exploit for electronics.

12. Internet of Things (IoT) – the interconnectivity and data exchange between smart objects of various shapes and sizes over the internet and other networks.

13. Energy harvester – a device that draws energy from the environment, such as photovoltaic cells or radio-frequency energy harvesters.

14. Large-area electronics – an alternative to conventional silicon-based technologies that can be produced at low temperatures and on biodegradable substrates, making them more ecofriendly.

15. RF diode – a device that harvests energy reaching the 5G/6G frequency range for wireless energy harvesters.

Task 1

Answer the questions:

1. What is the current state of silicon's ability to accommodate faster computing?

2. What is graphene and why is it promising for nanoelectronics?

3. What is epigraphene and how is it used in nanoelectronics?

4. What is electron beam lithography and how is it used in creating the new nanoelectronics platform?

5. What is the cryogenic apparatus used for in measuring the electronic properties of the graphene platform?

6. What is the significance of the charges observed in the graphene edge state?

7. What potential implications does this discovery have for quantum and high-performance computing?

8. What is coulombic efficiency and why is it important in battery technology?

9. What is volume expansion and why is it relevant in battery technology?

10. What is SEI and what is its role in battery technology?

11. What is the potential problem with relying on battery technology to power sensor nodes in the IoT?

12. What are energy harvesters and how could they help achieve a sustainable IoT?

13. What are large-area electronics and why are they appealing for the IoT?

14. What is the potential impact of the IoT on daily life and industries?

Task 2

Say whether the statements are true or false:

1. Graphene has been promising as a replacement for silicon in nanoelectronics for decades.

2. The lack of a new electronics paradigm and damaging processing methods have hindered the potential of graphene in the past.

3. Walter de Heer and his collaborators have developed a new nanoelectronics platform based on graphene that is compatible with conventional microelectronics manufacturing.

4. The team may have discovered a new quasiparticle during their research.

5. Graphene cannot be miniaturized to a greater extent than silicon.

6. Graphene devices cannot be seamlessly interconnected without metal wires.

7. Quantum interference is not possible with silicon but is possible with graphene.

8. The researchers used chemical vapor deposition to grow the graphene on a silicon carbide crystal substrate.

9. The researchers used electron beam lithography to carve the graphene nanostructures and weld their edges to the silicon carbide chips.

10. Graphene electrons in previous technologies could travel tens of thousands of nanometers along the edge before scattering.

11. Graphene has been considered a potential replacement for silicon in nanoelectronics for a short period of time.

12. The edge currents observed in graphene were found to be carried by negatively charged electrons.

13. The quasiparticle observed in the graphene edge currents has no charge or energy.

14. The elusive Majorana fermion was predicted by Walter de Heer, not Ettore Majorana.

15. It will likely take 5-10 years before we see the first graphene-based electronics.

16. Wirelessly powered electronics could contribute to a more environmentally friendly internet of things.

17. Current approaches used to power sensor nodes rely on solar panels.

18. Large-area electronics have emerged as an appealing alternative to conventional silicon-based technologies due to progress in solution-based processing.

19. Large-area electronics cannot be produced on biodegradable substrates such as paper.

20. The KAUST team developed scalable methods for manufacturing RF diodes to harvest energy reaching the 5G/6G frequency range.

RESEARCHERS ZOOM IN ON BATTERY WEAR AND TEAR

by Sarah C.P. Williams, University of Chicago

PME researchers collected data on how different components of a thick lithium ion battery electrode evolve after successive cycles (one snapshot of the microscopy data shown on the left). Then, they used this data to create a computational model (right) illustrating the degradation and pointing toward how to improve the lifespan of the batteries. Credit: Laboratory for Energy Storage and Conversion.

From the moment you first use it, a new lithium-ion battery is degrading. After a few hundred charge cycles, you'll notice–your phone, laptop or electric car battery wears out more quickly. Eventually, it stops holding a charge at all.

Researchers at the University of Chicago's Pritzker School of Molecular Engineering (PME) have now used a combination of high-powered electron microscopy and computational modeling to understand, at an atomic level, exactly what occurs when lithium-ion batteries degrade. Their research points toward one approach to designing longer-lasting lithium-ion batteries–by focusing on an oft-ignored structural component, the carbon binder domain (CBD).

"To tackle many of the world's energy storage and conversion challenges over coming decades, we need to keep innovating and improving batteries," said Prof. Y. Shirley Meng, who led the research, published in the journal *Joule*. "This work is one step toward more efficient and sustainable battery technology."

Limited charge cycles

The widespread commercialization of lithium-ion batteries at the end of the twentieth century played a role in the advent of lightweight, rechargeable electronics. Lithium is the lightest metal and has a high energy density-to-weight ratio. When a lithium-ion battery is charged, lithium ions move from a positively charged cathode to a negatively charged anode. To release energy, those ions flow back from the anode to the cathode.

Throughout charging cycles, the active materials of the cathode and anode expand and contract, accumulating "particle cracks" and other physical damage. Over time, this makes lithium-ion batteries work less well.

Researchers have previously characterized the particle cracking and degradation that occurs in small, thin electrodes for lithium-ion batteries. However, thicker, more energy-dense electrodes are now being developed for larger batteries–with applications such as electric cars, trucks and airplanes.

"The kinetics of a thick electrode are quite different from those of a thin electrode," said project scientist Minghao Zhang of the University of California San Diego, a co-first author of the new paper. "Degradation is actually much worse in thicker, higher-energy electrodes, which has been a struggle for the field."

It's also harder to quantitatively study thick electrodes, Zhang pointed out. The tools that previously worked to study thin electrodes can't capture the structures of larger, denser materials.

Using high-powered microscopy to see how particles inside lithium-ion batteries change over time, researchers shed new light on how to make longer-lasting batteries. Credit: John Zich, University of Chicago

Combining microscopy and modeling

In the new work, Meng, Zhang and collaborators from Thermo Fisher Scientific turned to Plasma focused ion beam-scanning electron microscopy (PFIB-SEM) to visualize the changes that occur inside a thick lithium-ion battery cathode. PFIB-SEM uses focused rays charged ions and electrons to assemble an ultra-high-resolution picture of a material's three-dimensional structure.

The researchers used the imaging approach to collect data on a brand new cathode as well as one that had been charged and depleted 15 times. With the data from the electron microscopy experiments, the team built computational models illustrating the process of degradation in the batteries.

"This combination of nanoscale resolution experimental data and modeling is what allowed us to determine how the cathode degrades," said PME postdoctoral research fellow Mehdi Chouchane, a co-first author of the paper. "Without the modeling, it would have been very hard to prove what was happening."

The researchers discovered that variation between areas of the battery encouraged many of the structural changes. Electrolyte corrosion occurred more frequently with a thin layer at the surface of the cathode. This top layer therefore developed a thicker resistive layer, which led the bottom layer to expand and contract more than other parts of the cathode, leading to faster degradation.

The model also pointed toward the importance of CBD–a porous grid of fluoropolymer and carbon atoms that holds the active materials of an electrode together contribute and helps conduct electricity through the battery. Previous research has not characterized how the CBD degrades during battery use, but the new work suggested that the weakening of contacts between the CBD and active materials of the cathode directly to the decline in performance of lithium-ion batteries over time.

"This change was even more obvious than the cracking of the active material, which is what many researchers have focused on in the past," said Zhang.

Batteries of the future

With their model of the cathode, Meng's group studied how tweaks to the electrode design might impact its degradation. They showed that changing the CBD structure network could help prevent the worsening of contacts between the CBD and active materials, making batteries last longer–a hypothesis that engineers can now follow up with physical experiments.

The group is now using the same approach to study even thicker cathodes, as well as carrying out additional modeling on how to slow electrode degradation.

Said Dr. Zhao Liu, senior manager for battery market development at Thermo Fisher Scientific, who contributed to the research, "This study develops a methodology of how to design electrodes to enhance future battery performance."

Glossary

1. Lithium-ion battery – a type of rechargeable battery that uses lithium ions to store and release energy.

2. Charge cycles – the number of times a battery is charged and discharged.

3. Cathode – the positively charged electrode in a battery.

4. Anode – the negatively charged electrode in a battery.

5. Particle cracks – physical damage that occurs to the active materials of the cathode and anode during charging cycles.

6. Microscopy – the use of a microscope to view and study materials at a microscopic level.

7. Computational modeling – the use of computer simulations to model and analyze complex systems.

8. Carbon binder domain (CBD) – a structural component of lithium-ion batteries that binds the active materials of the cathode together.

9. Electrolyte corrosion – the breakdown of the electrolyte in a battery due to chemical reactions with the active materials.

10. Resistive layer – a layer of material that resists the flow of electricity.

11. Degradation – the gradual decline in the performance or quality of something.

12. Active materials – the materials in a battery that store and release energy during charging and discharging cycles.

13. Contacts – the points where different components of a battery come into contact with each other.

14. Hypothesis – a proposed explanation for a phenomenon, which can be tested through further experimentation or observation.

15. Electrode – a component of a battery that conducts electricity between the battery and an external circuit.

16. Modeling – the use of computer simulations to model and analyze complex systems.

Task 1

Say whether the folloing statements are true or false:

1. A new lithium-ion battery never degrades.

2. Lithium-ion batteries work less well over time due to physical damage.

3. Thicker electrodes in lithium-ion batteries are less prone to degradation than thinner ones.

4. The University of Chicago's Pritzker School of Molecular Engineering research focuses on designing shorter-lasting lithium-ion batteries.

5. The carbon binder domain (CBD) is a structural component that holds the active materials of an electrode together.

6. Weakening of contacts between the CBD and active materials contributes to the decline in performance of lithium-ion batteries over time.

7. High-powered electron microscopy and computational modeling were used by researchers at the University of Chicago's Pritzker School of Molecular Engineering to understand how lithium-ion batteries degrade.

8. The tools that previously worked to study thin electrodes can capture the structures of larger, denser materials.

9. Plasma focused ion beam-scanning electron microscopy (PFIB-SEM) was used to collect data on a brand new cathode only.

10. The research conducted by the University of Chicago's Pritzker School of Molecular Engineering could lead to more efficient and sustainable battery technology.

11. The thicker resistive layer on the top layer of the cathode contributes to faster degradation of lithium-ion batteries.

12. The weakening of contacts between the CBD and active materials of the cathode has not been characterized in previous research.

13. The cracking of the active material is the only factor that researchers have focused on in the past when studying degradation of lithium-ion batteries.

14. Changes to the CBD structure network can help prevent the worsening of contacts between the CBD and active materials in lithium-ion batteries, making them last longer.

15. The University of Chicago's Pritzker School of Molecular Engineering is only studying thinner cathodes in their research.

Task 2

Answer the following questions:

1. What is the cause of lithium-ion batteries wearing out over time?

2. How does the movement of lithium ions in a lithium-ion battery release energy?

3. What is the focus of the University of Chicago's Pritzker School of Molecular Engineering's research on lithium-ion batteries?

4. What is the carbon binder domain (CBD) and how does it play a role in designing longer-lasting lithium-ion batteries?

5. What are some applications for thicker, more energy-dense electrodes in lithium-ion batteries?

6. Why is it harder to quantitatively study thick electrodes in lithium-ion batteries?

7. What imaging approach did researchers use to visualize changes inside a thick lithium-ion battery cathode?

8. What did researchers discover about the variation between areas of a lithium-ion battery?

9. What is the role of computational modeling in the University of Chicago's Pritzker School of Molecular Engineering's research on lithium-ion batteries?

10. What is the potential impact of the University of Chicago's Pritzker School of Molecular Engineering's research on lithium-ion batteries?

11.What is the cause of faster degradation in certain areas of a lithium-ion battery cathode?

12. What is the role of the carbon binder domain (CBD) in the performance of lithium-ion batteries?

13. What is the focus of the University of Chicago's Pritzker School of Molecular Engineering's research on lithium-ion batteries?

14. How can changing the CBD structure network impact the degradation of a lithium-ion battery cathode?

15.What is the potential impact of the research conducted by the University of Chicago's Pritzker School of Molecular Engineering on future battery technology?

2D MATERIAL MAY ENABLE ULTRA-SHARP CELLPHONE PHOTOS IN LOW LIGHT NOVEL DEVICE ALSO COMBINES LIGHT SENSING, COMPUTING TO SAVE ENERGY

Date: December 12, 2022
Source: Penn State
Summary:

A new type of active pixel sensor that uses a novel two-dimensional material may both enable ultra-sharp cellphone photos and create a new class of extremely energy-efficient Internet of Things (IoT) sensors, according to researchers.

A new type of active pixel sensor that uses a novel two-dimensional material may both enable ultra-sharp cellphone photos and create a new class of extremely energy-efficient Internet of Things (IoT) sensors, according to a team of Penn State researchers.

"When people are looking for a new phone, what are the specs that they are looking for?" said Saptarshi Das, associate professor of engineering science and mechanics and lead author of the study published Nov. 17 in *Nature Materials*. "Quite often, they are looking for a good camera, and what does a good camera mean to most people? Sharp photos with high resolution."

Most people just snap a photo of a friend, a family gathering, or a sporting event, and never think about what happens "behind the scenes" inside the phone when one snaps a picture. According to Das, there is quite a bit happening to enable you to see a photo right after you take it, and this involves image processing.

"When you take an image, many of the cameras have some kind of processing that goes on in the phone, and in fact, this sometimes makes the photo look even better than what you are seeing with your eyes," Das said. "These next generation of phone cameras integrate image capture with image processing to make this possible, and that was not possible with older generations of cameras."

However, the great photos in the newest cameras have a catch – the processing requires a lot of energy.

"There's an energy cost associated with taking a lot of images," said Akhil Dodda, a graduate research assistant at Penn State at the time of the study who is now a research staff member at Western Digital, and co-first author of the study. "If you take 10,000 images, that is fine, but somebody is paying the energy costs for that. If you can bring it down by a hundredfold, then you can take 100 times more images and still spend the same amount of energy. It makes photography more sustainable so that people can take more selfies and other pictures when they are traveling. And this is exactly where innovation in materials comes into the picture."

The innovation in materials outlined in the study revolves around how they added in-sensor processing to active pixel sensors to reduce their energy use. So, they turned to a novel 2D material, which is a class of materials only one or a few atoms thick, molybdenum disulfide. It is also a semiconductor and sensitive to light, which makes it ideal as a potential material to explore for low-energy in-sensor processing of images.

"We found that molybdenum disulfide has very good photosensitive response," said Darsith Jayachandran, graduate research assistant in engineering and mechanics and co-first author of the study. "From there, we tested it for the other properties we were looking for."

These properties included sensitivity to low light, which is important for the dynamic range of the sensor. The dynamic range refers to the ability to "see" objects in both low light such as moonlight and bright light such as sunlight. The human eye can see stars at night better than most cameras due to having superior dynamic range.

Molybdenum disulfide also demonstrated strong signal conversion, charge-to-voltage conversion and data transmission capabilities. This makes the material an ideal candidate to enable an active pixel sensor that can do both light sensing and in-sensor image processing.

"From there, we put the sensors into an array," Jayachandran said. "There are 900 pixels in a nine square millimeter array we developed, and each pixel is about 100 micrometers. They are much more sensitive to light than current CMOS sensors, so they do not require any additional circuitry or energy use. So, each pixel requires much less energy to operate, and this would mean a better cellphone camera that uses a lot less battery."

The dynamic range and image processing would enable users to take sharp photos in a variety of adverse conditions for photography, according to Das.

"For example, you could take clearer photos of friends outside at night or on a rainy or foggy day," Das said. "The camera could do denoising to clear up the fog and the dynamic range would enable say a night photo of a friend with stars in the background."

Das noted that the three main facilities in the Materials Research Institute were instrumental in creating and testing the material.

"The 2D materials we used for the experiments were grown at the Two-Dimensional Crystal Consortium facility at Penn State which is a National Science Foundation Materials Innovation Platform (MIP) facility, the characterization of the material was done in the Materials Characterization Laboratory, and we also used the cleanrooms in the Nanofabrication Laboratory," Das said. "Having easy access to these facilities right on campus played a major role in making this research successful."

Along with enabling a top-rate phone camera in the future, the team also envisions their improved sensor technology could have other applications. This would include better light sensors for Internet of Things and Industry 4.0 applications. Industry 4.0 is the term for a growing movement that combines traditional industry practices and cutting-edge digital technology such as the Internet of Things, cloud data storage, and artificial intelligence/machine learning. The goal is to improve manufacturing by developing more efficient processes and practices through intelligent automation, and sensors are key.

"Sensors that can see through machines while in operation and identify defects are very important in the IoT," Dodda said. "Conventional sensors consume a lot of energy so that is a problem, but we developed an extremely energy efficient sensor that enables better machine learning, etc. and saves a lot in energy costs."

Along with Das, Dodda and Jayachandran, other authors of the study include from Penn State Andrew Pannone, Nicholas Trainor, Sergei Stepanoff, Megan Steves, Shiva Subbulakshmi Radhakrishnan, Saiphaneendra Bachu, Claudio Ordonez, Jeffrey Shallenberger, Joan Redwing, Kenneth Knappenberger and Douglas Wolfe.

