NANOTECHNOLOGY WORLD MAGAZINE

Nanoelectronics

Nanotech Solutions for Electronic Devices and Data Storage

BIOINSPIRED ELECTRONICS

Interview

A transistor inspired by human synapses

FLEXIBLES

"Inkable" nanomaterial promises big benefits for bendable electronics

ENGINEERED MATERIALS

Engineering graphene-based quantum circuits with atomic precision

ELECTRONIC DEVICES

First transformable nano-scale electronic devices

MAY 2023

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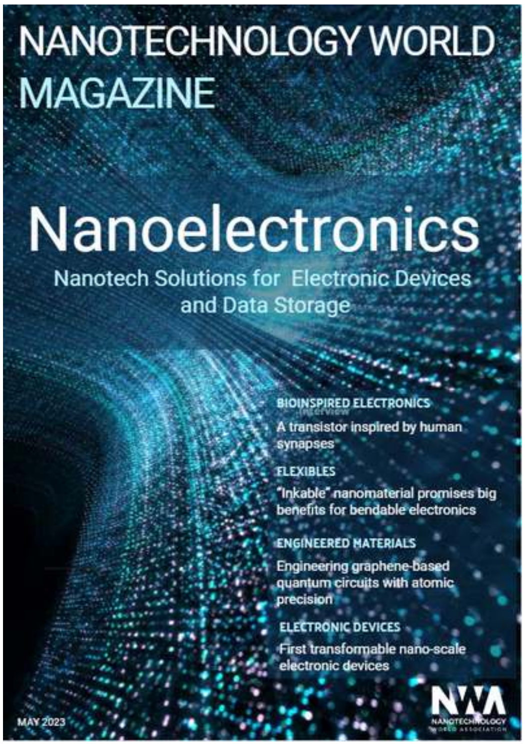

Nanotechnology World Magazine
May 2023

Nanotechnology has revolutionized electronics, enabling faster, portable systems that handle large data volumes and enhance display screens in electronic devices.

Next issue: August 2023

Nanotech Solutions for Quantum Technologies

FEATURES

Electronics get smarter with nanotechnology

New materials have consistently led to technological breakthroughs across various fields – and this includes electronics. As traditional silicon-based technology now reaches its performance limits, researchers are turning to a wide range of engineered nanomaterials to build the next generation of smarter, faster, lighter, more energy-efficient and overall superior devices.

Graphene, with its exceptional mechanical strength, electrical conductivity, and thermal properties, has long been regarded as a promising material. Researchers have made remarkable progress in constructing high-speed transistors using carbon nanotubes and graphene, developing molecular-sized transistors, and creating self-aligning nanostructures for nanoscale integrated circuit manufacturing. Iron and nickel nanowires are being investigated for their potential in creating dense memory devices through "racetrack memory." Copper nanoparticles enable lead-free solder, which can benefit space missions as well as other high-stress environments. Integrating silicon nanophotonics components into CMOS integrated circuits could enable faster data transmission than current electrical signals allow. Atomically-thin indium-tin oxide sheets show promise for manufacturing cost-effective, flexible, and energy-efficient touch screens, making electronic devices more eco-friendly.

These are just a few examples which underscore the crucial role nanotechnology will play in shaping the future of electronics.

Despite the tremendous opportunities, challenges remain. High production costs hinder widespread adoption, and concerns about the environmental impact of certain nanoelectronic materials need to be addressed.

Collaboration among scientists, engineers, policymakers, and industry leaders is paramount as we venture further into this exciting realm. Together, we can navigate complexities, ensure responsible innovation, and leverage nanotechnology's transformative power to create a smarter, faster, and superior tomorrow for electronics.

Marine Le Bouar
Founder and CEO, Nanotechnology World Association
Editor in Chief, Nanotechnology World Magazine

UPCOMING EVENTS

Sensors Converge
June 20-22, 2023
Santa Clara CA, USA

SEMICON WEST
June 25-29, 2023
Munich, Germany

LASER World of PHOTONICS 2023
June 27-30, 2023
Munich, Germany

ITF Semicon USA
July 10, 2023
Santa Clara CA, USA

CIOE 2023
September 6 - 8, 2023
Shenzhen, China

PCB West
September 19 - 22, 2023
Santa Clara CA, USA

EPIC Technology Meeting on Microelectronics & Photonics
November 13-14, 2023
Munich, Germany

Elektra 2023
November 29. 2023
London, UK

IEEE Global Communications Conference
December 4 - 8, 2023
Kuala Lumpur, Malaysia

electronica 2024
November 12 - 15, 2024
Munich, Germany

A transistor inspired by human synapses

CEA-Leti designed the transistor with mass-production in mind: it is manufactured on 200 mm wafers with CMOS compatible processes.

Sami Oukassi, Senior Scientist
Direction de la recherche technologique DRT
CEA-Leti

The human brain is by far the most efficient computing system, which is not very surprising as it is the result of millions of years of evolution. The brain combines various types of cells, but the primary functional unit is a neuron cell. These neurons are responsible for generating and analyzing signals that control our emotions, memories, movements, thinking, and feelings; these are the traits that make us humans. A human brain contains approximately 10^{11} neurons [1]. Each of them is made up of a cell body called soma, an axon, and multiple dendrites. Axon carries information from soma to a junction, where it is collected by dendrites of other neurons. The intersection is called a synapse, and the strength of the synapse (synaptic weight) decides the connection strength between two neurons, which can be altered by neural activities. This process is known as synaptic plasticity and is believed to be the backbone of human learning ability.

The chemical synapse between two neurons is illustrated in Figure 1. At these synapses, information transfer from one neuron to another occurs through the release of neurotransmitters by one neuron (pre-synaptic neuron) and the detection of the neurotransmitters by an adjacent neuron (post-synaptic neuron). The postsynaptic neuron behaves like a tiny computer, integrating all signals, which later determines whether it will “fire” or not. When a neuron fires, the resulting action potential travels towards the synaptic cleft through its axon. The arrival of the action potential at the axon terminal results in the merging of neurotransmitter vesicles with the presynaptic membrane, and a subsequent release of the neurotransmitters into the synaptic cleft. The neurotransmitter diffuses through the synaptic cleft, binds to and activates a receptor in the postsynaptic membrane, modifying the plasticity of the connection, i.e., the synaptic weight.

In the learning phase, these synaptic weights are updated in an analog and parallel fashion based on multiple learning rules [2].

Although the behavior and connections between neurons can be partially simulated on a Von Neumann-architecture computer, such a system will consume excessive power, for example "MilkyWay-2" supercomputer [3] consumes a normal power of 20 MW compared to 20 W ultralow consumption of the human brain on real time processing tasks [4]. Furthermore, such a computing system is not capable of exploiting the architecture of the brain due to the fundamental differences between these two systems. As a result, a race is on to develop new types of devices and hardware architectures that can better resemble bio intelligent systems at the physical level, and thus more efficiently emulate the brain at the functional level.

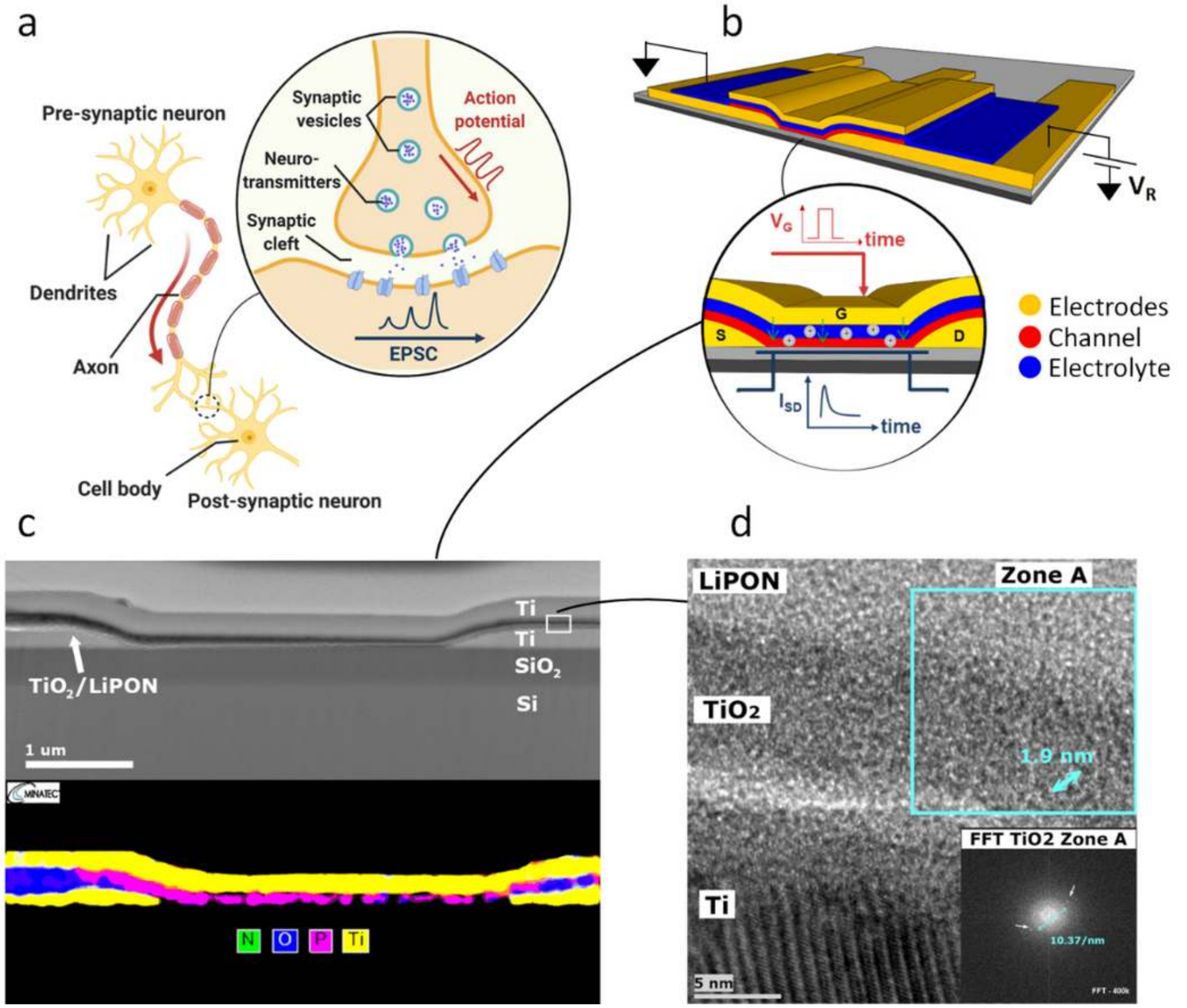

***Figure 1:** The analogy between biological and artificial synapses. a Illustration of chemical synapses in a mammalian brain. b Schematic view of our micro-fabricated SynT. c SEM and EDS characterizations of SynT's gate stack. d HRTEM image with the focus on the neighborhood of TiO2 channel (inset: FFT on the selected Zone A)*

As the brain consumes extremely low energy, the first crucial step in realizing these hardware systems is to achieve a suitable device that can function as a synapse with low power consumption and desired plasticity. Accordingly, researchers have explored a variety of materials, device architectures and systems with programmable conductance, also known as synaptic devices.

If a material is physically reconfigurable at the atomic scale, its properties can be modulated in a nonvolatile yet reversible manner, thus can facilitate a paradigm shift in building highly efficient computing systems. Within this framework, by controlling the internal ion distribution in a solid-state film, a material's chemical composition and physical properties can be reversibly reconfigured using an applied electric field. In an electrochemical synaptic transistor, the ions inside the electrolyte could be driven toward and even into the channel material, leading to its conductance change. Such ionic dynamics much resemble the pre-synapse process emits synaptic transmitters, which then move across the synaptic cleft, pass the ion channels on the post-synapse, and finally enhance the post-synapse signal. During intercalation, The mobile ions in the electrolyte would migrate into the target material under the influence of the gate voltage following electrochemical redox reactions. As a result, the electrical property of the channel layer changes, see Figure 2.

The intercalation effect has been widely studied in electrode materials used for battery cells, with $LiCoO_2$ and graphene nanosheets being the few types that have been thoroughly studied. Hence, for some layered structure materials, such as WSe_2, MoS_2, graphene, and some sub-stoichiometric salts, ions can get into the crystal structure and get stored inside the channel materials. Recent research studies have showed that intercalations inside neuromorphic devices are of two main types, namely electronic redistribution [5], [6] and phase transition of channel materials [7] induced by intercalation of external mobile ions. The intercalated ions could remain inside the channel materials even after the controlling voltage is removed, leading to a constant memory effect. By repeatedly applying voltage pulses to the gate, relatively the same amount of ions would be intercalated into the channel material, leading to a linear increase in channel conductance. With the amount of inserted ions being controlled to the minimum, one can program analog conductance states with a large number of conductance states and small energy consumption of femto-Joule or less per WRITE action, which is comparable to the biological synapses' operations. These features of ion intercalation synaptic transistors (SynTs) indicate a great fit for bio-inspired computing applications such as artificial neural network (ANN), in which these transistors are the constituting elements. Furthermore, desirable synaptic

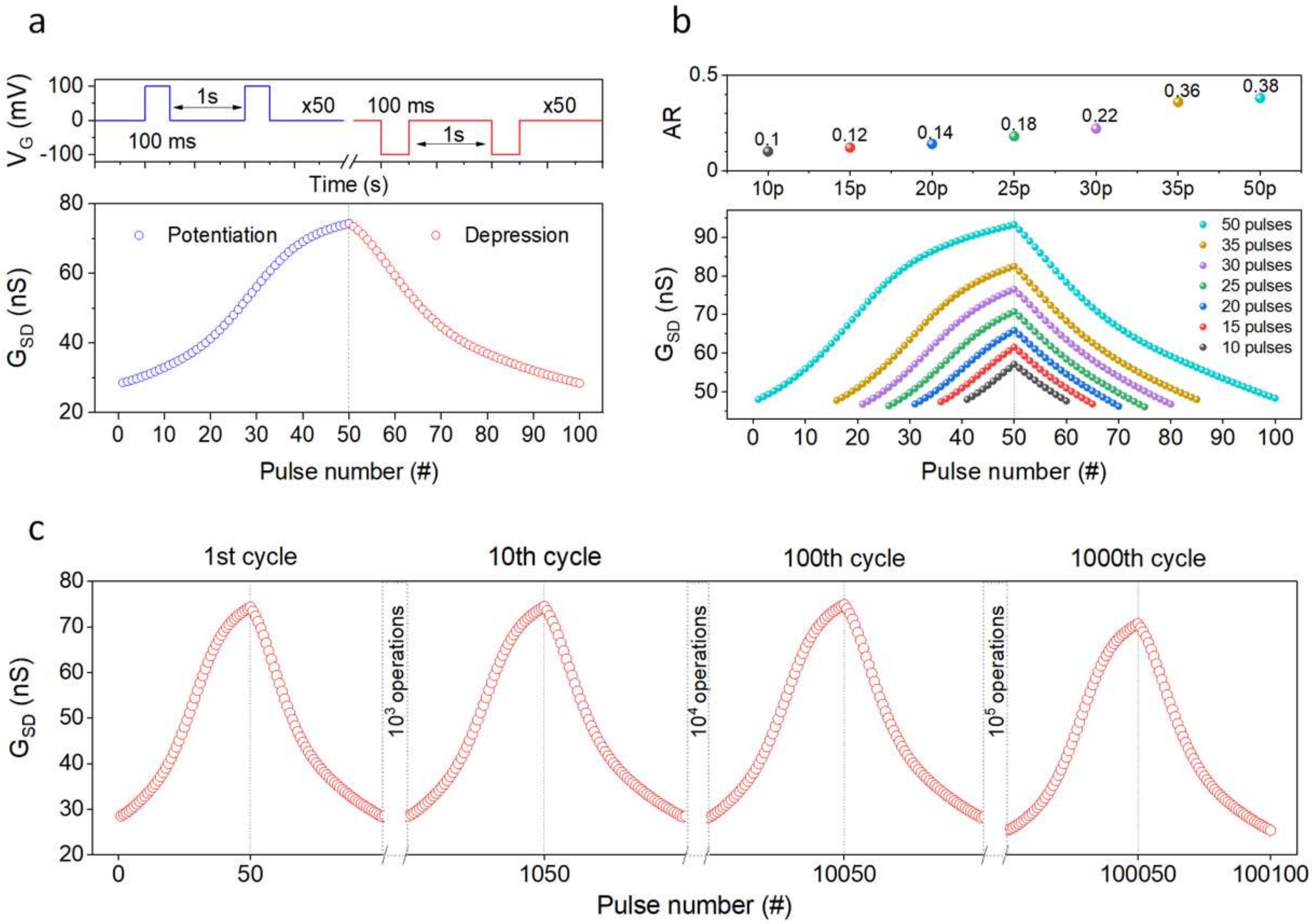

Figure 2: *Mimicking synaptic plasticity on SynTs. a Charge transfer curve (channel conductance GSD as a function of gate voltage VG) with a gate sweep of 50 mV/s in the potential range [-3 V, 3 V] (inset: Focused working window of [-0.5 V, 1.5 V]). b Conductance GSD change under incremental voltage amplitude pulses from 100 mV to 300 mV with a duration td of 0.1 s. c Retention (during 50s) of GSD after each potentiation pulse (200 mV, 0.5 s), and d Retention of GSD after each depression pulse (-200 mV, 0.5 s).*

functions have been demonstrated with ion intercalation types of electrochemical synaptic transistors, such as short-term plasticity (LTP), long-term plasticity (LTP), spiking-time dependent plasticity (STDP), and spiking-rate dependent plasticity (SRDP) [8], [9]. The listed functions are the requirements for the next generation of the neural networks inspired by the biological nervous system, spiking neural network (SNN). They employ spiking neurons as computational units that process information with the timing of spikes. Therefore, SNNs provide the potential for spatiotemporal information processing with high time and energy efficiency.

Furthermore, artificial synapses based SynTs have attracted tremendous attention toward massive parallel computing operations. However, most SynTs still suffer from downscaling limitations and high energy consumption. To overcome such drawbacks, a complementary metal–

oxide–semiconductor (CMOS) back-end-of-line compatible solid-state SynT is presented [10], which includes an ultrathin (10 nm thick) quasi-amorphous LixTiO2 channel. A nonvolatile conductance modulation (<75 nS) is achieved through reversible lithium intercalation into the channel, and synaptic functions, such as long-term potentiation/depression involve ultralow switching energy of 2 fJ μm−2. Moreover, this SynT shows excellent endurance (>10^5 weight updates) and recognition accuracy (>95% on the MNIST data test using crossbar simulations). A comprehensive electrochemical study allows deeper insight into the specific pseudo-capacitive mechanism at the origin of conductance modulation. The transistor presented by CEA-Leti is analog. In other words, instead of having two possible states, open & closed, it has around 50 possible states. This enables to reproduce how synapses function.

CEA-Leti designed the transistor with mass-production in mind: it is manufactured on 200 mm wafers with CMOS compatible processes. The project is only at the first stages of the evaluation process, further developments are needed to continue bringing the transistor to maturity and ensure an in-depth evaluation of its durability and reliability.

Once the transistor is fully evaluated and confirmed, its low energy consumption would enable it to be integrated into neuromorphic circuits. These circuits are targeting deep neural networks, are mostly dedicated to image/voice recognition so far. During learning phases, these circuits are used intensively and any savings in terms of energy consumption are particularly valuable at this moment.

CEA-Leti has filed three patent requests to protect this promising technology.

References page 68

About CEA-Leti

CEA-Leti, a technology research institute at CEA Tech, pioneers micro and nanotechnologies, tailoring differentiating applicative solutions that ensure competitiveness in a wide range of markets. The institute tackles critical challenges such as healthcare, energy, transport and ICTs.

Its multidisciplinary teams deliver solid expertise for applications ranging from sensors to data processing and computing solutions, leveraging world-class pre-industrialization facilities.

CEA-Leti builds long-term relationships with its industrial partners - global companies, SMEs and startups – and actively supports the launch of technology startups.

US

nLIGHT Lands $86M Defense Contract to Develop High-Energy Laser

nLIGHT has been awarded an $86 million contract to produce a high-energy laser (HEL) prototype for the next phase of development in support of the U.S. Department of Defense's (DOD) High-Energy Laser Scaling Initiative (HELSI).

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EUROPE

Intrinsic Semiconductor Technologies Secures £7m Investment to Solve the Memory Bottleneck for Data Hungry Applications

Innovative non-volatile memory technology from UCL spin-out will create a new generation of small devices with big brains that embed intelligence everywhere

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US

Infineon buys GaN Systems for US$830 million

Infineon to acquire GaN Systems, strengthening its GaN portfolio and further reinforcing its global leadership in Power Systems

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SiPearl: Initial closing of Series A with €90m financing to launch Rhea, the energy-efficient HPC1-dedicated microprocessor

Key industry partners (Arm, Eviden) as well as European and French public investors (EIB, EIC, France 2030) participate to this initial funding round.

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US

Paragraf Acquires CRISPR-Chip Developer Cardea Bio, Accelerating CRISPR QC's Business Opportunity

Paragraf, Ltd. has acquired Cardea Bio, the technology platform developer of the CRISPR-Chip - a graphene-based biosensor that powers CRISPR QC's CRISPR Analytics Platform.

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ASML and Eindhoven University of Technology strengthen longstanding collaboration

This includes a jointly defined research program, the construction of a new ASML research facility on the TU/e campus, including the creation of a state-of-the-art cleanroom.

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EUROPE

New Origin secures €6m PhotonDelta funding to create independent photonic chip foundry

New Origin of Enschede, the Netherlands, was spun out of the MESA+ NanoLab as a subsidiary of University of Twente Holding

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EUROPE

QuantWare closes €6 million seed round

Largest ever Seed Round for a Dutch quantum startup, to make superconducting quantum computers massively scalable.

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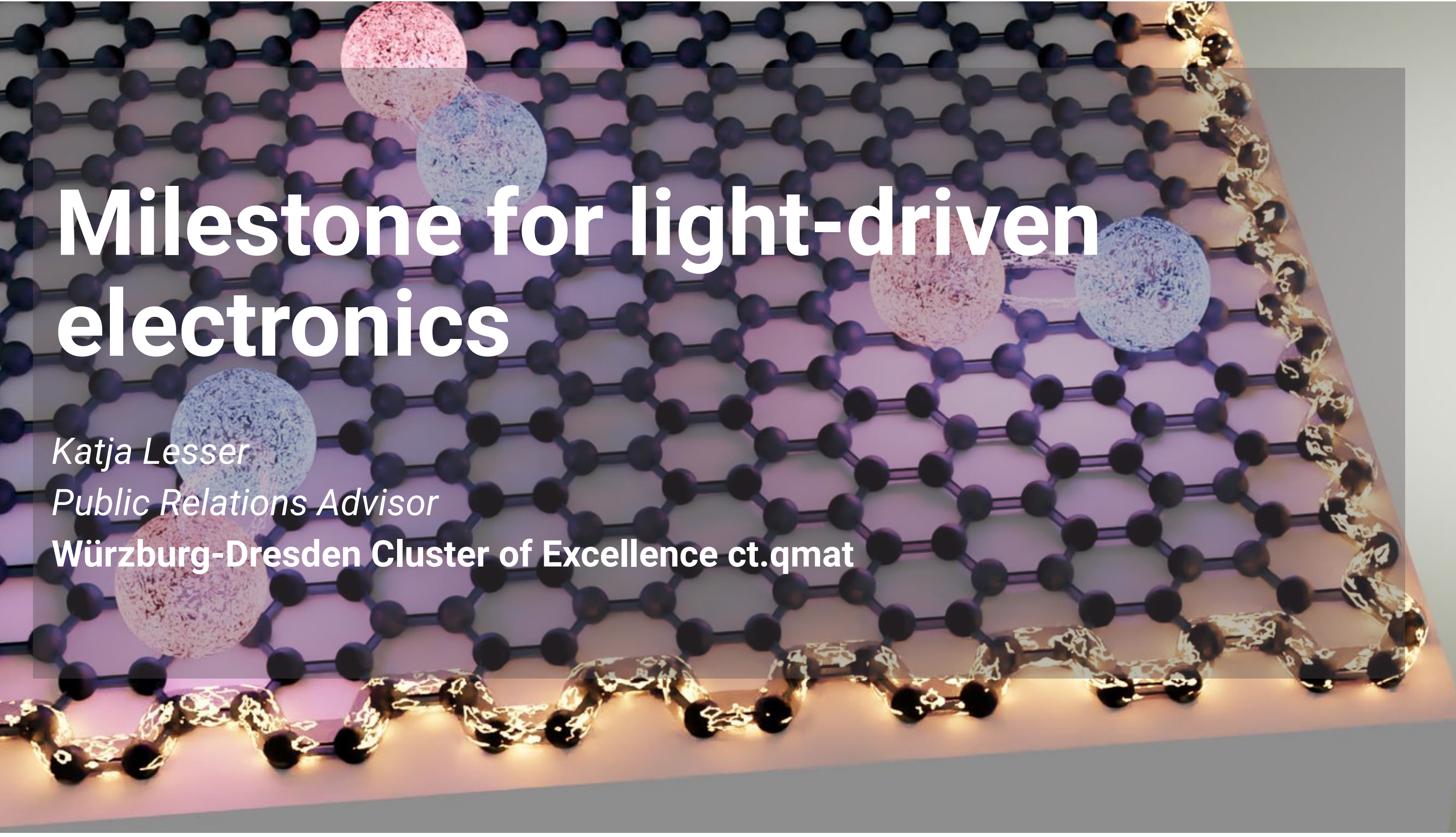

Milestone for light-driven electronics

Katja Lesser
Public Relations Advisor
Würzburg-Dresden Cluster of Excellence ct.qmat

An international team of scientists collaborating within the Würzburg-Dresden Cluster of Excellence ct.qmat has achieved a breakthrough in quantum research – the first detection of excitons (electrically neutral quasiparticles) in a topological insulator. This discovery paves the way for a new generation of light-driven computer chips and quantum technologies. It was enabled thanks to smart material design in Würzburg, the birthplace of topological insulators. The findings have been published in the journal Nature Communications.

New toolbox for solid state physics

In their search for novel materials for future quantum technologies, one area that scientists from the Cluster of Excellence ct.qmat – Complexity and Topology in Quantum Matter – at the two universities in Würzburg and Dresden are concentrating on is topological insulators, which enable the lossless conduction of electrical current and robust information storage. The first experimental realization of this materials class took place in Würzburg in 2007, prompting a worldwide research boom in solid-state physics that continues to this day.

Previous concepts for using topological insulators are based on the application of electrical voltages in order to control currents – an approach adopted from conventional computer chips. However, if the exotic material properties are based on electrically neutral particles (which are neither positively nor negatively charged), an electric voltage no longer works. Such quantum phenomena therefore require other tools if they are to be generated at all – for example, light.