The work was supported by the Department of Defense and the National Science Foundation.

Glossary

1. Specs: specifications or features of a product.

2. Resolution: the degree of detail in an image or video, usually measured in pixels.

3. Image processing: manipulating or enhancing digital images using algorithms and computer software.

4. Energy cost: the amount of energy required to perform a certain task or function.

5. Active pixel sensor: a type of image sensor that converts light into electrical signals and performs image processing functions within the sensor itself.

6. Semiconductor: a material that conducts electricity under certain conditions and can be used to create electronic devices such as transistors and integrated circuits.

7. Low light sensitivity: the ability of a camera or sensor to capture clear images in low light conditions.

8. Dynamic range: the range of brightness levels that a camera or sensor can capture, from the darkest shadows to the brightest highlights.

9. CMOS sensor: a type of image sensor commonly used in digital cameras and smartphones.

10. Molybdenum disulfide: a novel 2D material that is a semiconductor and sensitive to light, ideal for low-energy in-sensor processing of images.

11. Photosensitive response: the ability of a material to respond to light and convert it into electrical signals.

12. Signal conversion: the process of converting an electrical signal from one form to another.

13. Charge-to-voltage conversion: the process of converting an electrical charge into voltage.

14. Data transmission capabilities: the ability of a material to transmit data (information) through electrical signals.

15. Array: an arrangement of objects or items in rows and columns.

Task 1

Answer the questions:

1. What is the focus of the study published in Nature Materials?

2. What is the downside of the image processing required for good phone camera photos?

3. What is in-sensor processing?

4. What material did the researchers use in their study to improve energy efficiency in phone cameras?

5. Why is molybdenum disulfide an ideal material for low-energy in-sensor processing of images?

6. What are the properties that the researchers were looking for in their search for an ideal material for low-energy in-sensor processing of images?

7. How many pixels are in the nine square millimeter array developed by the researchers?

8. What is the benefit of using molybdenum disulfide in phone cameras?

9. What adverse conditions for photography could the dynamic range and image processing enabled by molybdenum disulfide help with?

10. How could the use of molybdenum disulfide in phone cameras benefit users?

11. What facilities at Penn State were instrumental in creating and testing the 2D material used in the study?

12. What other applications could the improved sensor technology developed in the study have besides phone cameras?

13. Why are energy-efficient sensors important for IoT applications?

Task 2

Say whether the statements are true or false:

1. Most people do not think about the image processing that goes on in their phone when they take a photo.

2. The newest phone cameras have improved image processing but it requires a lot of energy.

3. Taking a lot of images does not have an energy cost.

4. In-sensor processing can reduce the energy use of active pixel sensors.

5. Molybdenum disulfide is a type of 3D material.

6. Molybdenum disulfide is a semiconductor and sensitive to light.

7. Molybdenum disulfide does not have strong signal conversion, charge-to-voltage conversion, and data transmission capabilities.

8. Each pixel in the nine square millimeter array developed by the researchers requires much more energy to operate than current CMOS sensors.

9. The improved sensor technology developed in the study could only have applications in phone cameras.

10. The dynamic range and image processing capabilities of the improved sensor technology could enable users to take clearer photos in a variety of adverse conditions.

11. The Materials Research Institute at Penn State played a significant role in the creation and testing of the 2D material used in the study.

12. The improved sensor technology developed by the researchers is only applicable to phone cameras.

13. Conventional sensors are more energy efficient than the extremely energy efficient sensor developed by the researchers.

RESEARCHERS DEVELOP ALL-OPTICAL APPROACH TO PUMPING CHIP-BASED NANOLASERS

NEW TECHNOLOGY COULD AID IN MEETING THE EVER-GROWING NEED TO MOVE MORE DATA FASTER

Date: December 15, 2022
Source: Optica

Summary:

Researchers have developed a new all-optical method for driving multiple highly dense nanolaser arrays. As described in Optica, the approach could enable chip-based optical communication links that process and move data faster than today's electronic-based devices.

Researchers have developed a new all-optical method for driving multiple highly dense nanolaser arrays. The approach could enable chip-based optical communication links that process and move data faster than today's electronic-based devices.

"The development of optical interconnects equipped with high-density nanolasers would improve information processing in the data centers that move information across the internet," said research team leader Myung-Ki Kim from Korea University. "This could allow streaming of ultra-high-definition movies, enable larger-scale interactive online encounters and games, accelerate the expansion of the Internet of Things and provide the fast connectivity needed for big data analytics."

In *Optica*, Optica Publishing Group's journal for high-impact research, the researchers demonstrate that densely integrated nanolaser arrays – in which the lasers are just 18 microns apart – can be fully driven and programmed with light from a single optical fiber.

"Optical devices integrated onto a chip are a promising alternative to electronic integrated devices, which are struggling to keep up with today's data processing demands," said Kim. "By eliminating the large and complex electrodes typically used to drive laser arrays, we reduced the overall dimensions of the laser array while also eliminating the heat generation and processing delays that come with electrode-based drivers."

Replacing electrodes with light

The new nanolasers could be used in optical integrated circuit systems, which detect, generate, transmit and process information on a microchip via light. Instead of the fine copper wires used in electronic chips, optical circuits use optical waveguides, which allow much higher bandwidths while generating less heat. However, because the size of optical integrated circuits is quickly reaching into the nanometer regime, there is a need for new ways to drive and control their nano-sized light sources efficiently.

To emit light, lasers need to be supplied with energy in a process called pumping. For nanolaser arrays, this is typically accomplished using a pair of electrodes for each laser within an array, which requires significant on-chip space and energy consumption while also causing processing delays. To overcome this critical limitation, the researchers replaced these electrodes with a unique optical driver that creates programmable patterns of light via interference. This pump light travels through an optical fiber onto which nanolasers are printed.

To demonstrate this approach, the researchers used a high-resolution transfer-printing technique to fabricate multiple photonic crystal nanolasers spaced 18 microns apart. These arrays were applied onto the surface of a 2-micron-diameter optical microfiber. This had to be done in a way that precisely aligned the nanolaser arrays with the interference pattern. The interference pattern could also be modified by adjusting the driving beam's polarization and pulse width.

Laser driving with a single fiber

The experiments showed that the design allowed multiple nanolaser arrays to be driven using light traveling through a single fiber. The results matched well with numerical calculations and showed that the printed nanolaser arrays could be fully controlled by the pump beam interference patterns.

"Our all-optical laser driving and programming technology can also be applied to chip-based silicon photonics systems, which could play a key role in the development of chip-to-chip or on-chip optical interconnects," said Kim. "However, it would be necessary to prove how independently the modes of a silicon waveguide can be controlled. If this can be done, it would be a huge leap forward in the advancement of on-chip optical interconnects and optical integrated circuits."

Glossary

1. All-optical: using only light to transmit and process information.

2. Nanolaser: a very small laser, typically with dimensions in the nanometer range.

3. Chip-based: referring to a technology that uses microchips to perform electronic or optical functions.

4. Optical communication: transmitting information through light waves instead of electrical signals.

5. Electronic-based: relying on electronic circuits to process and transmit information.

6. Interconnects: connections between different parts of a system, such as electronic or optical components.

7. Data processing: performing operations on data to extract insights or useful information.

8. Internet of Things: a network of interconnected devices that can communicate and exchange data without human intervention.

9. Big data analytics: using statistical methods to analyze large datasets and extract insights from them.

10. Integrated circuit: a miniaturized electronic or optical circuit consisting of multiple components on a single chip.

11. Electrodes: metal contacts used to supply energy to electronic or optical components.

12. Bandwidth: the amount of data that can be transmitted over a communication channel in a given time period.

13. Photonic crystal: a material with a periodic structure that can manipulate the flow of light.

14. Polarization: the orientation of the electric field in a light wave.

15. Pulse width: the duration of a pulse of light or other signal.

16. Numerical calculations: using mathematical models and algorithms to simulate and predict the behavior of a system.

17. Silicon photonics: a technology that integrates optical components on a silicon chip for high-speed data processing and communication.

Task 1

Find words in the text that mean the following:

1. fighting
2. removing
3. total
4. to make something happen at a later time than originally planned
5. sudden change

Task 2

Answer the questions:

1. What is the new all-optical approach developed by researchers?
2. How could the new technology help in information processing?
3. Who is the research team leader for the all-optical approach?
4. What are the advantages of using optical circuits over electronic circuits?
5. How do lasers emit light?
6. What is the critical limitation that researchers tried to overcome in nanolaser arrays?
7. What did researchers use to replace the electrodes for driving nanolasers?
8. How did the researchers apply the nanolaser arrays onto the surface of the optical microfiber?
9. How did the experiments show that the nanolaser arrays could be fully controlled?
10. How can the all-optical laser driving and programming technology be applied to chip-based silicon photonics systems?

Task 3

Say whether the statements are true, false or not given:

1. Researchers have developed a new method for driving multiple highly dense nanolaser arrays that could enable chip-based optical communication links.
2. The new technology can help in the streaming of ultra-high-definition movies, accelerate the expansion of the Internet of Things, and provide the fast connectivity needed for big data analytics.
3. Researchers replaced fine copper wires with optical waveguides in electronic chips.
4. Nanolasers need to be supplied with energy in a process called pumping.
5. Researchers used a low-resolution transfer-printing technique to fabricate multiple photonic crystal nanolasers spaced 18 microns apart.
6. The experiments showed that the printed nanolaser arrays could not be fully controlled by the pump beam interference patterns.
7. The all-optical laser driving and programming technology cannot be applied to chip-based silicon photonics systems.
8. Adversarial networks were the first synthetic images to be created.
9. Google, OpenAI, and Stability AI have developed text-to-image generators.

DEVELOPMENT OF AN IONIC DEVICE CAPABLE OF BRAIN-LIKE INFORMATION PROCESSING

by National Institute for Materials Science

A Tokyo University of Science research team has developed an AI device with high information processing performance. This was achieved by recreating the so-called "edge-of-chaos" state occurring in the brain using ion–electron-coupled dynamics at the solid electrolyte/diamond interface. This technology may be used to develop energy-efficient edge AI devices with a wide range of applications, including pattern recognition in images (including facial recognition), voices and odors.

The human brain is far more energy efficient than the computers used in current AI technologies and superior in information processing performance. One possible reason for this is that the "edge-of-chaos" state taking place in the brain has not been incorporated into computers.

Attempts have been made to develop hardware capable of recreating the edge-of-chaos state by fabricating large-scale integrated circuits consisting of numerous miniaturized devices. However, actually developing these circuits has proven challenging and their performance has only been estimated through simulations.

This research team recently developed an AI device with high information processing performance by reproducing the brain's edge-of-chaos state using ion–electron-coupled dynamics at the lithium ion conducting solid electrolyte thin film/diamond thin film interface. This device operates in the same manner as an electric double layer transistor in that its electrical resistance changes with the changing charge/discharge states of the electric double layer.

The device is able to induce an edge-of-chaos state, enabling it to produce electrical responses with spike and relaxation patterns similar to those of synaptic responses in the brain and efficiently process information. As a result, this AI device was able to convert waveform input signals into signals in a different, intended waveform six times more accurately than other similar small AI devices, achieving the world's highest performance at this task.

This research demonstrated that brain-like information processing can be achieved by recreating the brain's edge-of-chaos state in an electric double layer a few nanometers in thickness at the solid electrolyte thin film/diamond thin film interface.

This new nanoscale technology may potentially be applicable in the development of practical, high-performance, small AI devices. These could include energy-efficient edge AI devices that could be combined with various sensors to create smart watches, surveillance cameras, voice recognition systems and other technologies with a wide range of applications (e.g., medicine, disaster preparation, manufacturing and security).

Glossary

1. AI device: A device that uses artificial intelligence to process information.

2. Edge-of-chaos state: A state occurring in the brain that is characterized by a balance between order and chaos.

3. Ion-electron-coupled dynamics: The interaction between ions and electrons in a material.

4. Solid electrolyte: A material that conducts ions but not electrons.

5. Diamond interface: The boundary between two materials, one of which is diamond.

6. Energy-efficient: Using minimal energy to achieve a desired result.

7. Pattern recognition: The ability of a computing system to identify patterns in data.

8. Synaptic responses: The electrical signals produced by neurons in the brain.

9. Nanoscale technology: Technology that operates on a scale of nanometers, or billionths of a meter.

10. Smart watches: Watches that incorporate computing and communication capabilities.

11. Surveillance cameras: Cameras used for monitoring and recording activity in a particular area.

12. Voice recognition systems: Computing systems that can recognize and interpret human speech.

13. Medicine: The branch of science concerned with the diagnosis, treatment, and prevention of disease.

14. Disaster preparation: Planning and preparation for natural or man-made disasters.

15. Manufacturing: The production of goods using machinery and labor.

16. Security: Measures taken to protect against unauthorized access or harm.

Task 1

Find words and expressions meaning the following

1. set of similar things

2. working or operating quickly an effectively in an organized way

3. to guess or calculate the cost, size, value, etc. of something

4. to cause something to happen

Task 2

Answer the following questions:

1. What is the "edge-of-chaos" state and how does it relate to the human brain and AI technology?

2. How has the Tokyo University of Science research team developed an AI device with high information processing performance?

3. Why is the human brain more energy efficient than current AI technologies?

4. What has been the challenge in developing hardware that can recreate the edge-of-chaos state in computers?

5. How does the AI device developed by the research team operate and what is its electrical resistance like?

6. What is the significance of the device's ability to induce an edge-of-chaos state and produce electrical responses similar to those of synaptic responses in the brain?

7. How does this AI device compare to other similar small AI devices in terms of waveform input signal conversion accuracy?

8. What are some potential applications for this new nanoscale technology in the development of small AI devices?

Task 3

Say whether the following statements are true, false, or not mentioned:

1. The Tokyo University of Science research team developed an AI device with high information processing performance.

2. The "edge-of-chaos" state occurring in the brain has been incorporated into computers, making them as energy efficient as the human brain.

3. Attempts to develop hardware capable of recreating the edge-of-chaos state have been unsuccessful.

4. The AI device developed by the research team operates like a solar panel.

5. The AI device developed by the research team achieved the world's highest performance at converting waveform input signals into signals in a different, intended waveform.

LIGHT-BASED TECH COULD INSPIRE MOON NAVIGATION AND NEXT-GEN FARMING

Date: January 18, 2023
Source: RMIT University
Summary:

Super-thin chips made from lithium niobate are set to overtake silicon chips in light-based technologies, with potential applications ranging from remote ripening-fruit detection on Earth to navigation on the Moon. They say the artificial crystal offers the platform of choice for these technologies due to its superior performance and recent advances in manufacturing capabilities.

Super-thin chips made from lithium niobate are set to overtake silicon chips in light-based technologies, according to world-leading scientists in the field, with potential applications ranging from remote ripening-fruit detection on Earth to navigation on the Moon.

They say the artificial crystal offers the platform of choice for these technologies due to its superior performance and recent advances in manufacturing capabilities.

RMIT University's Distinguished Professor Arnan Mitchell and University of Adelaide's Dr Andy Boes led this team of global experts to review lithium niobate's capabilities and potential applications in the journal *Science*.

The international team, including scientists from Peking University in China and Harvard University in the United States, is working with industry to make navigation systems that are planned to help rovers drive on the Moon later this decade.

As it is impossible to use global positioning system (GPS) technology on the Moon, navigation systems in lunar rovers will need to use an alternative system, which is where the team's innovation comes in.

By detecting tiny changes in laser light, the lithium-niobate chip can be used to measure movement without needing external signals, according to Mitchell.

"This is not science fiction – this artificial crystal is being used to develop a range of exciting applications. And competition to harness the potential of this versatile technology is heating up," said Mitchell, Director of the Integrated Photonics and Applications Centre.

He said while the lunar navigation device was in the early stages of development, the lithium niobate chip technology was "mature enough to be used in space applications."

"Our lithium niobate chip technology is also flexible enough to be rapidly adapted to almost any application that uses light," Mitchell said.

"We are focused on navigation now, but the same technology could also be used for linking internet on the Moon to the internet on Earth."

What is lithium niobate and how can it be used?

Lithium niobate is an artificial crystal that was first discovered in 1949 but is "back in vogue," according to Boes.

"Lithium niobate has new uses in the field of photonics – the science and technology of light – because unlike other materials it can generate and manipulate electro-magnetic waves across the full spectrum of light, from microwave to UV frequencies," he said.

"Silicon was the material of choice for electronic circuits, but its limitations have become increasingly apparent in photonics.

"Lithium niobate has come back into vogue because of its superior capabilities, and advances in manufacturing mean that it is now readily available as thin films on semiconductor wafers."

A layer of lithium niobate about 1,000 times thinner than a human hair is placed on a semiconductor wafer, Boes said.

"Photonic circuits are printed into the lithium niobate layer, which are tailored according to the chip's intended use. A fingernail-sized chip may contain hundreds of different circuits," he said.

How does the lunar navigation tech work?