Optics and electronics are linked by a quantum phenomenon

An international research team headed by Professor Ralph Claessen, quantum physicist from Würzburg and co-spokesperson of ct.qmat, has now made a crucial discovery. “For the first time, we’ve been able to generate and experimentally detect quasiparticles known as excitons in a topological insulator. We’ve thus created a new toolkit for solid-state physics that can be used to control electrons optically.” As Claessen emphasizes: “This principle could become the basis for a new type of electronic components.”

Excitons are electronic quasiparticles. Although they seem to behave like independent particles, they actually represent an excited electronic state that can only be generated in certain types of quantum matter. “We created excitons by applying a short light pulse to a thin film consisting of just one single layer of atoms,” explains Claessen. What’s unusual about this, he says, is that the excitons were activated in a topological insulator – something that wasn’t possible before. “This has opened up a completely new line of research for topological insulators,” adds Claessen.

For about ten years, excitons have been investigated in other two-dimensional semiconductors and regarded as information carriers for light-driven components. “For the first time, we’ve managed to optically excite excitons in a topological insulator. The interaction between light and excitons means we can expect new phenomena in such materials. This principle could be used, for example, to generate qubits,” says Claessen.

Qubits are computing units for quantum chips. They’re far superior to traditional bits and allow to solve tasks within minutes for which conventional supercomputers would literally take years. Using light instead of electrical voltage enables quantum chips with much faster processing speeds. The latest findings therefore pave the way for future quantum technologies and a new generation of light-driven devices in microelectronics.

Global expertise from Würzburg

The right starting material is crucial – in this case bismuthene. “It’s the heavy sibling of the miracle material graphene,” says Claessen, who first tailored the topological insulator in the lab five years ago. “We’re the global leaders in this field,” he adds. “Due to our sophisticated materials design, the atoms of the single layer of bismuthene are arranged in a honeycomb pattern, just like graphene. The difference is that bismuthene’s heavy atoms make it a topological insulator, meaning it can conduct electricity along the edge without loss – even at room temperature. This can’t be done by graphene.”

Huge potential

Now that the research team has generated excitons in a topological insulator for the first time, attention is being turned to the quasiparticles themselves. Scientists at ct.qmat are investigating whether bismuthene's topological properties are transferred to excitons. Proving this scientifically is the next milestone that the researchers have their sights on. It would even pave the way for the construction of topological qubits, which are considered particularly robust compared to their non-topological counterparts.

International cooperation

These findings result from close collaboration among scientists from Bologna, Wroclaw, New York, Oldenburg and Würzburg. The 2D material samples of bismuthene were produced at JMU Würzburg.

Publication

Observation of room temperature excitons in an atomically thin topological insulator
M. Syperek, R. Stühler, A. Consiglio, P. Holewa, P. Wyborski, Ł. Dusanowski, F. Reis, S. Höfling, R. Thomale, W. Hanke, R. Claessen, D. Di Sante, and C. Schneider
Nat. Commun. 13, 6313 (2022)

Contact

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Image
Three excitons (pairs consisting of an electron and an electron hole) on the topological insulator bismuthene. Due to the honeycomb atomic structure, electrons can only flow along the edges. (Credit: Pawel Holewa)

Watch the Video
Excitons in the topological insulator bismuthene

Universität Würzburg

Researchers report technique to fabricate nanosheets in one minute

A research group at Nagoya University in Japan, has developed a new technology to fabricate nanosheets, thin films of two-dimensional materials a couple of nanometers thick, in about one minute. The technology is based on simple drop and aspiration operations using an automatic pipette and does not require specialized knowledge or technology.

Read more

SRC publishes interim microelectronics and advanced packaging technologies roadmap, seeks public comments

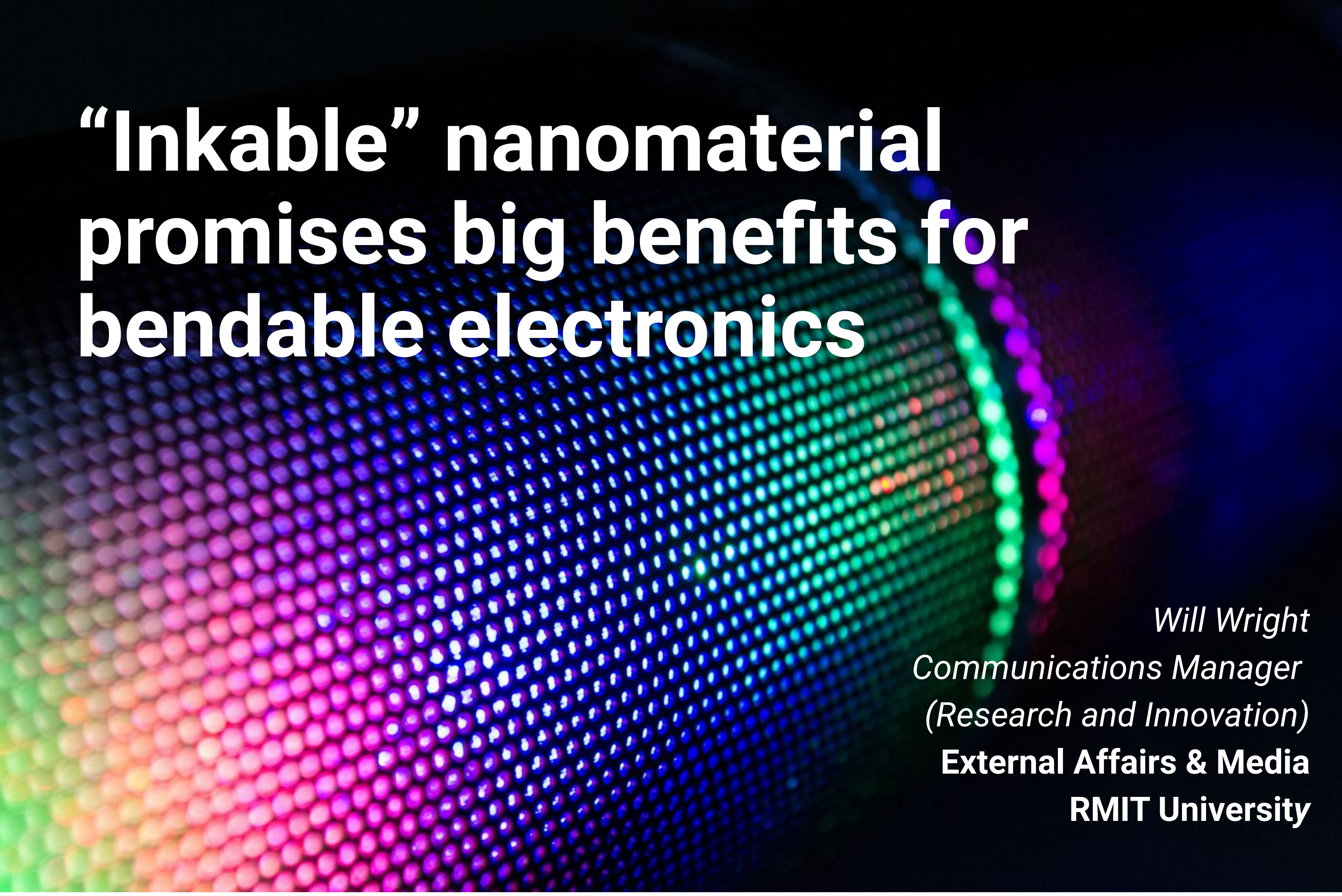
Semiconductor Research Corporation (SRC), a world-renowned semiconductor research and workforce development consortium, released an interim report for the Microelectronic and Advanced Packaging Technologies (MAPT) Roadmap – a far-reaching initiative for the semiconductor industry that, to date, has involved the participation of over 100 organizations of all sizes representing government, academia, and industry.

This multi-chapter roadmap is the result of a $300,000 competitively-selected award granted to SRC by the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) in April 2022. SRC was the only awardee chosen to focus on these emerging technologies, due to its strong history of thought leadership and continued innovation.

The report introduces a new comprehensive roadmap to guide the forthcoming microelectronic revolution, similar to how the International Technology Roadmap for Semiconductors (ITRS) served the industry in the past. The MAPT roadmap represents the inevitable shift of microelectronics from the historical two-dimensional (2D) device-centric paradigm to a future that exploits 3D and heterogeneous integration to seamlessly integrate multiple chiplets that enable complex System-in-Package platforms. The new paradigm uses system-scale design and architecture to integrate electronics, photonics, and micromechanical chiplets, taking into account cross-platform issues and relying critically on the rise of advanced packaging technologies.

Read the MAPT Roadmap Interim Report

“Inkable” nanomaterial promises big benefits for bendable electronics



Will Wright
Communications Manager (Research and Innovation)
External Affairs & Media
RMIT University

An international team of scientists is developing an inkable nanomaterial that they say could one day become a spray-on electronic component for ultra-thin, lightweight and bendable displays and devices.

The material, zinc oxide, could be incorporated into many components of future technologies including mobile phones and computers, thanks to its versatility and recent advances in nanotechnology, according to the team.

RMIT University’s Associate Professor Enrico Della Gaspera and Dr Joel van Embden led a team of global experts to review production strategies, capabilities and potential applications of zinc oxide nanocrystals in the journal Chemical Reviews, a high-impact international journal.

Professor Silvia Gross from the University of Padova in Italy and Associate Professor Kevin Kittilstved from the University of Massachusetts Amherst in the United States are co-authors.

“Progress in nanotechnology has enabled us to greatly improve and adapt the properties and performances of zinc oxide by making it super small, and with well-defined features,” said Della Gaspera, from the School of Science.

Zinc is cheap and abundant

Tiny and versatile particles of zinc oxide can now be prepared with exceptional control of their size, shape and chemical composition at the nanoscale," said van Embden, also from the School of Science.

"This all leads to precise control of the resulting properties for countless applications in optics, electronics, energy, sensing technologies and even microbial decontamination."

Sky's the limit with spray-on electronics

The zinc oxide nanocrystals can be formulated into ink and deposited as an ultra-thin coating. The process is like ink-jet printing or airbrush painting, but the coating is hundreds to thousands of times thinner than a conventional paint layer.

"These coatings can be made highly transparent to visible light, yet also highly electrically conductive – two fundamental characteristics needed for making touchscreen displays," Della Gaspera said.

The nanocrystals can also be deposited at low temperature, allowing coatings on flexible substrates, such as plastic, that are resilient to flexing and bending, the team says.

The team is ready to work with industry to explore potential applications using their techniques to make these nanomaterial coatings.

What is zinc oxide and how can it be used?

Zinc is an abundant element in the Earth's crust and more abundant than many other technologically relevant metals, including tin, nickel, lead, tungsten, copper and chromium.

"Zinc is cheap and widely used by various industries already, with global annual production in the millions of tonnes," van Embden said.

Zinc oxide is an extensively studied material, with initial scientific studies being conducted from the beginning of the 20th century.

"Zinc oxide gained a lot of interest in the 1970s and 1980s due to progress in the semiconductor industry. And with the advent of nanotechnology and advancement in both syntheses and analysis techniques, zinc oxide has rapidly risen as one of the most important materials of this century", Della Gaspera said.

Zinc oxide is also safe, biocompatible and found already in products such as sunscreens and cosmetics.

Potential applications, other than bendable electronics, that could use zinc oxide nanocrystals include:

- self-cleaning coatings
- antibacterial and antifungal agents
- sensors to detect ultraviolet radiation
- electronic components in solar cells and light emitting devices (LED)
- transistors, which are miniature components that control electrical signals and are the foundation of modern electronics
- sensors that could be used to detect harmful gases for residential, industrial and environmental applications.

Next steps

Scaling up the team’s approach from the lab to an industrial setting would require working with the right partners, Della Gaspera said.

“Scalability is a challenge for all types of nanomaterials, zinc oxide included,” he said.

“Being able to recreate the same conditions that we achieve in the laboratory, but with much larger reactions, requires both adapting the type of chemistry used and engineering innovations in the reaction setup.”

In addition to these scalability challenges, the team needs to address the shortfall in electrical conductivity that nanocrystal coatings have when compared to industrial benchmarks, which rely on more complex physical depositions.

The intrinsic structure of the nanocrystal coatings, which enables more flexibility, limits the ability of the coating to conduct electricity efficiently.