The team is working with the Australian company Advanced Navigation to create optical gyroscopes, where laser light is launched in both clockwise and anti-clockwise directions in a coil of fibre, Mitchell said.

"As the coil is moved the fibre is slightly shorter in one direction than the other, according to Albert Einstein's theory of relativity," he said.

"Our photonic chips are sensitive enough to measure this tiny difference and use it to determine how the coil is moving. If you can keep track of your movements, then you know where you are relative to where you started. This is called inertial navigation."

Potential applications closer to home

This technology can also be used to remotely detect the ripeness of fruit.

"Gas emitted by ripe fruit is absorbed by light in the mid-infrared part of the spectrum," Mitchell said.

"A drone hovering in an orchard would transmit light to another which would sense the degree to which the light is absorbed and when fruit is ready for harvesting.

"Our microchip technology is much smaller, cheaper and more accurate than current technology and can be used with very small drones that won't damage fruit trees."

Next steps

Australia could become a global hub for manufacturing integrated photonic chips from lithium niobate that would have a major impact on applications in technology that use every part of the spectrum of light, Mitchell said.

"We have the technology to manufacture these chips in Australia and we have the industries that will use them," he said.

"Photonic chips can now transform industries well beyond optical fibre communications."

Glossary

1. Superior – higher in quality, better.

2. Performance – the way in which something works or functions.

3. Manufacturing – the process of making goods on a large scale using machinery.

4. Navigation – the process of finding one's way to a particular destination.

5. GPS – Global Positioning System, a satellite-based navigation system.

6. Rovers – vehicles designed to explore the surface of a planet or moon.

7. External signals – signals coming from outside of the device or system.

8. Photonics – the science and technology of generating and manipulating photons (particles of light).

9. Electro-magnetic waves – waves of energy that consist of both electric and magnetic fields.

10. Semiconductor wafers – thin slices of material used in the production of electronic components.

11. Photonic circuits – circuits that use light instead of electricity to transmit information.

12. Gyroscopes – devices used for measuring or maintaining orientation and angular velocity.

13. Relativity – the theory developed by Albert Einstein that describes the relationship between space and time.

14. Inertial navigation – a navigation system that uses accelerometers and gyroscopes to determine position and velocity.

15. Mid-infrared – a region of the electromagnetic spectrum that lies between near-infrared and far-infrared wavelengths.

Task 1

Find words or expretions meaning the following:

1. network consisting of a closed loop, giving a return path for the current

2. thread

3. go past

4. very small

5. advanced, developed

6. able to be seen

7. the state of being popular or fashionable

8. to define

Task 2

Say whether the following statements are true or false

1. using drones it will be possible to determine the degree of ripening of fruits

2. Global Positioning System Technology Applicable to Moon Rovers Navigation

3. Lithium niobate was discovered at the beginning of the 21st century

4. Other lithium compounds may also be applicable to create artificial crystals for creating microchips

5. A film of lithium niobate is deposited on a semiconductor material slightly thicker than a human hair.

Task 3

Answer the following questions

1. Which country can become a global center for the production of lithium niobate photonic chips?

2. What is the feature of using lithium niobate in photonics?

3. Is lithium niobate semiconductor technology effective?

4. According to scientists, can ultrathin chips made from lithium niobate exceed silicon chips in light-based technologies?

5. What principle underlies the work of new photonic chips?

6. Can lithium niobate chip technology be adapted for other light applications? Can drones damage fruit trees?

7. When is it planned to introduce this technology for navigation systems?

8. How many different circuits can one chip contain?

9. In which journal was an article published on the prospects for the use of lithium niobate?

AN EXOTIC INTERPLAY OF ELECTRONS INTERNATIONAL RESEARCH TEAM DISCOVERS NOVEL QUANTUM STATE

Date: December 1, 2022
Source: Helmholtz-Zentrum Dresden-Rossendorf
Summary:

Water that simply will not freeze, no matter how cold it gets – a research group has discovered a quantum state that could be described in this way. Experts have managed to cool a special material to near absolute zero temperature. They found that a central property of atoms – their alignment – did not 'freeze', as usual, but remained in a 'liquid' state. The new quantum material could serve as a model system to develop novel, highly sensitive quantum sensors.

Water that simply will not freeze, no matter how cold it gets – a research group involving the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) has discovered a quantum state that could be described in this way. Experts from the Institute of Solid State Physics at the University of Tokyo in Japan, Johns Hopkins University in the United States, and the Max Planck Institute for the Physics of Complex Systems (MPI-PKS) in Dresden, Germany, managed to cool a special material to near absolute zero temperature. They found that a central property of atoms – their alignment – did not "freeze," as usual, but remained in a "liquid" state. The new quantum material could serve as a model system to develop novel, highly sensitive quantum sensors. The team has presented its findings in the journal *Nature Physics*.

On first sight, quantum materials do not look different from normal substances – but they sure do their own thing: Inside, the electrons interact with unusual intensity, both with each other and with the atoms of the crystal lattice. This intimate interaction results in powerful quantum effects that not only act on the microscopic, but also on the macroscopic scale. Thanks to these effects, quantum materials exhibit remarkable properties. For example, they can conduct electricity completely loss-free at low temperatures. Often, even slight changes in temperature, pressure, or electrical voltage are enough to drastically change the behavior of the material.

In principle, magnets can also be regarded as quantum materials; after all, magnetism is based on the intrinsic spin of the electrons in the material. "In some ways, these spins can behave like a liquid," explains Prof. Jochen Wosnitza from the Dresden High Field Magnetic Laboratory (HLD) at HZDR. "As temperatures drop, these disordered spins can then freeze, much like water freezes into ice." For example, certain kind of magnets, so-called ferromagnets, are non-magnetic above their "freezing," or more precisely ordering point. Only when they drop below it can they become permanent magnets.

High-purity material

The international team intended to create a quantum state in which the atomic alignment that is associated with the spins did not order, even at ultracold temperatures – similar to a liquid that will not solidify, even in extreme cold. To achieve this state, the research group used a special material – a compound of the elements, praseodymium, zirconium, and oxygen. They assumed that in this material, the properties of the crystal lattice would enable the electron spins to interact with their orbitals around the atoms in a special way.

"The prerequisite, however, was to have crystals of extreme purity and quality," Prof. Satoru Nakatsuji of the University of Tokyo explains. It took several attempts, but eventually the team was able to produce crystals pure enough for their experiment: In a cryostat, a kind of super thermos flask, the experts gradually cooled their sample down to 20 millikelvin – just one fiftieth of a degree above absolute zero. To see how the sample responded to this cooling process and inside the magnetic field, they measured how much it changed in length. In another experiment, the group recorded how the crystal reacted to ultrasound waves being directly sent through it.

An intimate interplay

The result: "Had the spins ordered, it should have caused an abrupt change in the behavior of the crystal, such as a sudden change in length," Dr. Sergei Zherlitsyn, HLD's expert in ultrasound investigations, describes. "Yet, as we observed, nothing happened! There were no sudden changes in either length or in its response to ultrasound waves." The conclusion: The pronounced interplay of spins and orbitals had prevented ordering, which is why the atoms remained in their liquid quantum state – the first time such a quantum state had been observed. Further investigations in magnetic fields confirmed this assumption.

This basic research result could also have practical implications one day: "At some point we might be able to use the new quantum state to develop highly sensitive quantum sensors," Jochen Wosnitza speculates. "To do this, however, we still have to figure out how to generate excitations in this state systematically." Quantum sensing is considered a promising technology of the future. Because their quantum nature makes them extremely sensitive to external stimuli, quantum sensors can register magnetic fields or temperatures with far greater precision than conventional sensors.

Glossary

1. Quantum state: A state in which the properties of atoms or particles are described using quantum mechanics.

2. Absolute zero: The lowest possible temperature, at which all matter has zero thermal energy.

3. Intrinsic spin: The inherent rotation of an electron or other particle.

4. Crystal lattice: The regular, repeating pattern of atoms or molecules in a crystal.

5. Loss-free conductivity: The ability to conduct electricity without any resistance or loss of energy.

6. Ferromagnets: Materials that become permanently magnetized below a certain temperature.

7. Ultracold temperatures: Extremely low temperatures approaching absolute zero.

8. Purity: The degree to which a substance is free from impurities or contaminants.

9. Orbitals: The regions around an atom where electrons are most likely to be found.

10. Cryostat: A device used for maintaining very low temperatures.

11. Ultrasound waves: High-frequency sound waves used for imaging or measuring properties of materials.

12. Interplay: Interaction or coordination between different elements or factors.

Task 1

Find words that mean the following:

1. stay
2. deep, secret
3. show
4. plan
5. adjustments
6. try, effort
7. sudden, dramatic

Task2

Answer the questions:

1. What is the quantum state discovered by the research group?
2. What type of material did the research group use in their experiment?
3. What is a cryostat?

4. What is the potential practical application of the new quantum state discovered?
5. What is quantum sensing?
6. What is the basis of magnetism in a material?
7. What are quantum materials?
8. What is one of the remarkable properties of quantum materials?
9. What did the research group measure to see how the sample responded to the cooling process and inside the magnetic field?
10. What did the research group observe when they cooled their sample down to near absolute zero temperature?

Task 3

Say whether the statements are true or false:

1. Quantum materials look different from normal substances.
2. The research group used a special material to create a quantum state in which the atomic alignment associated with the spins did not order, even at ultracold temperatures.
3. The new quantum material discovered could serve as a model system to develop novel, highly sensitive quantum sensors.
4. Quantum sensors are less sensitive to external stimuli than conventional sensors.
5. Magnetism in a material is based on the intrinsic spin of the atoms in the material.

A BAYESIAN MACHINE BASED ON MEMRISTORS
by Ingrid Fadelli, Tech Xplore

An optical microscopy image of the complete Bayesian machine. Credit: Damien Querlioz (CNRS/Univ. Paris-Saclay)

Over the past few decades, the performance of machine learning models on various real-world tasks has improved significantly. Training and implementing most of these models, however, still requires vast amounts of energy and computational power.

Engineers worldwide have thus been trying to develop alternative hardware solutions that can run artificial intelligence models more efficiently, as this could promote their widespread use and increase their sustainability. Some of these solutions are based on memristors, memory devices that can store information without consuming energy.

Researchers at Université Paris-Saclay- CNRS, Université Grenoble-Alpes-CEA-LETI, HawAI.tech, Sorbonne Université, and Aix-Marseille Université-CNRS have recently created a so-called Bayesian machine (i.e., an AI approach that performs computations based on Bayes' theorem), using memristors. Their proposed system, introduced in a paper published in *Nature Electronics,* was found to be significantly more energy-efficient than currently employed hardware solutions.

"Artificial intelligence is making major progress today but faces a challenge: its considerable energy consumption," Damien Querlioz, one of the researchers who carried out the study, told TechXplore. "It is now well understood that this consumption comes from the separation, in computers, between computation and memory functions. As artificial intelligence uses a lot of data, it requires a lot of memory, which is costly to access in terms of energy. Our brains are much more energy efficient because the memory functions are integrated as close as possible to the computation functions, and we wanted to reproduce this strategy."

Memristors are essentially electrical components based on nanodevices that limit or regulate the flow of electrical current in a circuit, while also recording how much energy passed in it beforehand. As they perform both computations and information storage, these devices can better reproduce the human brain's information processing strategies.

A zoomed-in optical microscopy image of the Bayesian machine on one of its 16 memristor arrays. Credit: Damien Querlioz (CNRS/Univ. Paris-Saclay)

"Until recently, memristors were an emerging technology, and we could not realize complete systems with them," Querlioz explained. "Now, our team built a 'Bayesian machine,' a small artificial intelligence with memristors. The prototype comprises 2,048 hafnium oxide memristors and 30,080 silicon transistors (MOSFETs)."

The Bayesian machine created by Querlioz and his colleagues integrates memristors with conventional complementary metal-oxide-semiconductor (CMOS) technology. The researchers created a prototype of the machine and assessed its performance on a gesture recognition task. Remarkably, they found that it could recognize specific human gestures using thousands of times less energy than a traditional hardware solution based on a microcontroller.

"Most of the research on memristor-based machine learning aims at implementing deep learning," Querlioz said. "This is, of course, an extremely important goal, as deep learning is so successful today. However, deep learning has some limitations: its results are not explainable, and it does not perform well when little data is available. Here, we chose to implement Bayesian reasoning, an alternative AI approach that does not do well in big data applications where deep learning works so well, but excels in small data situations, and provides fully explainable results."

In the future, the memristor-based Bayesian machine created by this team of researchers could help to increase the energy-efficiency of AI models, while also potentially inspiring the development of other similar solutions. It could be particularly useful for safety-critical applications, such as medical sensors or circuits to monitor the safety of industrial facilities. Hawai.tech, a start-up that contributed to the development of the team's Bayesian algorithm, is now using the machine to create these sensors.

"We have designed a considerably scaled-up version of the Bayesian machine, which is currently being fabricated, and we have applied the principles behind the machine to other machine learning approaches as well," Querlioz added. "As we are scaling our designs in complexity, we are starting to hit the limits of what is possible for an academic group. So, we are simultaneously working on new technologies, the next memristors."

Glossary

1. Machine learning: a type of artificial intelligence that allows machines to learn and improve from experience.

2. Computational power: the ability of a computer to perform complex calculations and processes.

3. Memristors: memory devices that can store information without consuming energy.

4. Energy-efficient: using less energy to perform a task.

5. Bayes' theorem: a mathematical formula used in probability theory to calculate the likelihood of an event occurring based on prior knowledge.

6. Artificial intelligence: the simulation of human intelligence in machines.

7. Nanodevices: very small electronic devices, often on the nanoscale.

8. Computation: the process of performing calculations or processing data.

9. Memory functions: the ability to store and retrieve information.

10. Hafnium oxide: a type of material used in the production of memristors.

11. Silicon transistors: electronic components used to amplify or switch electrical signals.

12. Gesture recognition: the ability of a machine to recognize and interpret human gestures.

13. Microcontroller: a small computer on a single integrated circuit used to control other devices.

14. Deep learning: a type of machine learning that uses neural networks to analyze and interpret large amounts of data.

15. Explainable results: results that can be easily understood and explained.

16. Safety-critical applications: applications where safety is a primary concern, such as medical sensors or industrial monitoring systems.

Task 1

Find words in the text that mean the following:

1. considerably, noticeblely
2. to need
3. the quality of being able to continue over a period of time
4. at the present time
5. the amount used
6. in advance

Task 2

Answer the following questions:

1. What is the challenge faced by artificial intelligence today?
2. What are memristors?
3. What is the advantage of memristors over traditional hardware solutions?

4. What is the Bayesian machine?

5. What is the purpose of the Bayesian machine?

6. How did the researchers assess the performance of the Bayesian machine?

7. What are the limitations of deep learning?

8. What is the alternative AI approach implemented by the researchers?

9. What are some potential applications for the memristor-based Bayesian machine?

10. What is Hawai.tech doing with the machine developed by the researchers?

11. What is the current status of the development of the Bayesian machine, and what are the researchers doing to overcome the limitations they are facing?

Task 3

Say whether the following statemenmts are true or false:

1. The performance of machine learning models has not improved significantly in recent years.

2. Developing alternative hardware solutions for AI models could increase their sustainability.

3. Memristors are memory devices that consume a lot of energy.

4. Researchers at several universities have created a Bayesian machine using memristors.

5. The proposed system was found to be less energy-efficient than currently employed hardware solutions.

6. The separation of computation and memory functions in computers is a major contributor to the energy consumption of AI.

7. Memristors perform both computations and information storage, making them similar to the human brain's information processing strategies.

8. The prototype of the Bayesian machine comprises 2,048 silicon transistors and 30,080 hafnium oxide memristors. .

9. Deep learning is the only AI approach being implemented with memristors.

10. The memristor-based Bayesian machine could be useful for safety-critical applications such as medical sensors or monitoring industrial facilities. .

11. Hawai.tech is using the Bayesian algorithm to create sensors.

12. The academic group is not working on new technologies because they have hit the limits of what is possible.

RADIO WAVES FOR THE DETECTION OF HARDWARE TAMPERING

Date: June 8, 2022
Source: Ruhr-University Bochum
Summary:

Up to now, protecting hardware against manipulation has been a laborious business: expensive, and only possible on a small scale. And yet, two simple antennas might do the trick.

As far as data security is concerned, there is an even greater danger than remote cyberattacks: namely tampering with hardware that can be used to read out information – such as credit card data from a card reader. Researchers in Bochum have developed a new method to detect such manipulations. They monitor the systems with radio waves that react to the slightest changes in the ambient conditions. Unlike conventional methods, they can thus protect entire systems, not just individual components – and they can do it at a lower cost. The RUB's science magazine Rubin features a report by the team from Ruhr-Universität Bochum (RUB), the Max Planck Institute for Security and Privacy and the IT company PHYSEC.

Paul Staat and Johannes Tobisch presented their findings at the IEEE Symposium on Security and Privacy, which took place in the USA from 23 to 25 May 2022. Both researchers are doing their PhDs at RUB and conducting research at the Max Planck Institute for Security and Privacy in Bochum in Professor Christof Paar's team. For their research, they are cooperating with Dr. Christian Zenger from the RUB spin-off company PHYSEC.

Protection through radio waves

Data is ultimately nothing more than electrical currents that travel between different computer components via conductive paths. A tiny metallic object, located in the right place on the hardware, can be enough to tap into the information streams. To date, only individual components of systems, such as a crucial memory element or a processor, can be protected from such manipulations. "Typically, this is done with a type of foil with thin wires in which the hardware component is wrapped," explains Paul Staat. "If the foil is damaged, an alarm is triggered."

The radio wave technology from Bochum, however, can be used to monitor an entire system. To this end, the researchers install two antennas in the system: a transmitter and a receiver. The transmitter sends out a special radio signal that spreads everywhere in the system and is reflected by the walls and computer components. All these reflections cause a signal to reach the receiver that is as characteristic of the system as a fingerprint.

Technology reacts to the slightest changes

Tiny changes to the system are enough to have a noticeable effect on the fingerprint, as the team demonstrated in experiments. The IT experts equipped a conventional computer with radio antennas and punctured its housing with holes at regular intervals. Through these holes, the researchers let a fine metal needle penetrate the inside of the system and checked whether they notice the change in the radio signal. In the process, they varied the thickness of the needle, the position and the depth of penetration.

With the computer running, they reliably detected the penetration of a needle 0.3 millimetres thick with their system from a penetration depth of one centimetre. The system still detected a needle that was only 0.1 millimetres thick – about as thick as a hair – but not in all positions. "The closer the needle is to the receiving antenna, the easier it is to detect, explains Staat. "Therefore, in practical applications, it makes sense to think carefully about where you place the antennas," adds Tobisch. "They should be as close as possible to the components that require a high degree of protection."

Basically, the technology is suitable for both high-security applications and everyday problem. The IT company PHYSEC already uses it to prevent unauthorised manipulation of critical infrastructure components.

Glossary

1. Tampering – the act of making unauthorized changes or alterations to something.

2. Hardware – the physical components of a computer system.

3. Data security – the protection of digital information from unauthorized access, use, disclosure, disruption, modification, or destruction.

4. Radio waves – electromagnetic waves that have longer wavelengths and lower frequencies than visible light and can be used for communication.

5. Conductive paths – the routes through which electrical currents flow in a computer system.

6. Foil – a thin sheet of metal or plastic used for wrapping or covering something.

7. Processor – the central processing unit (CPU) of a computer system that performs most of the processing tasks.

8. Fingerprint – a unique characteristic or pattern that identifies something or someone.

9. Penetration depth – the distance that an object can enter into another object.

10. Infrastructure components – the physical components of a system that support its operation, such as power grids or transportation systems.

Task 1

Say whether the statements are true or false:

1. The researchers in Bochum have developed a new method to detect hardware manipulations by monitoring systems with sound waves.

2. Tampering with hardware that can be used to read out information is not a danger to data security.

3. The radio wave technology developed by the researchers in Bochum can only protect individual components of a system, not entire systems.

4. The researchers install three antennas in the system: a transmitter, a receiver, and a detector

5. Tiny changes to the system do not have a noticeable effect on the radio wave fingerprint.

6. In their experiments, the IT experts equipped a conventional computer with radio antennas and punctured its housing with holes at irregular intervals

7. In practical applications, it does not matter where you place the antennas for the radio wave technology to work effectively.

8. The radio wave technology developed by the researchers in Bochum is only suitable for high-security applications.

9. PHYSEC is not currently using the technology developed by the researchers in Bochum to prevent unauthorised manipulation of critical infrastructure components.

10. Paul Staat and Johannes Tobisch presented their findings at an event called the IEEE Symposium on Security and Privacy in the USA from 23 to 25 May 2022.

Task 2

Answer the following questions:

1. What is the new method developed by researchers in Bochum to detect hardware manipulations?

2. What is the danger of tampering with hardware that can be used to read out information?

3. What is the advantage of the radio wave technology developed by the researchers in Bochum?

4. How does the radio wave technology work to monitor an entire system?

5. What is the effect of tiny changes to the system on the radio wave fingerprint?

6. What did the IT experts demonstrate in their experiments with a conventional computer equipped with radio antennas?

7. What should be considered when placing antennas in practical applications of the technology?

8. What is the potential use of the technology developed by the researchers in Bochum?

9. What is PHYSEC using the technology for?

10. What event did Paul Staat and Johannes Tobisch present their findings at?

IMPROVING DATA SECURITY FOR A HYBRID SOCIETY: INSIGHTS FROM NEW STUDY
by Tokyo University of Science

Researchers at the Tokyo University of Science use a combination of TTP and various players to encrypt the data. However, all the computation is performed on a single server. Credit: Ahmad Akmal Aminuddin Mohd Kamal from Tokyo University of Science

Society 5.0 envisions a connected society driven by data shared between people and artificial intelligence devices connected via the Internet of Things (IoT). While this can be beneficial, it is also essential to protect the privacy of data for secure processing, transmission, and storage. Currently, homomorphic encryption and secret sharing are two methods used to compute sensitive data while preserving its privacy.

Homomorphic encryption involves performing computations on encrypted data on a single server. While being a straightforward method, it is computationally intensive. On the other hand, secret sharing is a fast and computationally efficient way to handle encrypted data. In this method, the encrypted data or secret input is divided and distributed among multiple servers, each of which performs a computation such as multiplication with its piece of data.

The results of these computations are then used to reconstruct the original data. In such a system, the secret can only be reconstructed if a certain number of pieces, known as the threshold, are available. Therefore, if the servers are managed by a single organization, there is a higher risk that the data could be compromised if the required number of pieces falls into the hands of an attacker.

To improve data security, it is ideal for multiple companies to manage computing servers in a decentralized manner such that each server is operated independently. This approach reduces the likelihood of an attacker gaining access to the threshold number of pieces required to reconstruct a secret. However, implementing this system can be challenging in practice due to the need for a fast communication network to allow geographically separated servers to communicate with each other.

This leads to an important question: is there a way to maintain data integrity without having to rely on independent servers, and without incurring a high computational cost?

In a study published on November 14, 2022, in Volume 10 of *IEEE Access*, Professor Keiichi Iwamura and Assistant Professor Ahmad A. Aminuddin of Tokyo University of Science, Japan, introduced a new secure computation method where all the computations are performed on a single server without a significant computational cost.

The system consists of a trusted third party (TTP), one computing server, four players who provide secret inputs to the server, and one player who restores the computation result. The TTP is a neutral organization that generates random numbers which are provided to the server (these are known as shares) and the players in certain combinations.

These random numbers are used to encrypt the data. Each player then performs a computation with the random numbers and generates secret inputs which are sent to a server. The server then uses the shares and secret inputs, along with new values computed by the TTP, to perform a series of computations, the results of which are sent to a final player who reconstructs the computation result. This method allows for the decentralized computation of encrypted data while still performing the computation on a single server.

"In our proposed method, we realize the advantage of homomorphic encryption without the significant computational cost incurred by homomorphic encryption, thereby devising a way to securely handle data," says Prof. Iwamura, who led the study and is the paper's first author.

Moreover, the method can also be modified such that the random numbers generated by the TTP can be stored securely by a Trusted Execution Environment (TEE), which is a secure area in a device's hardware (processor). As the TEE takes over the role of the TPP during the subsequent computational process, it reduces the communication time and improves the speed at which the encrypted data is handled.

As our society becomes more reliant on the internet, we are moving towards storing data on the cloud rather than locally. To securely manage the growing amount of data, it is important to have a reliable and efficient method of handling it. "We realize a method that addresses all the drawbacks of the aforementioned methods, and it is possible to realize faster and more secure computations than conventional methods using secret sharing," says Assistant Prof. Aminuddin.

Glossary

1. Society 5.0: A connected society driven by data shared between people and artificial intelligence devices connected via the Internet of Things (IoT).

2. Homomorphic encryption: A method of performing computations on encrypted data on a single server.

3. Secret sharing: A method of dividing and distributing encrypted data or secret input among multiple servers, each of which performs a computation such as multiplication with its piece of data.

4. Data security: Measures taken to protect the privacy of data for secure processing, transmission, and storage.

5. Decentralized computing: The management of computing servers in a decentralized manner such that each server is operated independently.

6. Trusted third party (TTP): A neutral organization that generates random numbers used to encrypt data.

7. Random numbers: Numbers generated by the TTP used to encrypt data and perform computations.

8. Trusted Execution Environment (TEE): A secure area in a device's hardware (processor) that can store the random numbers generated by the TTP.

9. Cloud storage: Storing data on the cloud rather than locally.

10. Data handling: The management of data in a reliable and efficient manner.

Task 1

Find words and expressions meaning the following

1. the process of changing electronic information or signals into a secret code
2. to deal with
3. getting
4. starting point
5. to keep in good condition
6. happening by chance rather than according to the plan

Task 2

Answer the following questions:

1. What is Society 5.0?

2. Why is it important to protect the privacy of data in a connected society?

3. What are homomorphic encryption and secret sharing?

4. How does secret sharing work?

5. What is the risk of having a single organization manage computing servers in a secret sharing system?

6. What is the challenge of implementing a decentralized secret sharing system?

7. What is the new secure computation method proposed by researchers at Tokyo University of Science?

8. What is the role of the trusted third party (TTP) in this method?

9. How does this method allow for decentralized computation while still performing the computation on a single server?

10. How can the method be modified to improve the speed of handling encrypted data?

Task 3

Say whether the following statements are true, false or not mentioned:

1. Society 5.0 envisions a connected society driven by data shared between people and artificial intelligence devices connected via the Internet of Things.

2. Homomorphic encryption is a fast and computationally efficient way to handle encrypted data.

3. Homomorphic encryption and secret sharing are two methods used to compute sensitive data while preserving its privacy.

4. A single organization managing servers in a secret sharing system reduces the risk of data compromise if an attacker gains access to the threshold number of pieces required to reconstruct a secret.

5. In secret sharing, the encrypted data or secret input is divided and distributed among multiple servers, each of which performs a computation such as multiplication with its piece of data, and the results are used to reconstruct the original data.

6. The proposed method by Tokyo University of Science relies on independent servers to maintain data integrity

7. The random numbers generated by the TTP can be stored securely by a Trusted Execution Environment (TEE) to improve the speed of handling encrypted data.

8. The TTP generates random numbers that are used to decrypt the data.

9. The proposed method by Tokyo University of Science allows for the decentralized computation of encrypted data while still performing the computation on a single server.

10. The TEE is used to generate random numbers in the proposed method by Tokyo University of Science.

'INTERNET OF LIGHT' INTEGRATES ILLUMINATION, COMMUNICATION AND MINISTRATION

by Tsinghua University Press

A team of Chinese researchers proposed an Internet of Light network where LEDs can be taken as nodes with customized sensors to collect information such as light intensity, color, the level of hazardous gas and moving objects. All of these nodes constitute the sensor network. Credit: Intelligent and Converged Networks, Tsinghua University Press

When it comes to efficiency and quality, light-emitting diodes (LED) are the MVP of today's lighting technology. A team of Chinese researchers are using recent LED improvements as a springboard to launch a more interconnected illumination network.

In their study published on September 30, 2022 in *Intelligent and Converged Networks*, they proposed the concept of an Internet of Light that interfaces with the Internet of Things to improve human health and well-being by providing information services.

"As people spend more and more time indoors, it is absolutely necessary to provide an illumination network that offers intelligent lighting along with information services by combining information technologies with communication technologies," said Jian Song, Tsinghua University professor of electronic engineering.

Since LED is silicon-based, it can facilitate deep integration of illumination networks with different electronic and intelligent control mechanisms at low cost. On top of illumination control, researchers from information and communication technology (ICT) areas have demonstrated the feasibility of something called visible light communication (VLC), which transmits information by modulating LED light intensity. This form of communication could simultaneously support information services such as localization, data transmission and even optical therapy without causing eyestrain or damage.

"The rapid progress in the related areas of ICT and human science motivated us to propose the idea of Internet of Light (IoL) as a platform and develop its key functionalities," Song said.

To integrate IoL with ubiquitous illumination networks, the researchers combined sensors, communication modules and smart processing units into individual LED lamps to form a "node," and adopted telecommunication technologies, such as powerline communications (PLC) and 5G wireless communications as the means of networking.

An IoL sensor network comprised of specially designed sensing nodes can collect information such as light intensity, color, the level of hazardous gas, moving objects and more.

Applications of this type of IoL include "smart" nursing homes where a resident can be located for safety and security reasons or a kitchen gas leakage can be detected in time. Automatic adjustments in light intensity or color can customize a comfortable environment according to user preference or as a means to conduct optical therapy.

To accommodate these functionalities effectively and efficiently, the researchers developed algorithms and conducted hardware experiments to demonstrate system performance for high-speed data delivery. This included experimenting with real-time beam alignment VLC design that can swiftly adjust the direction of the emitting light source according to the user's position.

The researchers investigated resource optimization under different constraints such as communication and location services to allocate different frequencies and power, as well as communication and illumination to meet a variety of illumination requirements including intensity and uniformity.

"As both communication and position services will be carried out by the illumination networks, optimization of power allocation is critical," said Hui Yang, Tsinghua University professor of electronic engineering.

To support applications such as video transmission and real-time positioning, researchers are exploring scheduling algorithms that can accommodate a base station's stringent timing requirements and minimize latency.

Previous studies demonstrated that light can be used to treat certain dermatoses or neurodegenerative diseases, showing the possibility for non-intrusive optical treatment. The team explored this possibility by designing an experiment of light stroboscopic irradiation with flicker frequency of LED light.

"The preliminary results of our investigation confirmed the relationship between light stimulation and human reaction by electrodermal activity signal and other methods," said Xiaofei Wang, Tsinghua University professor of electronic engineering. "This demonstrates that an IoL platform can possibly regulate human emotions and brain activity by controlling the flicker frequency of the light source intelligently and automatically."

In future steps, the researchers plan to integrate individual technologies into an environment like a nursing facility, which could benefit from smart sensing, communications and optimization under resource constraints, according to the study.

The combination of lighting and environment creates a highly interactive, complex and dynamic system with huge discrepancy and great diversity for individual people," said Luoxi Hao, professor in the Tongji University College of Architecture and Urban Planning. "The advantages of real-time perception, instantaneous response and seamless information interconnection supported by IoL can surely play an important role in bringing a human-centric lighting concept into reality."

Glossary

1. Light-emitting diode (LED) – A semiconductor device that emits light when an electric current is passed through it.

2. Internet of Things (IoT) – A network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, and connectivity.

3. Human health and well-being – The overall state of a person's physical, mental, and social health.

4. Communication technologies – Technologies used for transmitting information between devices or networks.

5. Silicon-based – A technology that uses silicon to create semiconductors for electronic devices.

6. Visible light communication (VLC) – A form of communication that transmits information by modulating LED light intensity.

7. Powerline communications (PLC) – A method of communication that uses the existing power lines to transmit data.

8. 5G wireless communications – The fifth generation of wireless communication technology that provides faster data transfer speeds and lower latency.

9. Real-time – The ability to process and respond to data immediately as it is received.

10. Optimization – The process of making something as effective and efficient as possible.

11. Algorithms – A set of instructions or rules followed by a computer program to solve a problem or perform a task.

12. Base station – A fixed transceiver that communicates with wireless devices within its range.

13. Latency – The time delay between the moment something is initiated and the moment it becomes visible or audible.

14. Non-intrusive optical treatment – A type of medical treatment that uses light to treat certain conditions without the need for invasive procedures.

Task 1

Find words which mean the following:

1. to begin

2. to make something possible or easy

3. to examine carefully

4. to be helped by something or to help someone

5. illness

6. a difference between two things that should be the same

7. a range of different things or people

Task 2

Answer the following questions:

1. What is the Internet of Light?

2. How can LED facilitate deep integration of illumination networks with different electronic and intelligent control mechanisms?

3. What is visible light communication (VLC)?

4. What are some potential applications of IoL?

5. How do researchers combine sensors, communication modules, and smart processing units into individual LED lamps to form a "node"?

6. What types of information can an IoL sensor network collect?

7. What is real-time beam alignment VLC design?

8. Why is power allocation optimization critical in IoL?

9. What did the team explore in their experiment with LED light?

10. How can an IoL platform regulate human emotions and brain activity?

Task 3

Say whether the following statements true or false:

1. The team of Chinese researchers proposed an Internet of Light network that collects information such as light intensity, color, hazardous gas levels and moving objects.

2. LED technology is not efficient or of good quality.

3. The Internet of Light is not meant to improve human health and well-being.

4. LED technology is not silicon-based.

5. Visible light communication (VLC) can transmit information by modulating LED light intensity.

6. The IoL sensor network cannot collect information on hazardous gas levels or moving objects.

7. The researchers did not develop algorithms or conduct hardware experiments to demonstrate system performance for high-speed data delivery.