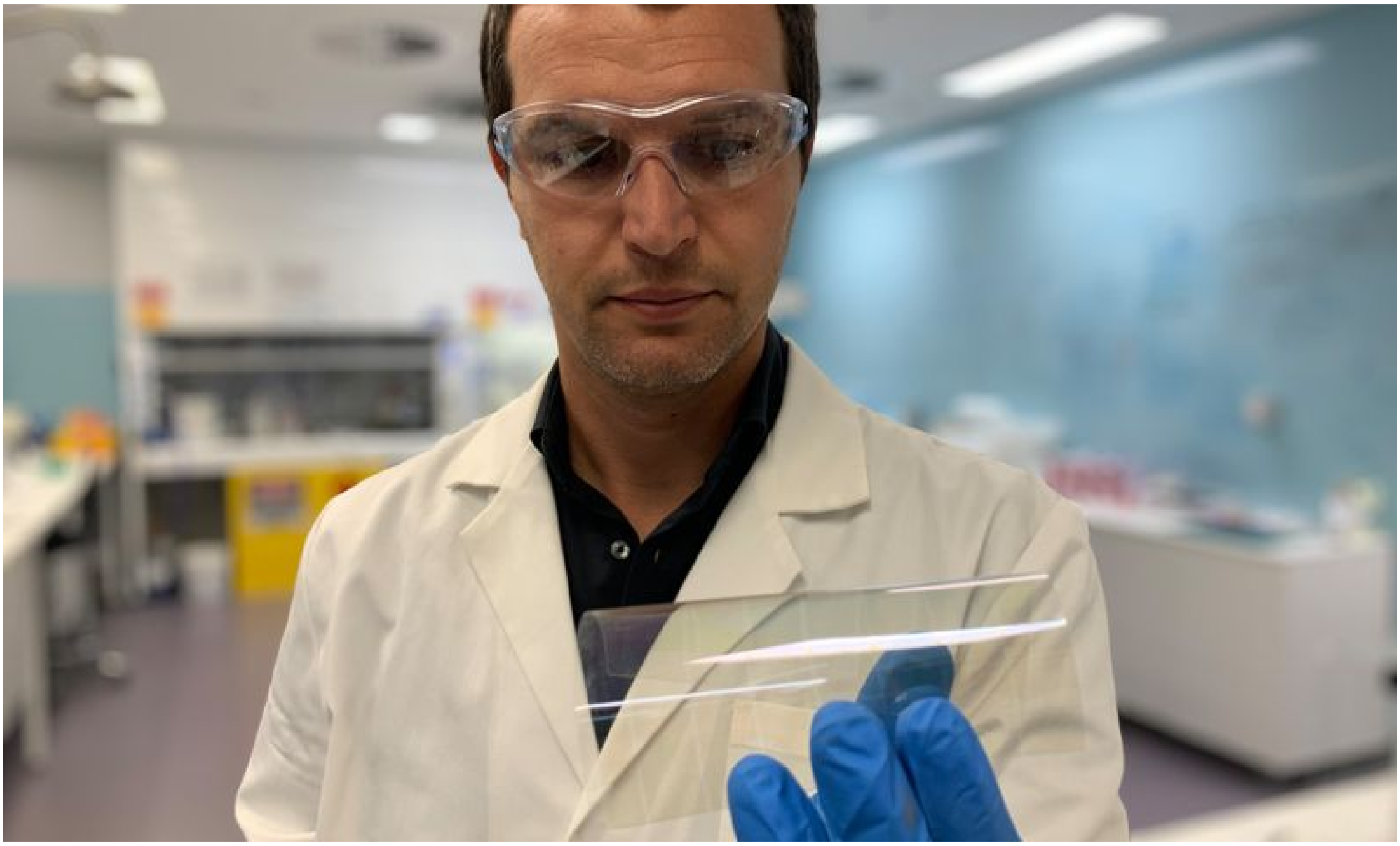
“We and other scientists around the world are working towards addressing these challenges and good progress is being made,” Della Gaspera said.

He sees great opportunities to collaborate with other organisations and industry partners to tackle these kinds of challenges.

“I am confident that, with the right partnership, these challenges can be solved,” Della Gaspera said.

“I am confident that, with the right partnership, these challenges can be solved"

Associate Professor Enrico Della Gaspera



An ultra-thin coating of zinc oxide nanocrystals can be sprayed onto flexible substrates, such as plastic, that are resilient to flexing and bending, the team says. Credit: RMIT University

'Colloidal Approaches to Zinc Oxide Nanocrystals' is published in Chemical Reviews (DOI: 10.1021/acs.chemrev.2c00456).

The RMIT team has contributed to other peer-reviewed research on zinc oxide nanocrystals in recent years, including:

• the synthesis of nanocrystals with unprecedented control of their size and chemical composition
• an innovative way to improve the conductivity of coatings at low temperatures
• the use of nanocrystals as antibacterial and antifungal agents.

RMIT University

Purdue and India establish milestone semiconductor alliance; sign partnership in the presence of Minister Ashwini Vaishnaw

Agreement provides foundation to advance workforce development, joint research and innovation, and global industry collaborations

Purdue University continues to rapidly expand its global boundaries in semiconductors, announcing a transformative agreement to become the flagship academic partner and collaborator with the government of India.

Tech brief

Silanna UV Presents High Power 235nm far UVC LEDs Using New SPSL Technology

This revolutionary UVC LED technology from Silanna UV offers huge advantages for applications as diverse as disinfection, water quality monitoring, gas sensing, liquid chromatography, and chemical and biological analysis.

Ultra-high-speed pulse control technology Nano Pulse Control™

Convert high voltages to low voltages using a single IC. Achieve simpler, more compact systems.

Weebit Nano ReRAM IP now available in SkyWater Technology's S130 process

Weebit Nano and SkyWater Technology announce availability of Weebit's resistive RAM (ReRAM) IP in SkyWater's 130nm CMOS (S130) process.

Sivananthan Labs completes Phase II STTR program

Contract to develop, fabricate and evaluate GaAs-based nano-structured source emitting entangled photons at 1550nm

Socionext Introduces New 7nm ADC and DAC for 5G Direct RF Transmitters and Receivers

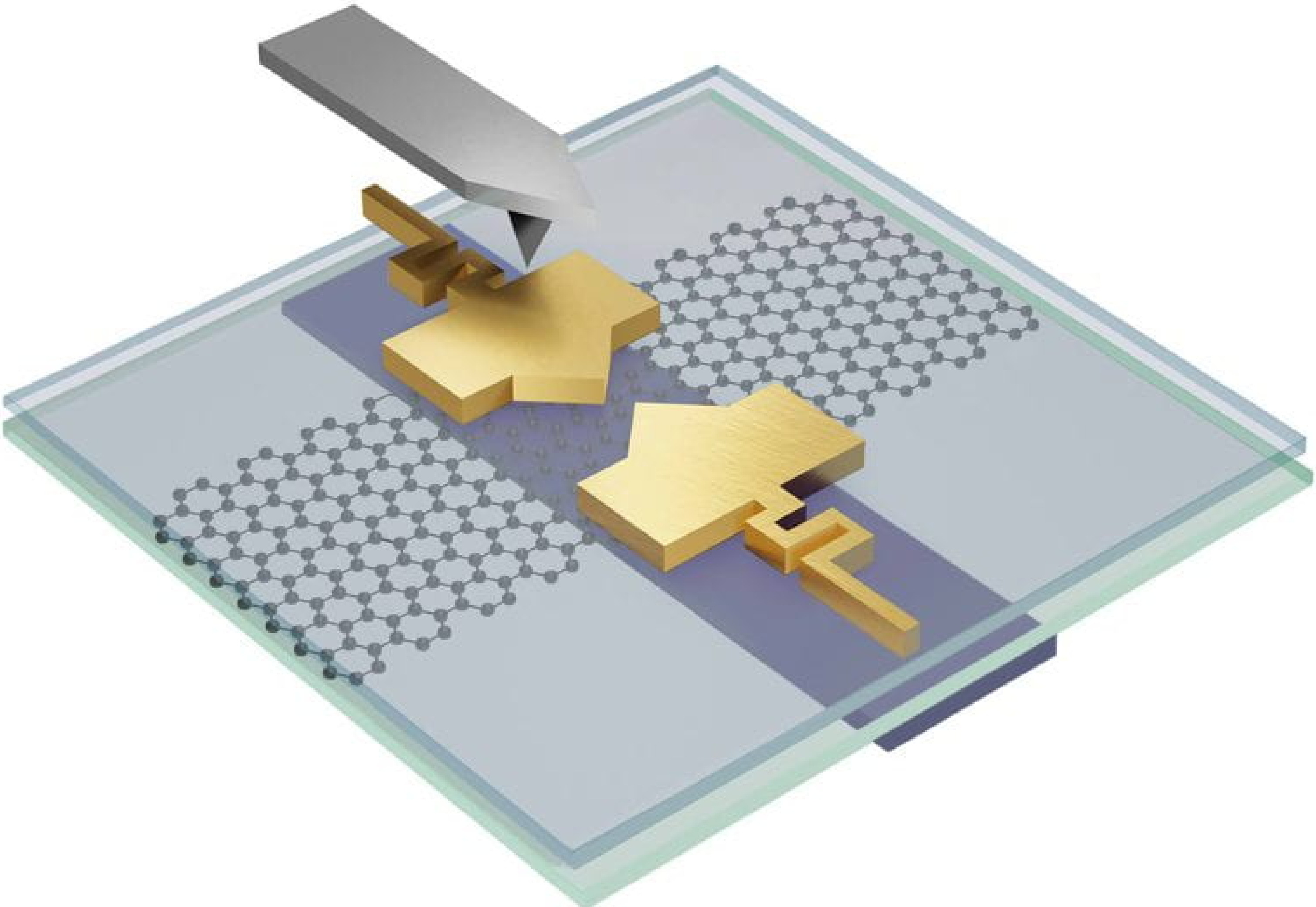
Socionext is a global leader in providing innovative custom System-on-Chip solutions for wide range of applications including data center and networking

UC Irvine physicists discover first transformable nano-scale electronic devices

The finding has potential to fundamentally change the nature of these items

Lucas Van Wyk Joel Sr. | Science Writer

School of Physical Sciences | University of California, Irvine



The golden parts of the device depicted in the above graphic are transformable, an ability that is "not realizable with the current materials used in industry," says Ian Sequeira, a Ph.D. student who worked to develop the technology in the laboratory of Javiar Sanchez-Yamahgishi, UCI assistant professor of physics & astronomy. Yuhui Yang / UCI

The nano-scale electronic parts in devices like smartphones are solid, static objects that once designed and built cannot transform into anything else. But University of California, Irvine physicists have reported the discovery of nano-scale devices that can transform into many different shapes and sizes even though they exist in solid states.

It's a finding that could fundamentally change the nature of electronic devices, as well as the way scientists research atomic-scale quantum materials. The study is published recently in Science Advances.

"What we discovered is that for a particular set of materials, you can make nano-scale electronic devices that aren't stuck together," said Javier Sanchez-Yamagishi, an assistant professor of physics & astronomy whose lab performed the new research. "The parts can move, and so that allows us to modify the size and shape of a device after it's been made."

The electronic devices are modifiable much like refrigerator door magnets – stuck on but can be reconfigured into any pattern you like.

"The significance of this research is that it demonstrates a new property that can be utilized in these materials that allows for fundamentally different types of devices architectures to be realized, including mechanically reconfigure parts of a circuit," said Ian Sequeira, a Ph.D student in Sanchez-Yamagishi's lab.

The electronic devices are modifiable much like refrigerator door magnets – stuck on but can be reconfigured into any pattern you like

If it sounds like science fiction, said Sanchez-Yamagishi, that's because until now scientists did not think such a thing was possible.

Indeed, Sanchez-Yamagishi and his team, which also includes UCI Ph.D. student Andrew Barabas, weren't even looking for what they ultimately discovered.

"It was definitely not what we were initially setting out to do," said Sanchez-Yamagishi. "We expected everything to be static, but what happened was we were in the middle of trying to measure it, and we accidentally bumped into the device, and we saw that it moved."

What they saw specifically was that tiny nano-scale gold wires could slide with very low friction on top of special crystals called "van der Waals materials."

Taking advantage of these slippery interfaces, they made electronic devices made of single-atom thick sheets of a substance called graphene attached to gold wires that can be transformed into a variety of different configurations on the fly.

Because it conducts electricity so well, gold is a common part of electronic components.

But exactly how the discovery could impact industries that use such devices is unclear.

Meanwhile, the team expects their work could usher in a new era of quantum science research.

"It could fundamentally change how people do research in this field," Sanchez-Yamagishi said.

"Researchers dream of having flexibility and control in their experiments, but there are a lot of restrictions when dealing with nanoscale materials," he added. "Our results show that what was once thought to be fixed and static can be made flexible and dynamic."

Other UCI co-authors include Yuhui Yang, a senior undergraduate at UCI, and postdoctoral scholar Aaron Barajas-Aguilar.

Mechanically reconfigurable van der Waals devices via low-friction gold sliding
Andrew Z. Barabas, Ian Sequeira, Yuhui Yang, Aaron H. Barajas-aguilar, Takashi Taniguchi, Kenji Watanabe And Javier D. Sanchez-yamagishi
SCIENCE ADVANCES | 7 Apr 2023
Vol 9, Issue 14
DOI: 10.1126/sciadv.adf9558

UC Irvine

Oxford Instruments Plasma Technology: Significant partnership with KAUST
Significant partnership with KAUST: hardware upgrade and support its cutting-edge ALD research with the addition of ALE capability

NS Nanotech Opens Canadian Research Centre
New Montreal-based R&D centre will leverage exclusive licenses to nanoLED technology patents held by McGill University for next-generation displays

EV Group and Notion Systems team up to combine nanoimprint lithography with inkjet coating for new high-volume-manufacturing applications
Per the joint agreement, the two companies will develop a customized inkjet module to be integrated in EVG's industry-benchmark HERCULES® NIL platform based on EVG's SmartNIL® technology.

PsiQuantum Expands Development Engagement and Plan for Production Ramp of Quantum Computing Technology at SkyWater's Minnesota Fab
SkyWater Technology announced PsiQuantum has expanded its development agreement with the company and its plan to produce silicon photonic chips that will become part of future quantum computing systems.

ASML and Eindhoven University of Technology strengthen longstanding collaboration
The two parties signed a memorandum of understanding to jointly develop a 10-year strategic research road map in the fields of plasma physics, artificial intelligence, mechatronics and semiconductor lithography.

Amazon Web Services Partners with Element Six on Diamonds for Quantum Networking
Element Six and AWS are working together to develop new technologies to make diamond a more flexible and accessible material – helping drive growth and progress for this technology.

US-Europe semiconductors collaboration milestone as Purdue, imec, Indiana announce partnership
Purdue University and the state of Indiana continue to make giant leaps in semiconductor research growth with a first-of-its-kind agreement with a cutting-edge European nano- and digital technology innovation hub.

SiLC Technologies Launches Industry's Most Compact, Powerful Coherent Machine Vision Solution

SiLC Technologies, Inc. (SiLC), recognized for advancing the state of machine vision, today announced the launch of the EyeonicTM Vision System, the industry's most compact and powerful coherent vision system. The new system features the highest resolution, highest precision and longest range while remaining the only FMCW LiDAR solution to offer polarization information.

The Eyeonic Vision System integrates the company's unique photonics technology into the industry's first available turnkey vision solution – a highly flexible subsystem that reduces time to market for manufacturers seeking to incorporate machine vision into their products. Targeted to robotics, autonomous vehicles, smart cameras and other advanced products, the Eyeonic Vision System sets a new benchmark, delivering the highest levels of vision perception to identify and avoid objects with very low latency, even at distances of greater than 1 kilometer.

"Our goal is to change the status quo for machine vision," said Mehdi Asghari, SiLC founder and CEO. "When bringing vision to machines the criticality of ranging precision, direct monitoring of motion through instantaneous velocity, spatial resolution for recognition of fine features and polarization for material detection cannot be understated. For machines to augment our lives they must have a vision solution that is powerful, compact, scalable, and unaffected by environmental conditions including interference from other systems.

Our groundbreaking technology will empower the next generation of machine vision applications with bionic vision that will exceed that of humans and yet be compact, cost effective and power efficient."

At the heart of the Eyeonic Vision System is the company's fully integrated silicon photonics chip. With roughly 10 milli-degrees of angular resolution coupled with mm-level precision, it provides more than 10x the definition and precision of legacy LiDAR offerings. This enables the Eyeonic Vision Sensor to measure the shape and distance of objects with high precision at great distances.

The new Vision System couples the Eyeonic Vision Sensor and a digital processing solution based on a powerful FPGA. The compact, flexible architecture of the new system enables synchronization of multiple vision sensors for unlimited points/second. The Eyeonic Vision System is highly versatile – supporting multiple scanner options and providing customers with the flexibility to tailor their designs to maximize performance for distance and field of vision for their application. It is accompanied by a broad range of accessories.

About SiLC Technologies

On a mission to enable machines to see like humans, SiLC Technologies is bringing forth its deep expertise in silicon photonics to advance market deployment of FMCW LiDAR solutions.

"Our goal is to change the status quo for machine vision"

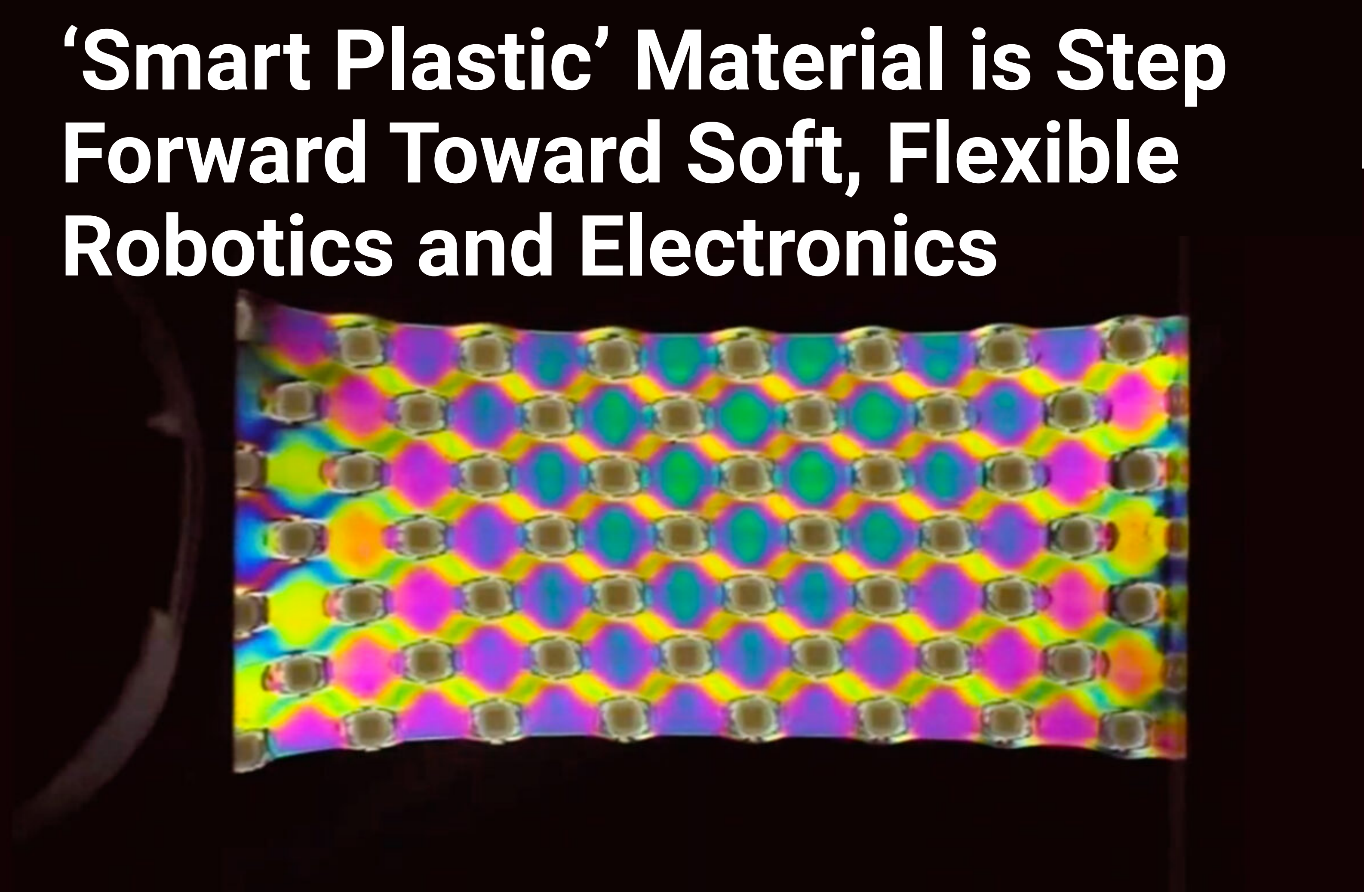
Mehdi Asghari, SiLC founder and CEO

The company's breakthrough 4D+ Eyeonic Chip integrates all photonics functions needed to enable a coherent vision sensor, offering a tiny footprint while addressing the need for low cost and low power. SiLC's innovations are targeted to robotics, autonomous vehicles, biometrics, security, industrial automation and other leading markets.

SiLC was founded in 2018 by silicon photonics industry veterans with decades of commercial product development and manufacturing experience. SiLC's 4D LiDAR chip has been recognized by Frost & Sullivan as ideally positioned to disrupt the global LiDAR market and the company has been named a Cool Vendor in Silicon Photonics by Gartner. Investors in SiLC include Dell Technology Capital, Sony Innovation Fund by IGV, FLUXUNIT – ams OSRAM Ventures, UMC Capital, Alter Ventures and Epson.

For more information, visit **www.silc.com**

‘Smart Plastic’ Material is Step Forward Toward Soft, Flexible Robotics and Electronics



Inspired by living things from trees to shellfish, researchers at The University of Texas at Austin set out to create a plastic much like many life forms that are hard and rigid in some places and soft and stretchy in others. Their success — a first, using only light and a catalyst to change properties such as hardness and elasticity in molecules of the same type — has brought about a new material that is 10 times as tough as natural rubber and could lead to more flexible electronics and robotics.

“This is the first material of its type,” said Zachariah Page, assistant professor of chemistry and corresponding author on the paper. “The ability to control crystallization, and therefore the physical properties of the material, with the application of light is potentially transformative for wearable electronics or actuators in soft robotics.”

Scientists have long sought to mimic the properties of living structures, like skin and muscle, with synthetic materials. In living organisms, structures often combine attributes such as strength and flexibility with ease. When using a mix of different synthetic materials to mimic these attributes, materials often fail, coming apart and ripping at the junctures between different materials.

Oftentimes, when bringing materials together, particularly if they have very different mechanical properties, they want to come apart," Page said. Page and his team were able to control and change the structure of a plastic-like material, using light to alter how firm or stretchy the material would be.

Chemists started with a monomer, a small molecule that binds with others like it to form the building blocks for larger structures called polymers that were similar to the polymer found in the most commonly used plastic. After testing a dozen catalysts, they found one that, when added to their monomer and shown visible light, resulted in a semicrystalline polymer similar to those found in existing synthetic rubber. A harder and more rigid material was formed in the areas the light touched, while the unlit areas retained their soft, stretchy properties.

Because the substance is made of one material with different properties, it was stronger and could be stretched farther than most mixed materials.

The reaction takes place at room temperature, the monomer and catalyst are commercially available, and researchers used inexpensive blue LEDs as the light source in the experiment. The reaction also takes less than an hour and minimizes use of any hazardous waste, which makes the process rapid, inexpensive, energy efficient and environmentally benign.

The researchers will next seek to develop more objects with the material to continue to test its usability.

"We are looking forward to exploring methods of applying this chemistry towards making 3D objects containing both hard and soft components," said first author Adrian Rylski, a doctoral student at UT Austin.

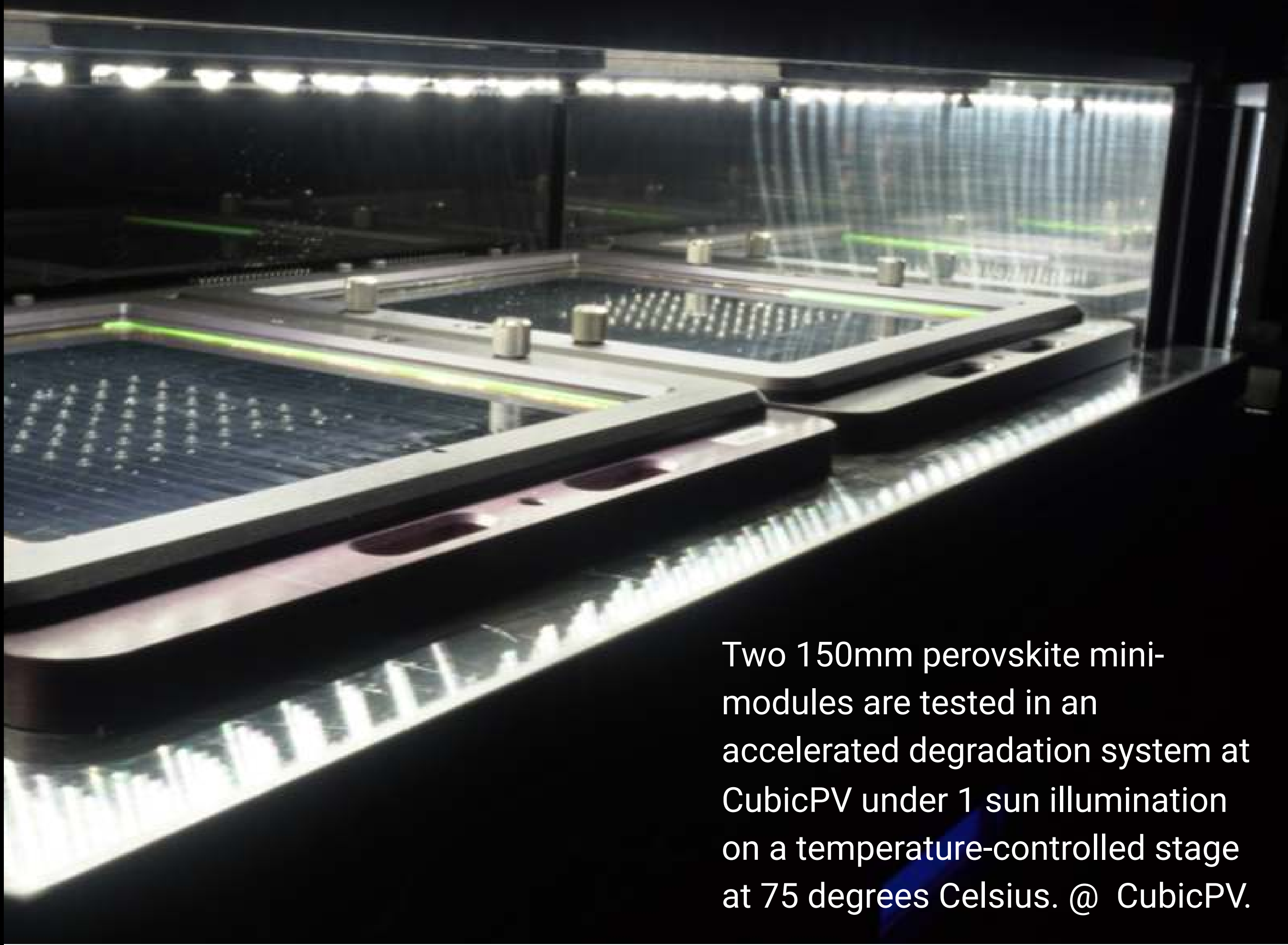
The team envisions the material could be used as a flexible foundation to anchor electronic components in medical devices or wearable tech. In robotics, strong and flexible materials are desirable to improve movement and durability.

Henry L. Cater, Keldy S. Mason, Marshall J. Allen, Anthony J. Arrowood, Benny D. Freeman and Gabriel E. Sanoja of The University of Texas at Austin also contributed to the research.

The research was funded by the National Science Foundation, the U.S. Department of Energy and the Robert A. Welch Foundation.