8. The researchers are not exploring scheduling algorithms to minimize latency and accommodate base station timing requirements.

9. The team of researchers found a relationship between light stimulation and human reaction through their experiment with light stroboscopic irradiation.

10. The researchers do not plan to integrate their technologies into nursing facilities in the future.

3D-PRINTED ANTENNAS COULD BRING 5G AND 6G TO REMOTE COMMUNITIES

by University of Sheffield

3D-printed radio antennas. Credit: University of Sheffield

3D-printed radio antennas that could help bring stronger mobile phone signals and faster internet connections to people living in remote communities have been developed by researchers at the University of Sheffield.

The millimeter wave (mmWave) aerials, which have been designed, made and tested by researchers from the University of Sheffield's Department of Electronic and Electrical Engineering, have radio frequency performance that matches those produced using conventional manufacturing techniques. The 3D-printed antennas could speed up the development of new 5G and 6G infrastructure as well as help to open up access to the technologies for people living in remote areas, both in the U.K. and around the world.

Antennas currently used to build telecommunication networks are typically slow and costly to manufacture. This is hindering innovation, delaying the development of prototypes and making it difficult to build new infrastructure. The researchers at Sheffield have developed a new design that enables radio antennas to be made much cheaper and faster using 3D printing without compromising on performance. The technique means antennas can be produced in as little as a few hours, for only a few pounds, but with similar performance capabilities as antennas manufactured in the conventional way which usually cost hundreds of pounds to create.

Below are some 3D surface plots created at the measurement lab–these plots show a comparison between a traditionally manufactured example, and the 3D printed antenna created by the team at the University of Sheffield. The antennas use silver nanoparticles, which have excellent electrical properties for radio frequency, and have been tested at various frequencies used by 5G and 6G networks, up to 48 GHz. Their gain and time domain response-affecting the direction and strength of signal they can receive and transmit – is almost indistinguishable from those manufactured traditionally.

Picture of measured antennas' 3D surface plots. Credit: University of Sheffield

Eddie Ball, from the Communications Research Group at the University of Sheffield, said, "This 3D-printed design could be a game changer for the telecommunications industry. It enables us to prototype and produce antennas for 5G and 6G networks at a far lower cost and much quicker than the current manufacturing techniques. The design could also be used to produce antennas on a much larger scale and therefore have the capability to cover more areas and bring the fastest mobile networks to parts of the world that have not yet had access."

Radio frequency testing of the antenna was performed using the University of Sheffield's industry-leading UKRI National mmWave Measurement Lab. The mmWave measurement facility can measure systems on chip and antennas to

110GHz, which is invaluable for communications research, such as that carried out on the 3D-printed antenna.

Glossary

1. Radio frequency – The range of frequencies used for wireless communication.

2. Millimeter wave (mmWave) – A high-frequency band of radio waves used for wireless communication.

3. Aerials – Antennas used for transmitting and receiving radio signals.

4. Conventional manufacturing techniques – Traditional methods of manufacturing that are commonly used.

5. 5G and 6G infrastructure – The next generation of wireless communication technology.

6. Prototypes – Models or samples of a product that are created for testing or evaluation.

7. Gain and time domain response – The ability of an antenna to receive and transmit signals in a specific direction and with a specific strength.

8. Silver nanoparticles – Tiny particles of silver that have excellent electrical properties for radio frequency.

9. Direction and strength of signal – The orientation and power of the signal being transmitted or received by an antenna.

10. Communications research – Research focused on improving wireless communication technology.

11. UKRI National mmWave Measurement Lab – An industry-leading facility for measuring systems on chip and antennas up to 110GHz.

12. Game changer – Something that significantly alters the way things are done or thought about.

Task 1

Find words which mean the following:

1. antenna
2. making it difficult for somebody to do something or for something to happen
3. ordinary
4. the range of possible values of a particular variable
5. having no differences, identical
6. consequently, thus
7. equipment

Task 2

Say whether the following is true, false or is not mentioned:

1. Researchers from the University of Sheffield's Department of Electronic and Electrical Engineering, have produced millimeter wave aerials using conventional manufacturing techniques.

2. Developed antennas could help to open up access to the technologies for people living in remote areas.

3. The 3D-printed antennas could be used only in development of 6G infrastructure.

4. Production of new antennas takes as little as a few minutes and costs only a few pounds.

5. Antennas manufactured in the conventional way usually cost hundreds of pounds to create.

6. Properties of manufactured antennas are absolutely different from 3D-printed.

7. 3D-printed antennas can be used in 4G networks.

8. The design on new antennas could also be used to produce them on a much larger scale.

Task 3

Answer the following questions:

1. How did the researchers crate the designed antennas?

2. What advantages do the developed antennas have?

3. What is the main problem with currently used antennas?

4. What did the researchers compare their antennas to?

5. Which plots dis the researches use to show a comparison between antennas?

6. What did researches use to obtain excellent electrical properties for radio frequency?

7. What parameters of antennas have been tested by researchers in order to compare with manufactured ones?

8. What frequencies have been tested?

9. Why could 3D-printed design be a game changer for the telecommunications industry?

10. Where was radio frequency testing of the antenna performed?

THE OPTICAL FIBER THAT KEEPS DATA SAFE EVEN AFTER BEING TWISTED OR BENT

Date: January 10, 2023
Source: University of Bath
Summary:

An optical fiber that uses the mathematical concept of topology to remain robust, thereby guaranteeing the high-speed transfer of information, has been created by physicists.

Optical fibres are the backbone of our modern information networks. From long-range communication over the internet to high-speed information transfer within data centres and stock exchanges, optical fibre remains critical in our globalised world.

Fibre networks are not, however, structurally perfect, and information transfer can be compromised when things go wrong. Tßo address this problem, physicists at the University of Bath in the UK have developed a new kind of fibre designed to enhance the robustness of networks. This robustness could prove to be especially important in the coming age of quantum networks.

The team has fabricated optical fibres (the flexible glass channels through which information is sent) that can protect light (the medium through which data is transmitted) using the mathematics of topology. Best of all, these modified fibres are easily scalable, meaning the structure of each fibre can be preserved over thousands of kilometres.

The Bath study is published in the latest issue of *Science Advances*.

Protecting light against disorder

At its simplest, optical fibre, which typically has a diameter of 125 µm (similar to a thick strand of hair) comprises a core of solid glass surrounded by cladding. Light travels through the core, where it bounces along as though reflecting off a mirror.

However, the pathway taken by an optical fibre as it crisscrosses the landscape is rarely straight and undisturbed: turns, loops, and bends are the norm. Distortions in the fibre can cause information to degrade as it moves between sender and receiver. "The challenge was to build a network that takes robustness into account," said Physics PhD student Nathan Roberts, who led the research.

"Whenever you fabricate a fibre-optic cable, small variations in the physical structure of the fibre are inevitably present. When deployed in a network, the fibre can also get twisted and bent. One way to counter these variations and defects is to ensure the fibre design process includes a real focus on robustness. This is where we found the ideas of topology useful."

To design this new fibre, the Bath team used topology, which is the mathematical study of quantities that remain unchanged despite continuous distortions to the geometry. Its principles are already applied to many areas of physics research. By connecting physical phenomena to unchanging numbers, the destructive effects of a disordered environment can be avoided.

The fibre designed by the Bath team deploys topological ideas by including several light-guiding cores in a fibre, linked together in a spiral. Light can hop between these cores but becomes trapped within the edge thanks to the topological design. These edge states are protected against disorder in the structure.

Bath physicist Dr Anton Souslov, who co-authored the study as theory lead, said: "Using our fibre, light is less influenced by environmental disorder than it would be in an equivalent system lacking topological design.

"By adopting optical fibres with topological design, researchers will have the tools to pre-empt and forestall signal-degrading effects by building inherently robust photonic systems."

Theory meets practical expertise

Bath physicist Dr Peter Mosley, who co-authored the study as experimental lead, said: "Previously, scientists have applied the complex mathematics of topology to light, but here at the University of Bath we have lots of experience physically making optical fibres, so we put the mathematics together with our expertise to create topological fibre."

The team, which also includes PhD student Guido Baardink and Dr Josh Nunn from the Department of Physics, are now looking for industry partners to develop their concept further.

"We are really keen to help people build robust communication networks and we are ready for the next phase of this work," said Dr Souslov.

Mr Roberts added: "We have shown that you can make kilometres of topological fibre wound around a spool. We envision a quantum internet where information will be transmitted robustly across continents using topological principles."

He also pointed out that this research has implications that go beyond communications networks. He said: "Fibre development is not only a technological challenge, but also an exciting scientific field in its own right.

"Understanding how to engineer optical fibre has led to light sources from bright 'supercontinuum' that spans the entire visible spectrum right down to quantum light sources that produce individual photons – single particles of light."

The future is quantum

Quantum networks are widely expected to play an important technological role in years to come. Quantum technologies have the capacity to store and process information in more powerful ways than 'classical' computers can today, as well as sending messages securely across global networks without any chance of eavesdropping.

But the quantum states of light that transmit information are easily impacted by their environment and finding a way to protect them is a major challenge. This work may be a step towards maintaining quantum information in fibre optics using topological design.

Glossary

1. Optical fibres: Flexible glass channels used to transmit information over long distances.

2. Robustness: The ability of a system to withstand disruptions and maintain its functionality.

3. Quantum networks: Networks that use quantum mechanics to transmit information securely and efficiently.

4. Topology: The mathematical study of quantities that remain unchanged despite continuous distortions to the geometry.

5. Light-guiding cores: The central part of an optical fibre that guides the transmission of light.

6. Edge states: Protected areas within the fibre that are less influenced by environmental disorder.

7. Photonic systems: Systems that use light to transmit and process information.

8. Experimental lead: The person responsible for the practical aspects of a research project.

9. Theory lead: The person responsible for the theoretical aspects of a research project.

10. Industry partners: Companies or organizations that collaborate with researchers to develop and commercialize new technologies.

11. Quantum states: The state of a quantum system that describes its properties such as energy, position, and momentum.

12. Eavesdropping: The act of secretly listening to or monitoring someone's conversation or communication without their knowledge or permission.

Task 1

Find words which mean the following:

1. base
2. endurance
3. extensible
4. mess
5. include
6. invariably
7. curved
8. jump
9. missing
10. cover

Task 2

Say whether the following is true, false or is not mentioned:

1. Fiber-optic networks are structurally perfect.

2. Physicists at the University of Bath in the UK have manufactured optical fibers that can protect light using the mathematics of topology.

3. The fiber can get bent into small loop and be broken.

4. The fiber designed by the Bath team includes several light-guiding cores in a fibre, linked together in triangles.

5. By implementing optical fibers with a topological design, researchers will get tools to prevent effects that degrade signal quality by creating initially reliable photonic systems.

6. Dr. Suslov believes that they really strive to help people create reliable communication networks.

7. Quantum technologies have the capacity to store and process information in less powerful ways than 'classical' computers can today, as well as sending messages insecure across global networks with very big chance of eavesdropping.

Task 3

Answer the following questions:

1. Why optical fibers are the backbone of our modern information networks?

2. What can the diameter of an optical fiber be compared with?

3. Why does Physics PhD student Nathan Roberts see the challenge in building a network that takes reliability into account??

4. What effects can be avoided by connecting physical phenomena to unchanging numbers??

5. What implications of optical fiber go beyond communications networks?

6. What has the understanding of how to construct an optical fiber led to?

7. What disadvantages has quantum states of light?

A SYSTEM TO ENABLE MULTI-KILOMETER AND SUB-TERAHERTZ COMMUNICATIONS AT EXTREMELY HIGH FREQUENCY BANDS

by Ingrid Fadelli, Tech Xplore

Compact transmitter and receiver for long-range communications above 100 GHz. Credit: Sen et al.

After the introduction of the fifth-generation technology standard for broadband cellular networks (5G), engineers worldwide are now working on systems that could further speed up communications. The next-generation wireless communication networks, from 6G onward, will require technologies that enable communications at sub-terahertz and terahertz frequency bands (i.e., from 100GHz to 10THz).

While several systems have been proposed for enabling communication at these frequency bands specifically for personal use and local area networks, some applications would benefit from longer communication distances. So far, generating high-power ultrabroadband signals that contain information and can travel long distances has been challenging.

Researchers at the NASA Jet Propulsion Laboratory (JPL), Northeastern University and the Air Force Research Laboratory (AFRL) have recently developed a system that could enable multi-gigabit-per-second (Gbps) communications in the sub-terahertz frequency band over several kilometers. This system, presented in a paper in *Nature Electronics*, utilizes on-chip power-combining frequency multiplier designs based on Schottky diodes, semiconducting diodes formed by the junction of a semiconductor and a metal, developed at NASA JPL.

"Frequencies above 100 GHz are traditionally not considered for communications applications because of unfavorable channel properties and lack of high-power devices," Dr. Ngwe Thawdar an AFRL researcher who carried out the study, told Tech Xplore.

"We have built a unique team here where NASA JPL brought the unique device expertise, Northeastern brought the signal processing and communications, and AFRL brought rigorous test and evaluation at scale in relevant environments. In this paper, we proved the viability of these frequencies for next generation communications applications and brought the terahertz communications technology from vision to reality."

The key goal of the recent work by Dr. Thawdar and her colleagues was to demonstrate the feasibility of communication links at frequencies above 100 GHz, for ranges over 1 km rand at data rates higher than 1 Gbps. The system they proposed exceeded their expectations, enabling communications at a range over 2km and with a data rate of over 1 Gbps.

"The key novelty of our system is the way in which we modulate the terahertz carrier signal with the information that we want to transmit," Dr. Josep Jornet from Northeastern University told Tech Xplore. "In traditional systems, a mixer (the device we use to add the information to the signal) is present at the transmitter right after the frequency multipliers that upconvert a lower-frequency signal to the terahertz band and before the antenna. In our case, we have so much power after the frequency multipliers that the mixer would simply blow up."

To overcome the power-related challenges associated with the problem they were tackling, Dr. Thawdar, Dr. Jornet and their colleagues tested two plausible solutions. The first entailed modulating the local oscillator in their system and then upconverting it to terahertz frequencies, while the second involved the modulation while the signals were half-way, through a so-called frequency multiplication process.

Both these strategies allowed them to add information and retain their desired maximum output power. Their only additional requirement was to carry out additional signal processing to pre-compensate for the distortion introduced by frequency multipliers.

"For many years, it was generally believed that terahertz communications were only feasible over short communication distances (tens of meters at most)," Dr. Priyangshu Sen from Northeastern University told Tech Xplore.

"Here, we show that with innovative technologies that are currently available to us, an intelligent combination of the different hardware building blocks and tailored signal processing, we can communicate at terahertz frequencies over several kilometers. This opens the door to terahertz communications potentially replacing costly and sometimes technically challenging optical fiber deployments, the access to ultrabroadband internet connectivity to communities that today do not have it."

The highly promising results achieved by this team of researchers could open new and exciting possibilities for communications at extremely high frequency bands. In the future, this work could inspire the study of even more challenging applications, such as the use of terahertz communications for satellite and space links.

"Now that we have shown the art of the possible at terahertz frequencies, out next step is to broaden our partnerships across the industrial base to enable next generation communications systems for both defense and commercial applications," Dr. Thawdar added.

Glossary

1. Sub-terahertz and terahertz frequency bands – Frequencies above 100GHz that are being explored for next-generation wireless communication networks.

2. Power-combining frequency multiplier designs – A technique for generating high-power ultrabroadband signals that contain information and can travel long distances.

3. Schottky diodes – Semiconducting diodes formed by the junction of a semiconductor and a metal, used in power-combining frequency multiplier designs.

4. Viability – The ability of something to work effectively.

5. Modulate – To vary the amplitude, frequency, or phase of a carrier wave in accordance with the signal to be transmitted.

6. Mixer – A device used to add information to a signal.

7. Local oscillator – An electronic oscillator used to generate a signal for mixing with another signal in a superheterodyne receiver.

8. Frequency multiplication process – A process used to increase the frequency of a signal.

9. Signal processing – The manipulation of signals to extract information or enhance their quality.

10. Pre-compensate – To adjust a signal before it is transmitted to account for distortion that will be introduced during transmission.

Task 1

Find words which mean the following:

1. to be helped by something
2. careful
3. ability to succeed
4. new, unusual
5. seemingly likely to be true
6. continue to have something
7. happening

Task 2

Answer the following questions:

1. What is the fifth-generation technology standard for broadband cellular networks called?

2. What frequency bands will be required for next-generation wireless communication networks from 6G onward?

3. Why have frequencies above 100 GHz traditionally not been considered for communications applications?

4. Who developed a system that could enable multi-gigabit-per-second (Gbps) communications in the sub-terahertz frequency band over several kilometers?

5. What is the key goal of the recent work by Dr. Thawdar and her colleagues?

6. What is the key novelty of the system developed by Dr. Thawdar and her colleagues?

7. How did Dr. Thawdar and her colleagues overcome the power-related challenges associated with the problem they were tackling?