Polymeric multimaterials by photochemical patterning of crystallinity
Adrian K. Rylski, Henry L. Cater, Keldy S. Mason, Marshall J. Allen, Anthony J. Arrowood, Benny D. Freeman, Gabriel E. Sanoja And Zachariah A. Page
SCIENCE Vol 378, Issue 6616
DOI: 10.1126/science.add6975

University of Texas at Austin



Two 150mm perovskite mini-modules are tested in an accelerated degradation system at CubicPV under 1 sun illumination on a temperature-controlled stage at 75 degrees Celsius. @ CubicPV.

Moving perovskite advancements from the lab to the manufacturing floor

U.S. Department of Energy selects MIT to establish collaborative research center for optimizing the development of tandem solar modules.

The following was issued as a joint announcement from MIT.nano and the MIT Research Laboratory for Electronics; CubicPV; Verde Technologies; Princeton University; and the University of California at San Diego.

Tandem solar cells are made of stacked materials — such as silicon paired with perovskites — that together absorb more of the solar spectrum than single materials, resulting in a dramatic increase in efficiency. Their potential to generate significantly more power than conventional cells could make a meaningful difference in the race to combat climate change and the transition to a clean-energy future.

However, current methods to create stable and efficient perovskite layers require time-consuming, painstaking rounds of design iteration and testing, inhibiting their development for commercial use. Today, the U.S. Department of Energy Solar Energy Technologies Office (SETO) announced that MIT has been selected to receive an $11.25 million cost-shared award to establish a new research center to address this challenge by using a co-optimization framework guided by machine learning and automation.

A collaborative effort with lead industry participant CubicPV, solar startup Verde Technologies, and academic partners Princeton University and the University of California San Diego (UC San Diego), the center will bring together teams of researchers to support the creation of

> “It’s a module-centric approach that creates a direct channel for R&D advancements into industry.”

perovskite-silicon tandem solar modules that are co-designed for both stability and performance, with goals to significantly accelerate R&D and the transfer of these achievements into commercial environments.

“Urgent challenges demand rapid action. This center will accelerate the development of tandem solar modules by bringing academia and industry into closer partnership,” says MIT professor of mechanical engineering Tonio Buonassisi, who will direct the center. “We’re grateful to the Department of Energy for supporting this powerful new model and excited to get to work.”

Adam Lorenz, CTO of solar energy technology company CubicPV, stresses the importance of thinking about scale, alongside quality and efficiency, to accelerate the perovskite effort into the commercial environment. “Instead of chasing record efficiencies with tiny pixel-sized devices and later attempting to stabilize them, we will simultaneously target stability, reproducibility, and efficiency,” he says. “It’s a module-centric approach that creates a direct channel for R&D advancements into industry.”

The center will be named Accelerated Co-Design of Durable, Reproducible, and Efficient Perovskite Tandems, or ADDEPT. The grant will be administered through the MIT Research Laboratory for Electronics (RLE).

David Fenning, associate professor of nanoengineering at UC San Diego, has worked with Buonassisi on the idea of merging materials, automation, and computation, specifically in this field of artificial intelligence and solar, since 2014. Now, a central thrust of the ADDEPT project will be to deploy machine learning and robotic screening to optimize processing of perovskite-based solar materials for efficiency and durability.

“We have already seen early indications of successful technology transfer between our UC San Diego robot PASCAL and industry,” says Fenning. “With this new center, we will bring research labs and the emerging perovskite industry together to improve reproducibility and reduce time to market.”

“Our generation has an obligation to work collaboratively in the fight against climate change,” says Skylar Bagdon, CEO of Verde Technologies, which received the American-Made Perovskite Startup Prize. “Throughout the course of this center, Verde will do everything in our power to help this brilliant team transition lab-scale breakthroughs into the world where they can have an impact.”

Several of the academic partners echoed the importance of the joint effort between academia and industry. Barry Rand, professor of electrical and computer engineering at the Andlinger Center for Energy and the Environment at Princeton University, pointed to the intersection of scientific knowledge and market awareness.
“Understanding how chemistry affects films and interfaces will empower us to co-design for stability and performance,” he says. “The center will accelerate this use-inspired

science, with close guidance from our end customers, the industry partners."

A critical resource for the center will be MIT.nano, a 200,000-square-foot research facility set in the heart of the campus. MIT.nano Director Vladimir Bulović, the Fariborz Maseeh (1990) Professor of Emerging Technology, says he envisions MIT.nano as a hub for industry and academic partners, facilitating technology development and transfer through shared lab space, open-access equipment, and streamlined intellectual property frameworks.

"MIT has a history of groundbreaking innovation using perovskite materials for solar applications," says Bulović. "We're thrilled to help build on that history by anchoring ADDEPT at MIT.nano and working to help the nation advance the future of these promising materials."

MIT was selected as a part of the SETO Fiscal Year 2022 Photovoltaics (PV) funding program, an effort to reduce costs and supply chain vulnerabilities, further develop durable and recyclable solar technologies, and advance perovskite PV technologies toward commercialization. ADDEPT is one project that will tackle perovskite durability, which will extend module life. The overarching goal of these projects is to lower the levelized cost of electricity generated by PV.

Research groups involved with the ADDEPT project at MIT include Buonassisi's Accelerated Materials Laboratory for Sustainability (AMLS), Bulović's Organic and Nanostructured Electronics (ONE) Lab, and the Bawendi Group led by Lester Wolfe Professor in Chemistry Moungi Bawendi. Also working on the project is Jeremiah Mwaura, research scientist in the ONE Lab.

MIT.nano

ADDEPT

Accelerated Co-Design of Durable, Reproducible, and Efficient Perovskite Tandems

Overachieving with overlay control

A new lens manipulator aligns microchip layers with unprecedented precision

Christine Middleton

A single microchip in your smartphone or laptop is made up of dozens of layers of circuitry. For the chip to work properly, all of those layers have to be aligned with nanometer-level precision.

Lithography systems – the machines that print microchip patterns on silicon wafers – try to make sure that each chip layer sits perfectly on top of the previous one. In deep ultraviolet (DUV) lithography systems such as those made by ASML, the pattern for each layer is encoded in light and transmitted to the wafer using a series of lenses. Those lenses are incredibly smooth, but they still have tiny imperfections that can slightly distort the pattern being printed.

If those distortions change at all from one layer to the next, then the layers don't quite line up. That misalignment can negatively affect a chip's performance. It can even stop the chip from working altogether – a situation that chipmakers desperately want to avoid.

When chipmakers measure misalignment on their wafers, they adjust their lithography systems to correct for it. But chipmakers are now able to detect subnanometer-scale errors that available systems aren't able to correct for – they simply can't make such tiny adjustments.

ASML teamed up with ZEISS, our strategic partner and maker of lenses for our lithography systems, to develop a solution: an improved lens-adjustment system. The new hardware and software upgrades, which are now fully integrated into ASML's TWINSCAN NXT:2100i, provide chipmakers with unprecedented correction capability.

Lithography, lenses and layers

How well the layers of a microchip are aligned is called overlay. Optimizing overlay isn't as simple as moving a wafer around to make sure it's placed at exactly the right spot before printing starts – although that's one part of it.

Another important consideration is that an imperfection in a lens might distort a particular area of the pattern being printed. And how exactly the pattern is distorted might change depending on where on the wafer it's being printed. Over time the light used to print the pattern can also cause certain parts of the optics to heat up, which unevenly aberrates the light passing through.

Because the distortions that cause overlay problems aren't static, the corrections can't be either. That's why the optics used in DUV lithography systems to project light onto wafers have lots of dynamically adjustable manipulators and stages.

The lithography systems use measurements of printed patterns to figure out what adjustments are needed. Those measurements can come from either the lithography systems themselves or from other machines, such as ASML's YieldStar products, which are specifically designed to help chipmakers optimize overlay. The lithography system then uses the measurements to intentionally distort the image being printed. The intentional distortions are designed to correct the unintentional ones.

Enabling tomorrow's technology

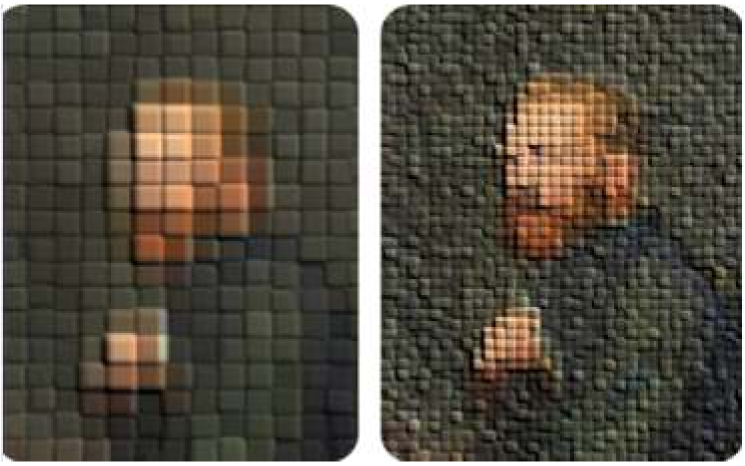
Challenges to improved precision

The new lens-adjustment system developed by ASML and ZEISS consists of many individual manipulators that adjust the lithography machine's lenses. With that level of control, chipmakers can make their intentional distortions smaller – which means they can correct smaller misalignments.

Along with hardware upgrades, getting better correction resolution also requires software improvements. The software determines the locations of overlay errors by dividing the measured wafer image into a grid. The error's location is identified by the grid space that it's located in.

The new software divides each wafer into a grid that's four times denser. By using more and smaller grid spaces, it can find smaller errors and instruct the hardware to correct for them.

Multiplying the number of grid spaces by four also means a four-fold increase in the amount of data that the software has to handle. So the software engineers working on the project had to speed up the computations. The new system can now analyze the larger amount of data it produces fast enough to keep up with the printing process and maintain the lithography system's productivity.



By using a denser grid, the new software paints a more detailed map of overlay errors.

A promising prototype

Tests on a prototype optics manipulator system at ASML delivered promising results. In one test, a lithography system was given a pattern to print. The lens manipulator was then asked to intentionally distort that pattern by introducing specific errors. The sizes of the errors produced on the printed wafer were within 10% of the requested sizes. So if a distortion was meant to be about 0.5 nm, it was accurate to less than 0.1 nm.

In a second test, two layers were printed on a wafer. Then the mismatch between the layers was measured and the system was asked to correct for it. With the correction, the size of the mismatch shrunk from about 0.65 nm to about 0.3 nm – almost as small as a single silicon atom.

After working with its own prototypes, ASML delivered lens-manipulation systems to customers for testing in their facilities. The customer feedback helped ensure that any remaining bumps got smoothed out. Chipmakers are starting to introduce the lens system into high-volume microchip manufacturing, starting with the TWINSCAN NXT:2100i.

Enabling tomorrow's technology

In addition to aligning layers printed using the same machine, the lens manipulator will also improve overlay of layers that are printed using different machines. Every lithography system is slightly different and produces a unique 'distortion fingerprint'. The fingerprint for the machine that prints one layer can be measured and communicated to the machine that will print the next layer. The second machine can then correct for overlay errors caused by the first one.

But why use more than one lithography systems to print a single wafer? The features in the different layers are different sizes. The first few layers have the smallest features, so those need to be printed using the newest systems with the best resolution. Larger features in the upper layers can then be printed using established technology.

In the future, more and more cutting-edge chips will have their first few critical layers printed using ASML's extreme ultraviolet (EUV) lithography systems. But higher layers will still be printed with DUV systems. So by smoothing machine-to-machine wafer transitions, the new lens manipulator will help chipmakers make state-of-the-art technology a reality.

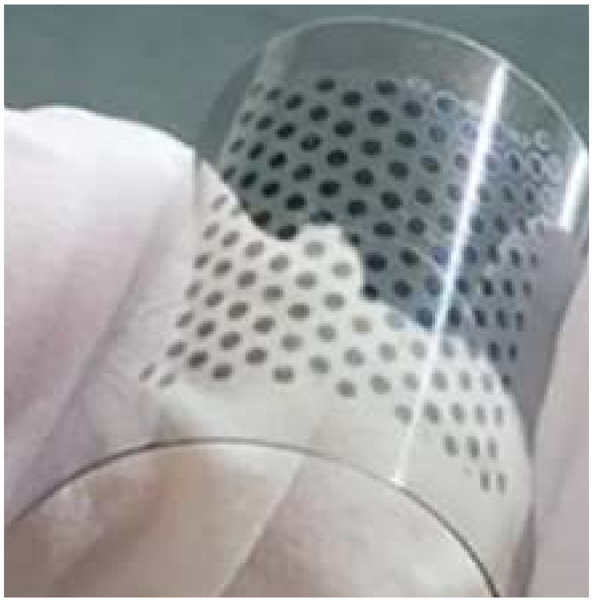
About ASML

ASML is a high-tech company, headquartered in the Netherlands. We manufacture the complex lithography machines that chipmakers use to produce integrated circuits, or computer chips. Over 30 years, we have grown from a small startup into a multinational company with over 60 locations across Europe, Asia and the US.

Behind ASML's innovations are engineers who think ahead. The people who work at our company include some of the most creative minds in physics, electrical engineering, mathematics, chemistry, mechatronics, optics, mechanical engineering, computer science and software engineering.

Because ASML spends more than €2 billion per year on R&D, our teams have the freedom, support and resources to experiment, test and push the boundaries of technology. They work in close-knit, multidisciplinary teams, listening to and learning from each other.

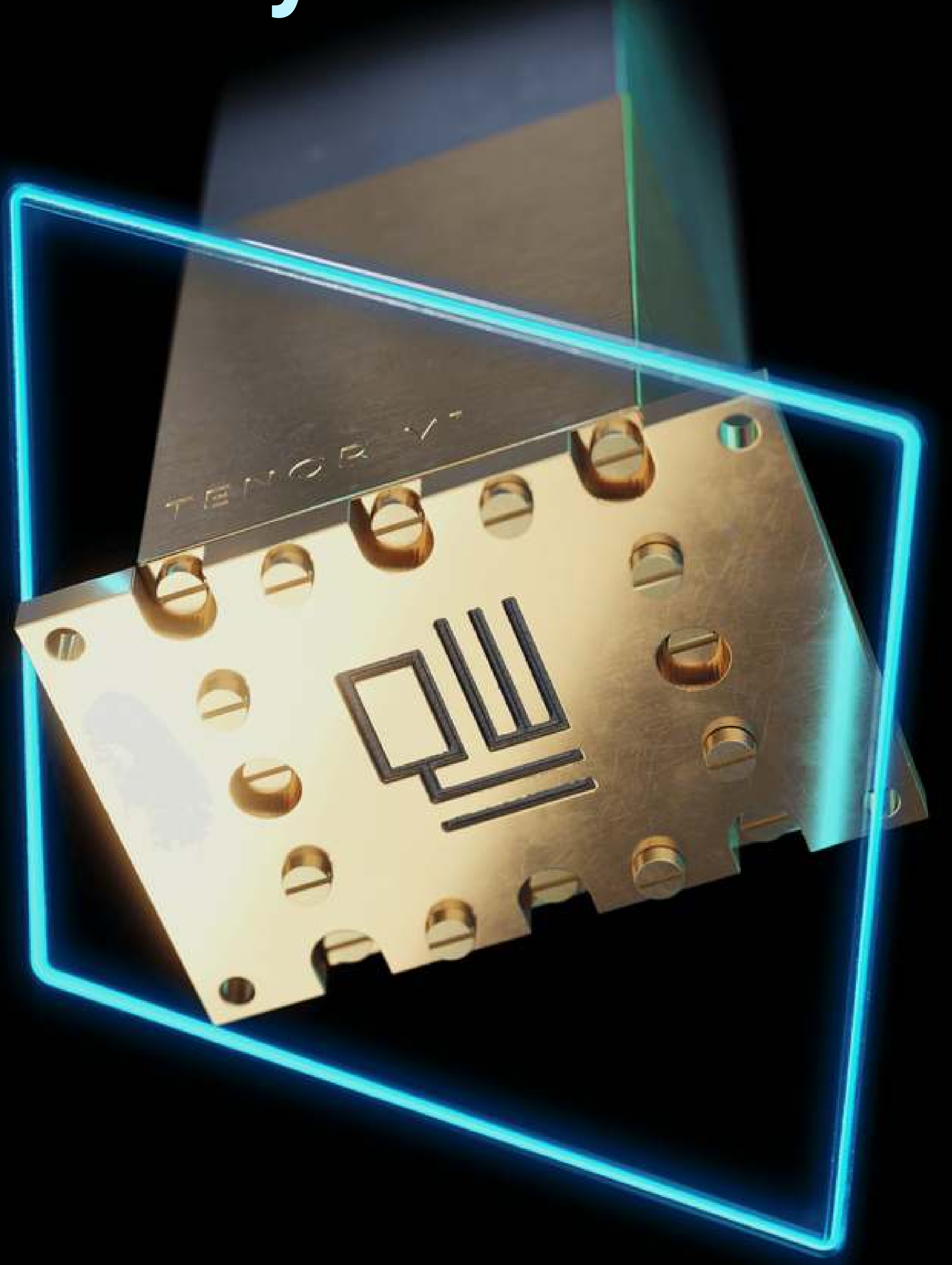
nature



Biocompatible memristive device based on an agarose@gold nanoparticle-nanocomposite layer obtained from nature for neuromorphic computing

Scientific Reports volume 13, Article number: 6491 (2023)
Open Access
Published: 20 April 2023

QuantWare launches technology that makes superconducting quantum computers massively scalable



QuantWare, the leading provider of large-scale superconducting quantum processors, has launched Tenor, a new processor which features a massively scalable technology and enables quantum computers with 64 fully controllable qubits to be built commercially.

Superconducting qubits have led the quantum computing race for the last few decades, but have yet to scale to truly useful qubit counts because of scaling bottlenecks. Previous generation devices have been planar: the connections between the qubits and the outside world were routed to the edges of the chip. This limits the number of qubits to the numbers seen today.

QuantWare has developed a patented 3D technology that routes the connections vertically, making it possible to scale superconducting quantum processors to thousands of qubits - opening the door to 'quantum advantage' where quantum computers will overtake the most powerful classical computer. Tenor marks a significant advance in commercial quantum computing because it is the first device commercially available that features this technology.

The quantum processor features 64 fully controllable qubits, which is a device with more than twice the number of qubits than the previously largest available quantum processor.

Because the qubits are fully controllable, these processors are very suitable for powerful error-correction schemes. Such a design requires more connections per qubit than the often used fixed frequency qubits, and as such were impossible at a scale of 64 qubits with conventional planar devices. QuantWare unlocks these powerful devices for the quantum community by bringing its technology to the market at a 10x lower price point than competing solutions.

QuantWare's aim is to become the 'Intel of quantum computing' by providing easy-to-use, increasingly powerful and affordable quantum processors to organisations across the world. Last year, QuantWare was selected to deliver quantum processing units for Israel's first fully functional quantum computer.

"The technology on which Tenor is built will massively scale the size of the devices available to the quantum market in the coming years", said Matthijs Rijlaarsdam, CEO of QuantWare. "There are scores of great quantum computing solutions but there hasn't been the tech available to enable them to significantly scale - until now.

"Similar to how the emergence of fabless companies revolutionised the semicon industry by significantly lowering the bar to entry, we will be able to provide the design elements and fabrication that will enable many more quantum startups to scale, innovate and compete."

Tooling up the CHIPS Act: How equipment ramp

Installing a semiconductor manufacturing tool takes time, peo install, and qualify hundreds of tools when ramping a new fab?

With the longstanding semiconductor supply crunch, semiconductor companies across the globe have been seeking ways to unlock capacity quickly. Given the long lead times of both new clean-room facilities and the manufacturing equipment that populates them, many have pursued capacity expansion opportunities that largely assume a relatively fixed plant and asset base. With the passage of the CHIPS Act and publication of the associated implementation strategy, many of the larger integrated device manufacturers (IDMs) and foundries are now planning to go big: building entirely new wafer fabs. Such leading-edge wafer fabs can require an investment of $10 billion to $12 billion (Figure 1), which is why the $52 billion of CHIPS Act support was so anxiously anticipated. While the effort and investment to build one fab is daunting enough, many leading IDMs and foundries are considering building mega-fabs, which are clusters of multiple fabs on one campus.

To produce those wafers, the fab needs to be filled with hundreds of some of the most high-tech and capital-intensive manufacturing equipment. About half of the $10 billion to $12 billion fab budget is spent on the equipment to fill it (Figure 1). This equipment performs functions categorized as deposition, etch, implant, photolithography, and metrology over blank or partially processed wafers.

to fast-track your new fab

ple and money. How do you simultaneously procure, receive,
?

Figure 1: *Public information, Deloitte estimates Representative numbers shown*

Photolithography tools, for example, use advanced lighting and optics techniques to create tiny geometric features on wafers, with dimensions in nanometers, that allow tens of billions of transistors to be placed on today's CPUs. Multiple instances of these tools need to be installed in the fab in specific positions in the line and interconnected by automated material handling to produce a completed wafer.

What makes this complex equipment so hard to install? Well, it's the complexity! The latest extreme ultraviolet (EUV) lithography machines from ASML have more than 100,000 components, weigh 180 tons, fill 150 shipping crates, and require 40 freight containers (or four jumbo jets) to transport to customers.[1] While all fab tools are not this big, most still require tens of crates, specialized OEM teams, several weeks, and hundreds of thousands of dollars to install, on top of the tool cost itself. But the challenges start well before the crates arrive. Specifications, quotes, and manufacturing bills of materials for these tools can be 30 or more pages with hundreds of line items, making translation of requirements to quotes, invoices, purchase orders, and build instructions difficult. As the equipment is shipped from the factory to the fab, components can be delayed, damaged, and sometimes completely lost. Similar challenges arise when managing the de-install and transfer of equipment from an existing fab to the new fab. Organizing the team and materials to install a tool or cluster of tools in proper sequence requires a complicated, interdependent project plan—particularly when installations are performed in a clean-room environment not intended for humans. Multiply all of this by the many hundreds of tools needed for a new fab, and you have an overwhelming equipment ramp problem.

Deloitte's holistic equipment lifecycle management (ELM) approach can help fast track your new fab equipment ramp. Some core capabilities from this approach include the following:

- **Equipment specification management:** A scalable and flexible specification data model records all critical equipment configuration details to facilitate translation to quotes, invoices, purchase orders, equipment build instructions, shipping manifests, and change management. This capability streamlines the entire front-end sales and procurement activities, and minimizes or eliminates translation errors.

- **Equipment tracking and traceability:** Physical tool components are tagged with RFID sensor devices that are mapped to detailed component and shipping data. These devices facilitate tracking, in near real-time, the movement of the components from the supplier or another site to the new fab, in near real time, to minimize asset location discovery time and asset loss.

- **Cloud-based control tower:** View on one screen the status and location of several thousand equipment components as they converge on the new fab. Identify and address delays in shipments, labor or resource availability, and/or task completions that impact the overall installation schedule.

With these capabilities as well as others, and best practices of a modernized ELM approach, semiconductor companies are expected to expand capacity and reach first wafers more efficiently while mitigating risk. Deloitte's ongoing work with IDMs, foundries, and equipment suppliers in the semiconductor ecosystem, and relationships with leading product management, supply chain management, and cloud-based systems providers, enable us to build an ELM solution that is tailored to your specific needs. Reach out to Deloitte today to prepare to fast track your next equipment ramp.

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[1] Samanth Subramanian, "The company that modern capitalism couldn't survive long without," Quartz, April 9, 2021; Sam Shead, "The Dutch firm that investors are going wild over is now creating a machine that could redefine electronics," CNBC, December 10, 2021.

Author

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Deloitte Technology industry group

Semiconductor Transformation Study (pdf)

Jülich researchers develop new germanium-tin transistor as alternative to silicon

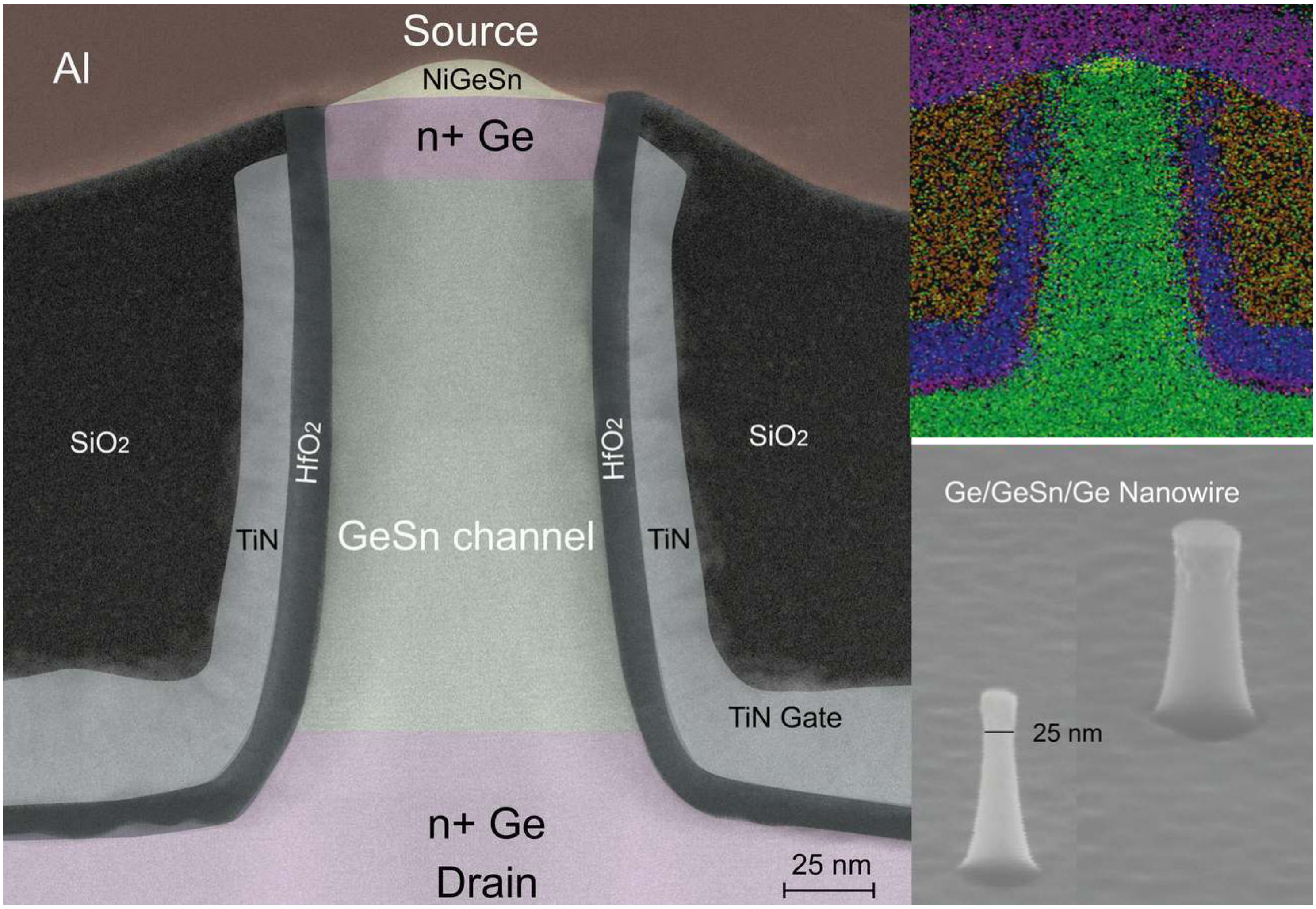
Scientists at Forschungszentrum Jülich have fabricated a new type of transistor from a germanium–tin alloy that has several advantages over conventional switching elements. Charge carriers can move faster in the material than in silicon or germanium, which enables lower voltages in operation. The transistor thus appears to be a promising candidate for future low-power, high-performance chips, and possibly also for the development of the future of quantum computers.