8. What was the range achieved by the system proposed by Dr. Thawdar and her colleagues?

9. What was the data rate achieved by the system proposed by Dr. Thawdar and her colleagues?

10. What does Dr. Priyangshu Sen from Northeastern University say about terahertz communications?

11. What is the potential benefit of terahertz communications replacing optical fiber deployments?

12. What are some potential future applications for terahertz communications?

Task 3

Say whether the following is true, false or is not mentioned:

1. The next-generation wireless communication networks will require technologies that enable communications at sub-terahertz and terahertz frequency bands.

2. Generating high-power ultrabroadband signals that contain information and can travel long distances has been easy.

3. The system developed by NASA JPL, Northeastern University, and AFRL could enable multi-gigabit-per-second (Gbps) communications in the sub-terahertz frequency band over several kilometers.

4. Frequencies above 100 GHz are traditionally considered for communications applications because of favorable channel properties and high-power devices.

5. The recent work by Dr. Thawdar and her colleagues aimed to demonstrate the feasibility of communication links at frequencies below 100 GHz.

6. The system proposed by Dr. Thawdar and her colleagues enabled communications at a range over 2km and with a data rate of over 1 Gbps.

7. In traditional systems, a mixer is present at the transmitter right after the antenna.

8. The first solution tested by Dr. Thawdar, Dr. Jornet, and their colleagues involved modulating the local oscillator in their system and then upconverting it to terahertz frequencies.

9. Terahertz communications were believed to be only feasible over short communication distances (tens of meters at most).

10. Innovative technologies that are currently available to us can allow communication at terahertz frequencies over several kilometers.

11. Terahertz communications could potentially replace optical fiber deployments.

12. The research on terahertz communications could inspire the study of using it for satellite and space links.

NEW ANTENNAS AND MICROCHIPS HELP ELECTRONICS BLUR THE LINE BETWEEN SCIENCE AND SCI-FI

by John Sullivan, Princeton University

Kaushik Sengupta. Credit: Princeton University

Sophisticated antenna arrays paired with high-frequency wireless chips act like superpowers for modern electronics, boosting everything from sensing to security to data processing. In his lab at Princeton, Kaushik Sengupta is working to expand those powers even further.

In recent years, Sengupta's lab has designed antenna arrays that help engineers make strides toward peering through matter, boosting communications in canyons of skyscrapers, putting a medical lab on a smart phone, and encrypting critical data with electromagnetic waves instead of software.

In a new article in *Advanced Science*, Sengupta's research team presented a new type of antenna array based on the paper-folding art of origami. The shape-shifting array, designed like a folded paper box called a waterbomb, allows engineers to create a reconfigurable and adaptable radar imaging surface.

To build the system, the team installed a new class of broadband metasurface antennas onto standard, flat panels. Then they connected a number of the antenna panels into a precisely designed origami surface with an offset checkerboard pattern. Through proper sequence of folding and unfolding the panels, the array assumes a variety of different shapes like curves, saddles and spheres.

With this ability to shift and expand, the origami system offers a wider resolution and has the ability to capture complex three-dimensional scenes beyond the capability of a standard antenna array. The waterbomb antenna can also morph its shape to manipulate electromagnetic waves in carefully calibrated ways. Combined with advanced algorithms, the waterbomb system can effectively process information from a wide range of electromagnetic fields. This shapeshifting ability allows engineers to expand the capabilities of devices used for sensing and imaging.

"For most applications, planar, or flat, systems are preferred because they are simpler and easier to design," said Sengupta, an associate professor of electrical and computer engineering. "But reconfigurable systems allow us to substantially expand our ability in computer imaging. Using origami, we are able to combine the simplicity of planar arrays with the expanded ability of reconfigurable systems. It's like a transformer robot in action."

Sengupta said origami-based arrays could vastly improve sensing technology needed for autonomous vehicles, robots and cyberphysical systems. The relative simplicity of the individual antenna systems also mean that the sensing arrays can be light and low-cost, making them easier to manufacture and deploy across a wide scale.

While rapid developments in energy and computation usually draw the most public attention, Sengupta and his colleagues at Princeton Engineering focus on the invisible wireless networks that allow these breakthroughs to empower society.

"You can think about all these really complex applications that are emerging– robotics, self-driving cars, smart cities, smart healthcare applications, artificial reality, virtual reality," he said. "All of these things are sitting on that web of wireless communications."

Any one of these applications would represent a major increase in demand for wireless networks. Together, they demand a fundamental rethinking of how we move data across the airwaves, both in terms of the microchips designed to handle the traffic and the signals transmitted by those chips. In brief, we need to pack far more information into signals and build computer systems that can process the information quickly, accurate and securely.

Origami allows engineers to rapidly shift arrays of antennas, greatly increasing their capabilities.

In the past few years, Sengupta's research has been recognized on both fronts. In 2021, he was named Outstanding Young Engineer by the Microwave Theory and Techniques Society (MTT-S), a leading scientific society for wireless communications. Last year, he received the New Frontier Award for his work on microchips from the Institute of Electrical and Electronics Engineers (IEEE), the world's largest electrical engineering society.

From chip design to signal processing, the awards reflect the broad approach to research taken by Sengupta's research team at the Integrated Micro-Systems Research Lab. In recent years, his group has demonstrated technology to expand into new frequency bands for faster and more secure transmissions, developed new sensing technology for scientific and medical applications, and produced methods to secure high-demand transmissions without slowing down applications.

In the most recent project, involving waterbomb origami, Sengupta's research team turned its focus from antenna arrays themselves into methods of shape-shifting multiple arrays into complex systems. The reconfigurable system not only allows for hyper-spectral sensing across a wide range of frequencies, it fuses the information together with the surface topology. This could prove valuable for vehicles and robots that require intensive communications while working in a variety of environments. It also could prove important for other electronic structures that require folding and tuning such as spacecraft and solar panels.

"By eliminating the constraints of flat-panel antenna arrays, we can combine principles of origami with high-frequency electronics and advanced signal processing to create versatile, highly efficient imaging and radar systems," Sengupta said.

Sengupta said his research team's technological approach varies across these projects, but the ultimate goal is to solve the challenges that changes will bring to the wireless world. One of those challenges is the data rates that the new applications will require. Take self-driving cars: Most of the focus is on the navigation technology or the processing power that an autonomous vehicle will require, but one of the greatest challenges is creating a wireless network to support the new technology.

"Think about the information deluge of a self-driving car," he said. Even a single car will require a vast amount of data to navigate a complex road system. For multiple cars sharing a highway, the demands for data will increase even further. "You need very high bandwidth connections, so you need to think about frequencies that we have not used before."

Medical technology is similarly poised for a massive change, with real-time health monitoring and new devices such as bandages that communicate with remote doctors and adjust treatment based on the patient's condition.

All of these developments will demand more speed, higher amounts of data delivery and tighter security than modern networks are capable of delivering. Sengupta said solving those problems will require work at both the level of new microchips and the frequencies used to transmit signals.

"The approaches we pursue are multidisciplinary," he said. "Our approach is to leverage concepts from different fields and merge them to create high-performance systems."

The article "Origami Microwave Imaging Array: Metasurface Tiles on a Shape-Morphing Surface for Reconfigurable Computational Imaging," was published Oct. 5, 2022, in *Advanced Science*.

Glossary

1. Antenna arrays – a group of antennas working together to improve signal strength and quality.

2. High-frequency wireless chips – computer chips that operate at high frequencies to enable faster data processing and communication.

3. Sensing – the ability to detect or perceive information from the environment.

4. Security – measures taken to protect information or devices from unauthorized access or damage.

5. Data processing – the manipulation and organization of data using computer software or hardware.

6. Metasurface antennas – antennas that use specially designed materials to manipulate electromagnetic waves.

7. Origami – the art of paper folding, used in this context to create a reconfigurable antenna array.

8. Radar imaging – a method of detecting objects and their location using radio waves.

9. Resolution – the level of detail in an image or signal.

10. Electromagnetic waves – waves of energy that consist of both electric and magnetic fields.

11. Algorithms – a set of instructions or rules for solving problems or completing tasks.

12. Autonomous vehicles – vehicles that can operate without human intervention.

13. Cyberphysical systems – systems that integrate physical and digital components, such as sensors and software.

14. Microchips – small electronic components used in computers and other devices.

15. Traffic – the amount of data being transmitted through a network or system.

16. Signal processing – the manipulation of signals to improve their quality or extract useful information.

17. Frequency bands – specific ranges of frequencies used for communication and transmission.

18. Sensing technology – technology that allows for the detection or perception of information from the environment.

19. Hyper-spectral sensing – sensing that uses a wide range of frequencies to gather detailed information about an object or environment.

20. Imaging and radar systems – systems that use electromagnetic waves to detect and locate objects.

21. Data rates – the amount of data that can be transmitted over a network or system in a given amount of time.

22. Bandwidth connections – the amount of data that can be transmitted over a network or system at one time.

23. Real-time health monitoring – monitoring of a patient's health in real-time using technology.

24. Multidisciplinary approach – an approach that combines concepts and methods from multiple fields to solve complex problems.

25. Frequencies – specific ranges of electromagnetic waves used for communication and transmission.

26. High-performance systems – systems that are designed to operate at high speeds and deliver high-quality results.

Task 1

Find words in the text that mean the following:

1. step, development
2. catch
3. change
4. impossible to see
5. an important discovery
6. request
7. need something
8. become lager
9. follow

Task 2

Answer the following questions:

1. What is the purpose of antenna arrays paired with high-frequency wireless chips?
2. What has Sengupta's lab designed antenna arrays for in recent years?
3. What is the new type of antenna array that Sengupta's research team presented in Advanced Science?
4. How is the origami-based antenna array designed?
5. What benefits does the waterbomb antenna offer?
6. What applications could benefit from origami-based arrays?
7. What was Sengupta's recent recognition in the field of wireless communications?

8. What is the Integrated Micro-Systems Research Lab focused on?

9. What is the recent project of Sengupta's research team involving waterbomb origami?

10. What challenges does Sengupta see in the wireless world?

11. What is one of the greatest challenges in creating a wireless network to support self-driving cars?

12. What is Sengupta's approach to solving wireless world problems?

Task 3

Say whether the following statements are true or false

1. The Integrated Micro-Systems Research Lab is focused on developing technology for slower and less secure transmissions.

2. Sengupta's recent project involves creating a reconfigurable system for hyper-spectral sensing using waterbomb origami.

3. Sengupta sees challenges in the data rates required for new applications like self-driving cars and real-time health monitoring.

4. One of the greatest challenges in creating a wireless network to support self-driving cars is finding frequencies that have not been used before.

5. Sengupta's approach to solving wireless world problems is multidisciplinary.

6. Sengupta's research team presented a new type of antenna array based on the paper-folding art of calligraphy.

7. In 2021, Sengupta was named Outstanding Young Engineer by the Society for Wireless Communications.

8. Sengupta's research team focuses solely on chip design.

9. The waterbomb origami project is focused on creating solar panels.

10. Sengupta's research team aims to solve the challenges that changes will bring to the wireless world.

11. Self-driving cars require low bandwidth connections.

12. Sengupta's approach to solving wireless world problems is not multidisciplinary.

USING COSMIC RAYS TO GENERATE AND DISTRIBUTE RANDOM NUMBERS AND BOOST SECURITY FOR LOCAL DEVICES AND NETWORKS

by University of Tokyo

When both sender and receiver have identical random numbers, they can share encrypted data without the need to share a key to decode it. This prevents so-called man-in-the-middle attacks. With COSMOCAT, muons (μ) arriving at the sender and receiver at the same time provide the source of the random number. Provided the devices are synchronized, the receiver can know which muon signal relates to which incoming message and can decode it accordingly.

State-of-the-art methods of information security are likely to be compromised by emerging technologies such as quantum computers. One of the reasons they are vulnerable is that both encrypted messages and the keys to decrypt them must be sent from sender to receiver.

A new method–called COSMOCAT–is proposed and demonstrated, which removes the need to send a decryption key since cosmic rays transport it for us, meaning that even if messages are intercepted, they could not be read using any theorized approach. COSMOCAT could be useful in localized various bandwidth applications, as there are limitations to the effective distance between sender and receiver.

In the field of information communication technology, there is a perpetual arms race to find ever more secure ways to transfer data, and ever more sophisticated ways to break them. Even the first modern computers were essentially code-breaking machines used by the U.S. and European Allies during World War II. And this race is about to enter a new regime with the advent of quantum computers, capable of breaking current forms of security with ease. Even security methods which use quantum computers themselves might be susceptible to other quantum attacks.

"Basically, the problem with our current security paradigm is that it relies on encrypted information and keys to decrypt it both being sent along a network from sender to receiver," said Professor Hiroyuki Tanaka from Muographix at the University of Tokyo.

"Regardless of the way messages are encrypted, in theory someone eavesdropping could use the keys to decode the secure messages eventually. Quantum computers just make this process faster. If we dispense with this idea of sharing keys and could instead find some way of using unpredictable random numbers to encrypt information, then it should lead to a system immune to interception. And I happen to work often with a source capable of generating truly random unpredictable numbers: cosmic rays from outer space."

Some use cases for COSMOCAT. As the distance is limited due to the nature of the muon shower arriving at the ground, COSMOCAT is best suited for networks within small areas such as buildings. Offices, data centers and buildings that make use of smart devices, and even electric-car charging stations, are some possible application areas.

Credit: © 2022 Hiroyuki Tanaka

Various random number generators have been tried over time, but the problem is how to share these random numbers while avoiding interception. Cosmic rays may hold the answer, as one of their byproducts, muons, are statistically random in their arrival times at the ground. Muons also travel close to the speed of light and penetrate solid matter easily.

This means that as long as we know the distance between the sender's detector and the receiver's detector, the time required for muons to travel from the sender to the receiver can be precisely calculated. And providing that a pair of devices are sufficiently synchronized, the muons' arrival time could serve as a secret key for both encoding and decoding a packet of data. But this key never has to leave the sender's device, as the receiving machine should automatically have it as well. This would plug the security hole presented by sending shared keys.

"I call the system Cosmic Coding and Transfer, or COSMOCAT," said Tanaka. "It could be used alongside or in place of current wireless communications technologies such as Wi-Fi, Bluetooth, near-field communication (NFC), and more. And it can exceed speeds possible with current encrypted Bluetooth standards. However, the distance it can be used at is limited; hence, it's ideally kept to small local networks, for example, within a building. I believe COSMOCAT is ready to be adopted by commercial applications."

At present, the muon-detecting apparatus are relatively large and require more power than other local wireless communication components. But as technology improves and the size of this apparatus can be reduced, it might soon be possible to install COSMOCAT in high-security offices, data centers and other local area networks.

Glossary

1. Random numbers: numbers generated by a process that is statistically unpredictable.

2. Encrypted data: data that has been transformed into a secret code to prevent unauthorized access.

3. Key: a code or password used to decrypt encrypted data.

4. Man-in-the-middle attacks: attacks in which an attacker intercepts communication between two parties to steal information or manipulate the conversation.

5. COSMOCAT: a method of information security that uses muons from cosmic rays as a source of random numbers to encrypt and decrypt data.

6. Muons: subatomic particles that are a byproduct of cosmic rays and can be used to generate random numbers.

7. Synchronized devices: devices that are coordinated in time and can use the arrival time of muons to encrypt and decrypt data.

8. Quantum computers: computers that use quantum mechanics to perform calculations and can break current forms of security.

9. Interception: the act of capturing or stealing information during communication.

10. Immune to interception: resistant to interception or hacking attempts.

11. Random number generators: devices or processes that generate random numbers.

12. Cosmic rays: high-energy particles from outer space that can penetrate solid matter.

13. Muon shower: a burst of muons produced by cosmic rays entering the Earth's atmosphere.

14. Encoding: the process of transforming data into a secret code.

15. Decoding: the process of transforming encrypted data back into its original form.

16. Wireless communications technologies: technologies that allow communication between devices without the need for physical connections, such as Wi-Fi, Bluetooth, and NFC.

17. Cosmic Coding and Transfer (COSMOCAT): a system of information security that uses muons from cosmic rays to generate random numbers for encryption and decryption, eliminating the need for sharing keys between sender and receiver.

Task 1

Find words that mean the following:

1. respectively

2. modern

3. to have disadvantages in security

4. constant

5. depends on smth

6. to refuse

7. flow

8. exactly/ accurate

9. to make better

Task 2

Answer the following questions:

1. Where is COSMOCAT using now?
2. Why can't we use regular random number generators?
3. Can a spacecraft completely replace modern security systems?
4. Why is the Cosmocat called so?
5. What is the main problem of the widespread installation of COSMOCAT?
6. What is needed to encode the signal from the COSMOCAT?
7. Why are even the most modern supercomputers vulnerable to attacks?
8. Why is COSMOCAT limited in areas of sending messages?
9. What's the general problem of the modern security paradigm?
10. Why does COSMOCAT use cosmic rays?

Task 3

Say whether the following statements are True, False or not mentioned:

1. COSMOCAT works on the principle of absolutely random numbers
2. The reason for the vulnerability of modern computers is the use of quantum supercomputers by hackers
3. There is no need of decryption key in using COSMOCAT
4. Quantum computers are used to make decryption faster
5. COSMOCAT was created to replace modern vulnerable security system
6. COSMOCAT can be used only in very local areas, like small offices
7. To decode information receiver have to know the equal distance between sender and receiver

A NEW TERAHERTZ WIRELESS LINK COULD BRIDGE THE DIGITAL DIVIDE, SAYS RESEARCHER

by Cody Mello-Klein, Northeastern University

Josep Jornet, an associate professor of electrical and computer engineering at Northeastern, proved it is possible to maintain a two kilometer-long connection using high frequency terahertz technology. It could help increase connectivity for rural communities, even more than 5G technology. Credit: Matthew Modoono/Northeastern University

For years, the idea of 6G was thought to be science fiction. Now, it's closer than ever before, but Josep Jornet, an associate professor of electrical and computer engineering at Northeastern, says there's still room for improvement.

Together with NASA, the U.S. Air Force and Amazon, Jornet proved for the first time that high-speed, high-bandwidth wireless communication at the terahertz frequency is possible across long distances. The research, recently published in *Nature Electronics*, shows that there is a path forward for mass wireless communication, one that could shrink the digital divide felt by rural communities outside high-speed optical fiber networks.

"You need to find a technology that can give you optical-like connectivity without the optical problems, and we think that terahertz technology is that," Jornet says.

The terahertz band is a set of frequencies above 100 gigahertz, pushing past 5G's 71 gigahertz limit. The rollout of 6G wireless will bring this level of service to the public, but although sending signals across the terahertz band has been proven, doing so at a great distance has been all but impossible. The higher the frequency is, the shorter the distance information can travel. For terahertz communications, that would amount to a one-foot communication, Jornet says.

But Jornet has a habit of making the impossible possible.

"My research is driven by showing people that things they believe will not work can work," he says.

Jornet and his team were able to form a 2-kilometer link, the longest terahertz connection ever established on Earth. It wasn't without challenges, though. For starters, a terahertz frequency radio isn't something Jornet could just find on Amazon, which is why he turned to NASA in the first place.

For years, NASA has been toying with terahertz wireless systems to sense signals in space, but the organization's efforts have been focused solely on receiving signals. When it comes to sending a signal, things get tricky.

Traditionally, a communication radio has a signal generator, a mixer, which adds the information to the signal, and an antenna that converts the signal into something that can be sent out over the airwaves. The problem is that terahertz frequencies are so high and require so much power to reach that any mixer placed in the radio would break. So, Jornet came up with an elegant solution.

"We don't have a mixer that can handle this much power. Fine, let's not have a mixer," he says.

Instead of putting the mixer after the signal source, Jornet and his team fed information straight into the source itself. However, doing so distorted the information to the point where it was a mangled mess. Another problem required another creative solution.

"Instead of trying to fix the information at the receiver, let me pre-distort my signal," he says. "I'm going to make the signal ugly, such that when it goes through the source, it becomes beautiful."

Surprisingly even to Jornet and his team, it worked. They had four days in the U.S. Air Force Base in Rome, New York, to pull off a long-distance terahertz connection, and by day two they were able to send and recover the information without any errors.

"In theory, you do the equations, and it sounds like it would work, but to make this theory you make many assumptions about how the device works internally," Jornet says. "Many times, when you go through this, you expect it not to work, so we were quite surprised that it actually worked."

The system Jornet and his collaborators designed was hitting frequencies and bandwidths that eclipsed 5G networks by more than "two orders of magnitude."

"In 6G, I think we will be happy with just one more order of magnitude," he says.

The impact of this kind of high-speed, high bandwidth connection would be monumental, providing higher data rates and more connectivity even for rural communities. Until recently with the rollout of 5G, rural communities have fallen between the cracks of the digital divide because the fiber optic cables that form the backbone of cutting edge communication networks are expensive to implement across long distances. But when it comes to wireless terahertz technology, rural communities might have an advantage.

"One of the requirements for this signal to travel is that there should not be obstacles," Jornet says. "You need to have line of sight. That's why we say this is great if you want to connect towers across farms, across lands, which otherwise would have to drill and put fiber optics in."

Jornet predicts that even before 6G is available in cellphones, terahertz will start to make a big difference in communication infrastructure.

"The first use case is going to be you as a user will still be using your phone, but suddenly you'll notice that your network is faster because many times the bottleneck is not your phone, it's the infrastructure," Jornet says. "What we're doing is accelerating infrastructure."

In the long run, cutting the fiber optic cord and transitioning to terahertz wireless will be a boon for more than just rural communities, Jornet says. And that's just the start. As usual, he already has his eye on the horizon–literally.

"As a scientist, my goal is to show that 2 kilometers was just the first stop. We want to go for space because that will also give connectivity to everyone," he says, referencing the Starlink satellite technology being pursued by SpaceX. "You will have connectivity like your Verizon Fios, independent of where you are in the world, just because you have a bunch of satellites orbiting the Earth with the right technology."

"It sounds crazy," he adds. "But it's not any crazier than 10 years ago when you said you could [reach] two kilometers."

Glossary

1. 6G: The next generation of wireless communication technology.

2. Terahertz frequency: A frequency band above 100 gigahertz, which is higher than the current limit of 5G.

3. Digital divide: The gap between those who have access to high-speed internet and those who do not.

4. Optical fiber networks: High-speed internet networks that use optical fibers to transmit data.

5. NASA: The National Aeronautics and Space Administration, a US government agency that conducts research and development related to space exploration and aeronautics.

6. U.S. Air Force: The aerial warfare service branch of the United States Armed Forces.

7. Amazon: An American multinational technology company that focuses on e-commerce, cloud computing, digital streaming, and artificial intelligence.

8. Wireless communication: Communication that takes place without the need for physical cables or wires.

9. Signal generator: A device that produces an electrical signal.

10. Mixer: A device that combines two or more signals into a single output signal.

11. Antenna: A device that converts electrical signals into electromagnetic waves and vice versa.

12. Radio: A device used for transmitting and receiving radio signals.

13. Bandwidth: The maximum amount of data that can be transmitted over a network or communication channel in a given amount of time.

14. Mangled mess: Distorted or unintelligible information.

15. Pre-distort: To intentionally distort a signal before it is transmitted in order to improve its quality after transmission.

16. Data rates: The speed at which data is transmitted over a network or communication channel.

17. Connectivity: The ability to connect to a network or communication channel.

18. Line of sight: Unobstructed view between two points necessary for wireless communication using terahertz frequency.

19. Bottleneck: A point of congestion or delay in a system, often causing slower data rates.

20. Starlink: Satellite technology being pursued by SpaceX to provide high-speed internet connectivity globally.

Task 1

Find words and expressions meaning the following:

1. fracture, slit
2. a problem that delays progress
3. something that is very helpful
4. something that blocks your way
5. strength
6. agricaltural, suburban
7. within, inside
8. speculate
9. very modern

Task 2

Answer the following questions:

1. What is the terahertz band, and why is it important for wireless communication?

2. What did Josep Jornet prove with his research on terahertz frequency wireless communication?

3. How did Jornet and his team overcome the problem of not having a mixer that can handle the high power required for terahertz frequencies?

4. What was the length of the longest terahertz connection ever established on Earth by Jornet and his team?

5. What is the focus of the research outlined in Nature Electronics?

6. What kind of DBN did the researchers specifically test their system with?

7. How did Jornet and his team surpass 5G networks with their system?

8. What is the potential impact of terahertz technology on rural communities?

9. Why have rural communities fallen between the cracks of the digital divide?

10. What advantage might rural communities have with terahertz technology?

11. How will terahertz technology make a big difference in communication infrastructure before 6G is available in cellphones?

12. What is Jornet's long-term goal for terahertz technology?

Task 3

Say whether the following stements are true or false:

1. Josep Jornet worked with NASA, the U.S. Air Force and Amazon to prove that high-speed, high-bandwidth wireless communication at the terahertz frequency is possible across long distances.

2. The research shows that there is a path forward for mass wireless communication, one that could shrink the digital divide felt by rural communities outside high-speed optical fiber networks.

3. Terahertz technology can travel long distances without any limitations.

4. Jornet and his team were able to form a 2-kilometer link, the longest terahertz connection ever established on Earth.

5. NASA has only been focused on receiving signals when it comes to terahertz wireless systems.

6. Jornet and his team fed information straight into the source itself instead of putting the mixer after the signal source.

7. The system Jornet and his collaborators designed was hitting frequencies and bandwidths that were lower than 5G networks.

8. The terahertz technology developed by Jornet and his team can provide high-speed, high-bandwidth wireless communication across long distances.

9. Rural communities have been left behind in terms of high-speed communication networks because of the cost of implementing fiber optic cables over long distances.

10. Terahertz technology requires line of sight and cannot travel through obstacles.

11. Jornet predicts that terahertz technology will improve communication infrastructure even before 6G is available for cellphones.

12. Jornet believes that transitioning from fiber optic cables to terahertz wireless communication will benefit not only rural communities but also other areas.

NEXT-GENERATION WIRELESS TECHNOLOGY MAY LEVERAGE THE HUMAN BODY FOR ENERGY RESEARCHERS USE THE BODY TO HARVEST WASTE ENERGY TO POWER WEARABLE DEVICES

Date: January 4, 2023
Source: University of Massachusetts Amherst
Summary:

While you may be just starting to reap the advantages of 5G wireless technology, researchers throughout the world are already working hard on the future: 6G. One of the most promising breakthroughs in 6G telecommunications is the possibility of Visible Light Communication (VLC), which is like a wireless version of fiberoptics, using flashes of light to transmit information. Now, a team has announced that they have invented a low-cost, innovative way to harvest the waste energy from VLC by using the human body as an antenna. This waste energy can be recycled to power an array of wearable devices, or even, perhaps, larger electronics.

While you may be just starting to reap the advantages of 5G wireless technology, researchers throughout the world are already working hard on the future: 6G. One of the most promising breakthroughs in 6G telecommunications is the possibility of Visible Light Communication (VLC), which is like a wireless version of fiberoptics, using flashes of light to transmit information. Now, a team of researchers at the University of Massachusetts Amherst has announced that they have invented a low-cost, innovative way to harvest the waste energy from VLC by using the human body as an antenna. This waste energy can be recycled to power an array of wearable devices, or even, perhaps, larger electronics.

"VLC is quite simple and interesting," says Jie Xiong, professor of information and computer sciences at UMass Amherst and the paper's senior author. "Instead of using radio signals to send information wirelessly, it uses the light from LEDs that can turn on and off, up to one million times per second." Part of the appeal of VLC is that the infrastructure is already everywhere – our homes, vehicles, streetlights and offices are all lit by LED bulbs, which could *also* be transmitting data. "Anything with a camera, like our smartphones, tablets or laptops, could be the receiver," says Xiong.

Previously, Xiong and first author Minhao Cui, a graduate student in information and computer sciences at UMass Amherst, showed that there's significant "leakage" of energy in VLC systems, because the LEDs also emit "side-channel RF signals," or radio waves. If this leaked RF energy could be harvested, then it could be put to use.

The team's first task was to design an antenna out of coiled copper wire to collect the leaked RF, which they did. But how to maximize the collection of energy?

The team experimented with all sorts of design details, from the thickness of the wire to the number of times it was coiled, but they also noticed that the efficiency of the antenna varied according to what the antenna touched. They tried resting the coil on plastic, cardboard, wood and steel, as well as touching it to walls of different thicknesses, phones powered on and off and laptops. And then Cui got the idea to see what happened when the coil was in contact with a human body.

Immediately, it became apparent that a human body is the best medium for amplifying the coil's ability to collect leaked RF energy, up to ten times more than the bare coil alone.

After much experimentation, the team came up with "Bracelet+," a simple coil of copper wire worn as a bracelet on the upper forearm. While the design can be adapted for wearing as a ring, belt, anklet or necklace, the bracelet seemed to offer the right balance of power harvesting and wearability.

"The design is cheap – less than fifty cents," note the authors, whose paper won the Best Paper Award from the Association for Computing Machinery's Conference on Embedded Networked Sensor Systems. "But Bracelet+ can reach up to micro-watts, enough to support many sensors such as on-body health monitoring sensors that require little power to work owing to their low sampling frequency and long sleep-mode duration."

"Ultimately," says Xiong, "we want to be able to harvest waste energy from all sorts of sources in order to power future technology."

A high-level overview of the pipeline. First, a text prompt is fed into a GLIDE model to produce a synthetic rendered view. Next, a point cloud diffusion stack conditions on this image to produce a 3D RGB point cloud.

Credit: *arXiv* (2022).

DOI: 10.48550/arxiv.2212.08751

A team of researchers at San Francisco-based OpenAI, has announced the development of a machine-learning system that can create 3D images from text much more quickly than other systems. The group has published a paper describing their new system, called Point-E, on the *arXiv* preprint server.

Over the past year, several groups have announced products or systems that can generate a 3D-modeled image based on a text prompt, e.g., "a blue chair on a red floor," or "a young boy wearing a green hat and riding a purple bicycle." Such systems generally have two parts. The first reads the text and tries to make sense of it. The second, trained on internet searches, renders the desired image.

Because of the complexity of the task, these systems can take a long time to return a model, ranging from hours to days. In this new effort, the researchers built a similar system that returns results within minutes, though they readily acknowledge that the results "fall short of the state-of-the-art in terms of sample quality."

To create images more quickly, the researchers adopted an approach somewhat different than others. Their system does not even create images in the traditional sense. Instead, it generates point clouds, which, when viewed together, resemble the desired image. The team took this approach because generating point clouds is far easier than generating actual images. To create the results, the system routes images it finds through another AI system they developed that converts what it receives to meshes, which produce the 3D point cloud model of the intended object.

The first part of the system was made using two modules–the first converts the text into an image idea and the second part finds images that are used to generate a generic image. In operation, the system runs very much the same as others of its kind–a user inputs a descriptive text prompt and the system returns an image model. They note that while the visual quality is not comparable to other systems, it might be more suitable to other applications, such as fabricating real-world objects via a 3D printer.

The researchers have made the system open access–users who wish to work with it can access the code on GitHub.

Glossary

1. 6G: The next generation of wireless telecommunications technology.

2. Visible Light Communication (VLC): A wireless communication method that uses flashes of light to transmit information.

3. Antenna: A device that can receive or transmit electromagnetic signals.

4. Infrastructure: The physical components necessary for a system to function.

5. Leakage: The unintentional release of energy or information.

6. Coiled copper wire: A type of antenna designed to collect leaked RF energy.

7. Amplifying: Increasing the strength or effectiveness of something.

8. Bracelet+: A coil of copper wire worn as a bracelet on the upper forearm, designed to harvest leaked RF energy.

9. GLIDE model: A machine learning model used to generate synthetic images from text prompts.

10. Point cloud diffusion stack: A machine learning algorithm that can generate 3D images from text prompts.

11. Preprint server: An online repository for scientific papers that have not yet been peer-reviewed or published in a journal.

12. Point cloud: A set of data points in a three-dimensional space that represents the shape of an object.

13. Machine learning: A type of artificial intelligence that enables computers to learn and improve from experience without being explicitly programmed.

14. Synthetic images: Images generated by a computer using algorithms rather than captured by a camera.

15. Text prompt: A short piece of text used to generate an image or other output through a computer system.

16. Meshes: A set of interconnected vertices, edges, and faces that define the shape of a three-dimensional object.

17. AI system: A computer system that can perform tasks that typically require human intelligence, such as recognizing patterns or making decisions.

18. Open access: Refers to resources or information that is freely available to the public without cost or restriction.

Task 1

Find words in the text that mean the following:

1. to get something good as a result of you actions
2. an important discovery
3. able to be seen or understood
4. to need something
5. a way of considering something
6. to look like

Task 2

Answer the following questions:

1. What is VLC and how does it transmit information?
2. What is the potential benefit of harvesting waste energy from VLC systems?
3. How did the researchers at UMass Amherst collect leaked RF energy from VLC systems?
4. What did the team discover about the efficiency of the antenna when it was in contact with different materials?
5. What is Bracelet+ and how does it work?
6. What award did the authors of the paper describing Bracelet+ win?
7. What is Point-E and what does it do?
8. What is the advantage of Point-E over other systems that generate 3D-modeled images based on text prompts?
9. Where was the paper describing Point-E published?

10. What is the goal of the researchers at UMass Amherst in harvesting waste energy from VLC systems?

11. What is the goal of systems that generate 3D-modeled images based on text prompts?

12. How long does it typically take for these systems to return a model?

13. What approach did the researchers adopt to create images more quickly?

14. How does the system route images to produce the 3D point cloud model?

15. Is the system open access?

Task 3

Say whether the following statemants are true or false:

1. Researchers are currently working on developing 6G telecommunications technology.

2. Visible Light Communication (VLC) uses radio signals to transmit information wirelessly.

3. The researchers at the University of Massachusetts Amherst have invented a way to use the human body as an antenna to harvest waste energy from VLC.

4. The infrastructure for VLC is not yet widely available.

5. The team designed an antenna out of coiled copper wire to collect leaked RF energy from VLC systems.

6. The efficiency of the antenna designed by the team varied depending on what it touched.

7. The team found that a human body is the best medium for amplifying the coil's ability to collect leaked RF energy.

8. The design for the "Bracelet+" is expensive and not easily adaptable for different wearables.

9. The authors' paper won the Best Paper Award from the Association for Computing Machinery's Conference on Embedded Networked Sensor Systems.

10. OpenAI has developed a machine-learning system called Point-E that can create 3D images from text more quickly than other systems.

11. Several groups have announced products or systems that can generate a 3D-modeled image based on a text prompt.

12. These systems generally have only one part, which reads the text and renders the desired image.

13. The researchers built a system that returns results within seconds, which surpasses the state-of-the-art in terms of sample quality.

14. The system generates actual images instead of point clouds, which are far easier to generate.

15. The researchers have made the system open access for users to access the code on GitHub.

A NOVEL, SPACE-TIME CODING ANTENNA PROMOTES 6G AND SECURE WIRELESS COMMUNICATIONS

Date: December 7, 2022
Source: City University of Hong Kong
Summary:

Scientists have developed a novel antenna that allows manipulation of the direction, frequency and amplitude of the radiated beam, and is expected to play an important role in the integration of sensing and communications (ISAC) for 6th-generation (6G) wireless communications.

A research team co-led by a scientist at City University of Hong Kong (CityU) has developed a novel antenna that allows manipulation of the direction, frequency and amplitude of the radiated beam, and is expected to play an important role in the integration of sensing and communications (ISAC) for 6th-generation (6G) wireless communications.

The structure and characteristics of traditional antennas cannot be changed once fabricated. However, the direction, frequency, and amplitude of the electromagnetic waves from this new-generation antenna, which is called a "sideband-free space-time-coding (STC) metasurface antenna," can be changed through space-time coding (i.e. software control), enabling great user flexibility.

The key to this innovative feature is that the response of the metasurface (artificial, thin-sheet material with sub-wavelength thickness and made of several subwavelength meta-atoms) can be changed by switching the meta-atoms on its surface between radiating and non-radiating states, like turning on and off switches, by controlling the electric current. This allows the STC metasurface antenna to realize complicated wave manipulation in the space and frequency domains through software control, and to create a desired radiation pattern and a highly directed beam.

Professor Chan Chi-hou, Acting Provost and Chair Professor of Electronic Engineering in the Department of Electrical Engineering at CityU, who led the research, highlighted that the antenna relies on the successful combination of two research advances, namely amplitude-modulated (AM) leaky-wave antennas and space-time coding techniques.

Dr Wu Gengbo, postdoctoral fellow in the State Key Laboratory of Terahertz and Millimeter Waves (SKLTMW) at CityU, first proposed the new concept of AM leaky-wave antennas in 2020 in his PhD studies at CityU. "The concept provides an analytical approach to synthesize antennas with the desired radiation patterns for different specific uses by simply changing the antennas' shape and structure," explained Dr Wu.

But as with other antennas, once the AM leaky-wave antenna is fabricated, its radiation characteristics are fixed. At about that time, Dr Dai Junyan, from a research group led by Academician Cui Tiejun and Professor Cheng Qiang, from Southeast University at Nanjing, China, who pioneered STC technologies, joined Professor Chan's group at CityU. "Dr Dai's expertise in space-time coding and digital metasurfaces to dynamically reconfigure antenna performance added a new, important dimension to the antenna research at the SKLTMW," said Professor Chan, who is also Director of the SKLTMW at CityU.

Moreover, the time modulation of electromagnetic waves on metasurfaces usually generates unwanted harmonic frequencies, called sidebands. These sidebands carry part of the radiated electromagnetic wave energy and interfere with the useful communication channels of the antenna, leading to "spectrum pollution." But Professor Chan and his team proposed a novel design, which makes use of a waveguide (a line for transmitting electromagnetic waves by successive reflection from the inner wall) and successfully suppressed the undesired harmonics, achieving a high-directivity beam and enabling secure communication.

"With the AM leaky-wave antenna and space-time coding technologies, we achieve the designated radiation characteristics by controlling the on-off sequences and duration of the 'switches' on the antenna through software," said Professor Chan.

"A high-directivity beam can be generated with the new antenna, allowing a wide range of radiation performance without having to redesign the antenna, except for using different STC inputs," added Dr Wu.

The energy from the radiated beam of the STC metasurface antenna can be focused to a focal point with fixed or varying focal lengths, which can be used for real-time imaging and treated as a type of radar to scan the environment and feedback data. "The invention plays an important role in the ISAC for 6G wireless communications," Professor Chan explained. "For example, the radiated beam can scan a person and create an image of the person, allowing mobile phone users to talk to each other with 3D hologram imaging. It also performs better against eavesdropping than the conventional transmitter architecture."

Glossary

1. Antenna: a device that converts electrical signals into electromagnetic waves and vice versa, used for communication or sensing purposes.

2. Radiated beam: the electromagnetic wave emitted by an antenna in a specific direction.

3. Direction: the orientation of the radiated beam.

4. Frequency: the number of cycles of the electromagnetic wave per second, measured in Hertz (Hz).

5. Amplitude: the maximum value of the electromagnetic wave, measured in volts.

6. Metasurface: an artificial, thin-sheet material with sub-wavelength thickness and made of several sub-wavelength meta-atoms, used to manipulate electromagnetic waves.

7. Space-time coding: a technique used to control the radiation characteristics of an antenna by changing the on-off sequences and duration of the switches on the antenna through software.

8. AM leaky-wave antenna: an antenna that relies on the successful combination of amplitude-modulated (AM) leaky-wave antennas and space-time coding techniques.

9. Spectrum pollution: interference caused by unwanted harmonic frequencies generated by time modulation of electromagnetic waves on metasurfaces.

10. Waveguide: a line for transmitting electromagnetic waves by successive reflection from the inner wall, used to suppress undesired harmonics and achieve a high-directivity beam.

11. Focal point: the point where the energy from the radiated beam of the STC metasurface antenna is focused, used for real-time imaging and radar scanning.

Task 1

Find words and expressions meaning the following

1. an answer or reaction

2. an area, internet

3. to need a particular thing in order to continue

4. to get involved.

5. to listen to someone's private conversation without them knowing

Task2

Say whether the following statements true or false or not given:

1. The research team at City University of Hong Kong has developed an antenna that allows manipulation of the direction, frequency and amplitude of the radiated beam.

2. Traditional antennas can have their structure and characteristics changed after they have been fabricated.

3. The response of the metasurface in the STC metasurface antenna can be changed by controlling the electric current of the meta-atoms.

4. The STC metasurface antenna can realize complicated wave manipulation in the space and frequency domains through hardware control.

5. Dr Wu Gengbo first proposed the concept of AM leaky-wave antennas in 2020 during his postdoctoral fellowship.

6. The radiation characteristics of an AM leaky-wave antenna are fixed once it is fabricated.

7. Dr Dai Junyan from Southeast University at Nanjing, China, joined Professor Chan's group at CityU to pioneer STC technologies.

8. Sidebands generated by time modulation of electromagnetic waves on metasurfaces can interfere with the useful communication channels of the antenna.

9. The novel design proposed by Professor Chan and his team uses a waveguide to generate sidebands and achieve a high-directivity beam.

10. The energy from the radiated beam of the STC metasurface antenna cannot be focused to a focal point for real-time imaging or radar scanning.

Task 3

Answer the following questions:

1. What is the name of the new-generation antenna developed by the research team at CityU?

2. How can the direction, frequency, and amplitude of the electromagnetic waves from the STC metasurface antenna be changed?

3. What is the key to the innovative feature of the STC metasurface antenna?

4. What are AM leaky-wave antennas?

5. How does the STC metasurface antenna achieve designated radiation characteristics?

6. What is a waveguide?

7. What is spectrum pollution?

8. What is the advantage of the new antenna in terms of user flexibility?

9. What can the energy from the radiated beam of the STC metasurface antenna be used for?

10. What is the expected role of the new antenna in 6G wireless communications?

GRAPH COMPUTING – A NEW WAY TO UNDERSTAND THE WORLD
by Intelligent Computing

Illustration of the ReRAM architecture. Credit: *Intelligent Computing* (2022). DOI: 10.34133/2022/9806758

In the era of Big Data, the relationship between data are complex and large in scale. The relationship between various data objects is described as Vertex and Edge, where the Vertex represents the data object and the Edge represents the relationship between the data objects. This data structure that represents the relationship of data objects is called Graph. Useful information can often be mined and applied to various scenarios by analyzing the graph.

Graph computing is a technology that studies the Graph in the human world, describing, portraying, analyzing and computing them. Currently, this emerging technology has been widely used, and a large number of graph algorithms have emerged. Through the analysis of large-scale graph data, important information hidden in the graph data can be obtained. Examples include the realtime epidemiology analysis, the targeted advertising, and the rapid identification of anomalous behaviors in the financial field.

In order to facilitate the understanding of the field of graph analytics, Prof. Dr. Hai Jin's team from Huazhong University of Science and Technology summarize the research status of graph computing key technologies of the software systems implementation and domain-specific architectures, and then summarize, compare, and analyze the latest research progress from three aspects: basic theory, system software, and system architecture. The review article was published on October 29 in *Intelligent Computing*.

Graph analytics mainly includes graph processing, graph mining and graph learning, and is very widely used in practical applications. As the amount of graph data continues to expand, graph computing faces a series of challenges.

The widespread adoption of graph analytics applications and the gradual increase in the size and complexity of graph data bring significant challenges for software technologies and hardware architectures for graph computing. In addition, there is a gap between the characteristics of graph analytics and the hardware features of general-purpose hardware.

To address the problems of large-scale graph computing, researchers have conducted extensive fundamental research and key technology studies in recent years.

At the software level, improvements have been made to existing general-purpose hardware platforms through software techniques, such as single-machine platform and distributed platform; at the hardware level, hardware acceleration has been performed mainly through architectural innovations to fill the significant gap between general-purpose hardware and the unique characteristics of graph analytics.

In recent years, novel computing and memory devices have emerged, and software optimization technologies and hardware acceleration technologies have achieved significant performance improvements.

Currently, graph analytics is still a popular research topic and faces a number of problems that need to be addressed. For example, domain-specific high-level synthesis, uncertain patterns for graph mining, large graphs and patterns for graph mining, dynamic graph learning, memory footprint limitations, heterogeneous graph learning, and so on.

Glossary

1. Big Data: Large and complex data sets that require advanced computing technologies to process and analyze.

2. Vertex: A data object in a graph structure that represents a point or node.

3. Edge: A relationship between two data objects in a graph structure.

4. Graph: A data structure that represents the relationship between data objects through vertices and edges.

5. Graph computing: Technology that studies, analyzes, and computes graph structures in the human world.

6. Graph processing: Analyzing and manipulating graph structures to extract useful information.

7. Graph mining: Extracting patterns and relationships from large-scale graph data.

8. Graph learning: Using machine learning techniques to analyze and predict patterns in graph data.

9. Software systems implementation: The process of designing and developing software systems to implement graph computing technologies.

10. Domain-specific architectures: Hardware architectures designed specifically for graph computing applications.

11. Basic theory: The fundamental principles and concepts underlying graph computing technologies.

12. System software: The software components used to implement graph computing technologies.

13. System architecture: The hardware components and system design used to implement graph computing technologies.

14. Hardware acceleration: Using specialized hardware components to improve the performance of graph computing applications.

15. General-purpose hardware: Standard hardware components that are not specifically designed for graph computing applications.

16. Memory footprint limitations: The amount of memory required to store large-scale graph data can be a limiting factor for graph computing applications.

17. Heterogeneous graph learning: Analyzing and predicting patterns in graphs with multiple types of vertices and edges.

18. Uncertain patterns: Patterns in graph data that are not well-defined or uncertain.

19. Dynamic graph learning: Analyzing and predicting patterns in graphs that change over time.

20. Performance improvements: Enhancements to software and hardware technologies that improve the speed and efficiency of graph computing applications.

Task 1

Answer the following questions:

1. What is the relationship between data objects called?

2. What is the data structure that represents the relationship of data objects called?

3. What can be obtained by analyzing large-scale graph data?

4. What are some examples of practical applications of graph analytics?

5. What challenges does graph computing face as the amount of graph data continues to expand?

6. What improvements have been made at the software level to address the problems of large-scale graph computing?

7. What is hardware acceleration mainly performed through to address the problems of large-scale graph computing?

8. What technologies have achieved significant performance improvements in recent years?

9. What are some problems that graph analytics currently faces?

10. What did Prof. Dr. Hai Jin's team from Huazhong University of Science and Technology do to facilitate the understanding of the field of graph analytics?

Task 2

Say wheather the following statenents are true or false:

1. The relationship between data objects in graph computing is represented by Vertex and Edge, where Vertex represents the data object and Edge represents the relationship between the data objects.

2. Graph analytics can reveal important information hidden in the graph data, such as patterns and trends.

3. Graph computing only includes graph processing and graph mining.

4. rof. Dr. Hai Jin's team from Huazhong University of Science and Technology summarized the research status of graph computing key technologies of the hardware systems implementation.

5. Graph computing faces challenges such as hardware limitations, software optimization, and the unique characteristics of graph analytics.

6. Ardware acceleration has been performed mainly through software techniques to address the problems of large-scale graph computing.

7. Graph analytics currently faces several challenges, including domain-specific high-level synthesis, uncertain patterns for graph mining, large graphs and patterns for graph mining, dynamic graph learning, memory footprint limitations, heterogeneous graph learning, and more.

8. Graph computing has no practical applications in healthcare, marketing, or finance.

9. Novel computing and memory devices have emerged in recent years, and software optimization technologies and hardware acceleration technologies have achieved significant performance improvements.

NEW PROGRAMMING TOOL TURNS SKETCHES, HANDWRITING INTO CODE

Date: November 28, 2022
Source: Cornell University
Summary:

Researchers have created an interface that allows users to handwrite and sketch within computer code – a challenge to conventional coding, which typically relies on typing.

Cornell University researchers have created an interface that allows users to handwrite and sketch within computer code – a challenge to conventional coding, which typically relies on typing.

The pen-based interface, called Notate, lets users of computational, digital notebooks open drawing canvases and handwrite diagrams within lines of traditional, digitized computer code.

Powered by a deep learning model, the interface bridges handwritten and textual programming contexts: notation in the handwritten diagram can reference textual code and vice versa. For instance, Notate recognizes handwritten programming symbols, like "n," and then links them up to their typewritten equivalents.

"A system like this would be great for data science, specifically with sketching plots and charts that then inter-operate with textual code," said Ian Arawjo, lead author of the paper and doctoral student in the field of information science. "Our work shows that the current infrastructure of programming is actually holding us back. People are ready for this type of feature, but developers of interfaces for typing code need to take note of this and support images and graphical interfaces inside code."

Arawjo also said the work demonstrates a new path forward by introducing artificial intelligence-powered, pen-based coding at a time when drawing tablets are becoming more widely used.

"Tools like Notate are important because they open us up to new ways to think about what programming is, and how different tools and representational practices can change that perspective," said Tapan Parikh, associate professor of information science and paper co-author.

Glossary

1. Interface: A system that allows communication between different devices or programs.

2. Conventional coding: The traditional way of writing computer code using a keyboard.

3. Deep learning model: An artificial intelligence model that can learn and improve based on data input.

4. Computational notebooks: Digital notebooks used for programming and data analysis.

5. Handwritten diagrams: Diagrams drawn by hand using a pen or stylus.

6. Textual programming: Writing code using text-based programming languages.

7. Notation: A system of symbols used to represent programming concepts and functions.

8. Inter-operate: To work together and share information between different systems or programs.

9. Infrastructure: The underlying structure or framework that supports a system or technology.

10. Graphical interfaces: User interfaces that use graphics and images to interact with the user.

11. Artificial intelligence-powered: Technology that uses artificial intelligence algorithms to power its functions.

12. Representational practices: The methods and tools used to represent data and information in a visual or symbolic form.

Task 1

Find words that mean the following:

1. in some area
2. traditional
3. depends on
4. connects something
5. for example
6. the same thing
7. the way in front of you
8. smh not real

Task 2

Say whether the statements are true or false, or not mentioned

1. The new interface is pen-based

2. It is called Notate

3. That invention is good for painters

4. You can use drawing canvases and handwrite diagrams within lines in the program

5. No way it can help data science

6. The current infrastructure of programming is holiday as back, as lead author of the paper thinks.

7. Drawing tablets are not very popular

Task 3

Answer the following questions:

1. What does traditional programming usually rely on?

2. What things does this interface connects?

3. How does Notate work?

4. What kind of data science is this system good for?

5. What do the developers of interfaces need to do?

6. Who is Ian Arawjo?

7. What does their work demonstrate?

8. Why are tools like Notate important?

9. Who is Tapan Parikh?

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