Over the past 70 years, the number of transistors on a chip has doubled approximately every two years – according to Moore's Law, which is still valid today. The circuits have become correspondingly smaller, but an end to this development appears to be in sight. "We have now reached a stage where structures are only 2 to 3 nanometers in size. This is approximately equal to the diameter of 10 atoms, which takes us to the limits of what is feasible. It doesn't get much smaller than this," says Qing-Tai Zhao of the Peter Grünberg Institute (PGI-9) at Forschungszentrum Jülich.

For some time now, researchers have been looking for a substitute for silicon, the primary material used in the semiconductor industry. "The idea is to find a material that has more favourable electronic properties and can be used to achieve the same performance with larger structures," the professor explains.

The research is in part focused on germanium, which was already being used in the early days of the computer era. Electrons can move much faster in germanium than in silicon, at least in theory. However, Qing-Tai Zhao and his colleagues have now gone one step further. To optimize the electronic properties even further, they incorporated tin atoms into the germanium crystal lattice. The method was developed several years ago at the Peter Grünberg Institute (PGI-9) of Forschungszentrum Jülich.

"The germanium–tin system we have been testing makes it possible to overcome the physical limitations of silicon technology," says Qing-Tai Zhao. In experiments, the germanium–tin



Electron micrograph of the germanium-tin transistor: The design follows a 3D nanowire geometry that is also used in the latest generation of computer processors. @ Forschungszentrum Jülich

transistor exhibits an electron mobility that is 2.5 times higher than a comparable transistor made of pure germanium.

Another advantage of the new material alloy is that it is compatible with the existing CMOS process for chip fabrication. Germanium and tin come from the same main group in the periodic table as silicon. The germanium-tin transistors could therefore be integrated directly into conventional silicon chips with existing production lines.

High potential for the computers of the future

Apart from classical digital computers, quantum computers could also benefit from the germanium–tin transistor. For some time, there have been efforts to integrate parts of the control electronics directly on the quantum chip, which is operated inside a quantum computer at temperatures close to absolute zero. Measurements suggest that a transistor made of germanium-tin will perform significantly better under these conditions than those made of silicon.

Jülich Researchers Develop New Germanium-Tin Transistor as Alternative to Silicon

"The challenge is to find a semiconductor whose switching can still be very fast with low voltages at very low temperatures," explains Qing-Tai Zhao. For silicon, this switching curve flattens out below 50 Kelvin. Then, the transistors need a high voltage and thus a high power, which ultimately leads to failures of the sensitive quantum bits because of the heating. "Germanium–tin performs better at these temperatures in measurements down to 12 Kelvin, and there are hopes to use the material at even lower temperatures," says Qing-Tai Zhao.

In addition, the germanium–tin transistor is a further step towards optical on-chip data transmission. The transmission of information with light signals is already standard in many data networks because it is considerably faster and more energy-efficient than data transfer via electrical conductors. In the field of micro- and nanoelectronics, however, data is usually still sent electrically. Colleagues from the Jülich working group of Dr. Dan Buca have already developed a germanium-tin laser in the past that opens up the possibility to transmit data optically directly on a silicon chip. The germanium-tin transistor, along these lasers, provides a promising solution for the monolithic integration of nanoelectronics and photonics on a single chip.

Reference

Vertical GeSn nanowire MOSFETs for CMOS beyond silicon
Mingshan Liu, Yannik Junk, Yi Han, Dong Yang, Jin Hee Bae, Marvin Frauenrath, Jean-Michel Hartmann, Zoran Ikonic, Florian Bärwolf, Andreas Mai, Detlev Grützmacher, Joachim Knoch, Dan Buca, Qing-Tai Zhao
Communications Engineering (25 February 2023), DOI: 10.1038/s44172-023-00059-2

UTA team exploring new technology to cool data centers

UTA-led project funded by $2.8 million award from Department of Energy

Data centers account for approximately 2% of total U.S. electricity consumption, while data center cooling can account for up to 40% of data center energy usage overall, according to the DOE. The DOE's selected projects—located at national labs, universities and businesses—seek to reduce the energy necessary to cool data centers. **Read more**

EV Group and Notion Systems team up to combine nanoimprint lithography with inkjet coating for new high-volume-manufacturing applications

Collaboration creates new application opportunities for nanoimprint lithography (NIL) and cements EVG's NIL leadership with inkjet capabilities in a fully automated NIL solution

EV Group (EVG), a leading supplier of wafer bonding and lithography equipment for the MEMS, nanotechnology and semiconductor markets, and Notion Systems, a leading supplier of industrial inkjet coating systems for functional materials, today announced that they have entered into an agreement to develop the first fully integrated and automated nanoimprint lithography (NIL) solution with inkjet coating capabilities.

Per the joint agreement, the two companies will develop a customized inkjet module to be integrated in EVG's industry-benchmark HERCULES® NIL platform based on EVG's SmartNIL® technology. The new inkjet module will be complementary to EVG's existing spin-coating modules and will be offered as an alternative option for dispensing NIL photoresists on substrates for high-volume-manufacturing (HVM) applications for NIL that have unique film deposition and uniformity needs.

Dr. Thomas Glinsner, Corporate Technology Director for EV Group, and Antonio Schmidt, SVP Sales and Marketing for Notion Systems, at SPIE Photonics West 2023 in San Francisco

Through this partnership, EVG further cements its leadership in NIL with inkjet capabilities in a fully integrated and automated NIL solution.

Per the joint agreement, the two companies will develop a customized inkjet module to be integrated in EVG's SmartNIL®

Continued on page 66

Light amplification by stimulated emission from electrically driven colloidal quantum dots finally achieved

In Nature article, Los Alamos National Laboratory team realizes long-sought capabilities for semiconductor nanocrystal light-amplification devices

Brian Keenan
Los Alamos National Laboratory

In a result decades in the making, Los Alamos scientists have achieved light amplification with electrically driven devices based on solution-cast semiconductor nanocrystals — tiny specs of semiconductor matter made via chemical synthesis and often called colloidal quantum dots. This demonstration, reported in the scientific journal Nature, opens the door to a completely new class of electrically pumped lasing devices — highly flexible, solution-processable laser diodes that can be prepared on any crystalline or non-crystalline substrate without the need for sophisticated vacuum-based growth techniques or a highly controlled clean-room environment.

“The capabilities to attain light amplification with electrically driven colloidal quantum dots have emerged from decades of our previous research into syntheses of nanocrystals, their photophysical properties and optical and electrical design of quantum dot devices,” said Victor Klimov, Laboratory Fellow and leader of the quantum dot research initiative. “Our novel, ‘compositionally graded’ quantum dots exhibit long optical gain lifetimes, large gain coefficients and low lasing thresholds — properties that make them a perfect lasing material. The developed approaches for achieving electrically driven light amplification with solution-cast nanocrystals from lighting and displays to quantum information, medical diagnostics and chemical sensing."

More than two decades of research

Research over more than two decades has sought to achieve colloidal quantum dot lasing with electrical pumping, a prerequisite for its widespread use in practical technologies. Traditional laser diodes, ubiquitous in modern technologies, produce highly monochromatic, coherent light under electrical excitation. But they have deficiencies: challenges with scalability, gaps in the range of accessible wavelengths, and, importantly an incompatibility with silicon technologies that limits their use in microelectronics. Those problems have spurred the search for alternatives in the realm of highly flexible and easily scalable solution-processable materials.

Chemically prepared colloidal quantum dots are especially attractive for implementing solution-processable laser diodes. In addition to being compatible with inexpensive and readily scalable chemical techniques, they offer the advantages of a size-tunable emission wavelength, low-optical gain thresholds and high-temperature stability of lasing characteristics.

However, multiple challenges have hindered the technology's development, including fast Auger recombination of gain-active multicarrier states, poor stability of nanocrystal films at high current densities required for lasing, and the difficulty of obtaining net optical gain in a complex electrically driven device wherein a thin electroluminescent nanocrystal layer is combined with various optically-lossy, charge-conducting layers that tends to absorb light emitted by the nanocrystals.

Solutions for colloidal quantum dot laser diode challenges

A number of technical challenges needed to be solved to realize electrically driven colloidal quantum dot lasing. Quantum dots not only need to emit light, they need to multiply generated photons via stimulated emission. That effect can be turned into laser oscillations, or lasing, by combining the quantum dots with an optical resonator that would circulate the emitted light through the gain medium. Solve that, and you have electrically driven quantum dot lasing.

In quantum dots, stimulated emission competes with very fast nonradiative Auger recombination, the primary impediment of lasing in these materials. The Los Alamos team developed a highly effective approach to suppress nonradiative Auger decay by introducing carefully engineered compositional gradients into the quantum dot interior.

Very high current densities are also required for attaining the lasing regime. That current, though, can doom a device.

"A typical quantum dot light-emitting diode operates at current densities that do not exceed about 1 ampere per square centimeter," said Namyoung Ahn, a Los Alamos Director's Postdoctoral Fellow and the lead device design expert for the project. "However, the realization of lasing requires tens to hundreds of amperes per square centimeter, which would normally lead to device breakdown due to overheating. This has been a key problem hindering realization of lasing with electrical pumping."

To resolve the overheating problem, the team confined the electric current in spatial and temporal domains, ultimately reducing the amount of generated heat and simultaneously improving heat exchange with a surrounding medium. To implement these ideas, the researchers incorporated an insulating interlayer with a small, current-focusing aperture into a device stack and used short electrical pulses (about 1 microsecond duration) to drive the LEDs.

The developed devices were able to reach approximately 2,000 amperes per square centimeter, sufficient to generate strong, broad-band optical gain spanning across multiple quantum dot optical transitions.

"A further challenge is to achieve a favorable balance between optical gain and optical losses in a complete LED device stack containing various charge conducting layers that can exhibit strong light absorption," said Laboratory postdoctoral researcher Clément Livache, who coordinated the spectroscopic component of this project. "To tackle this problem, we added a stack of dielectric bi-layers, forming a so-called distributed Bragg reflector."

Using a Bragg reflector as an underlying substrate, the researchers were able to control a spatial distribution of an electric field across the device and shape it so as to reduce field intensity in optically lossy charge conductive layers and to enhance the field in the quantum-dot gain medium.

With those innovations, the team demonstrated an effect pursued by the research community for decades: bright amplified spontaneous emission (ASE) realized with electrically pumped colloidal quantum dots. In the ASE process, “seed photons” produced by spontaneous emission launch a “photon avalanche” driven by stimulated emission from the excited quantum dots. This boosts the intensity of the emitted light, increases its directionality and enhances coherence. ASE can be considered as a precursor of lasing, the effect which emerges when an ASE-capable medium is combined with an optical resonator.

The ASE-type quantum dot LEDs represent considerable practical utility as sources of highly directional, narrow-band light for applications in consumer products (for example, displays and projectors), metrology, imaging and scientific instrumentation. Interesting opportunities are also associated with the prospective use of these structures in electronics and photonics, traditional and quantum, where they can help realize spectrally tunable on-chip optical amplifiers integrated with various types of optical interconnects and photonic structures.

The ASE-type quantum dot LEDs represent considerable practical utility as sources of highly directional, narrow-band light for applications in consumer products

What’s next?

Presently, the team is working on realizing laser oscillations with electrically pumped quantum dots. In one approach, they incorporate into the devices a so-called “distributed feedback grating,” a periodic structure that acts as an optical resonator circulating light in the quantum dot medium. The team also aims to extend spectral coverage of their devices, with a focus on demonstrating electrically driven light-amplification in the range of infrared wavelengths.

Infrared, solution-processable optical-gain devices could be of great utility in silicon technologies, communications, imaging and sensing.

Reference

Electrically Driven Amplified Spontaneous Emission from Colloidal Quantum Dots
Nature. DOI: 10.1038/s41586-023-05855-6

Los Alamos National Laboratory

Chip hunting: The semiconductor procurement solution when other options fail

McKinsey & Company

Supply-and-demand mismatches for semiconductors have generated production headaches across industries. Forward-looking companies are using artificial intelligence to optimize short-term procurement.

The supply of semiconductors has been, and remains, a significant challenge for industries around the world. Manufacturers in sectors such as automotive, consumer goods, and technology have been hit with shortages that held back production and put profits at risk. But some chief operating officers are building resilience into their supply chains by turning to artificial-intelligence-based solutions, which give them near-real-time insights into pricing and demand fluctuations.

The reasons for these semiconductor bottlenecks include limited capacity, high demand, and overordering—which means that they are likely to persist through 2023, McKinsey analysis shows (Figure 1). The most extreme pressure will be on mature chips for everyday applications, such as cars, electronics, home appliances, and medical devices. Growth in manufacturing capacity is set to remain patchy until at least 2026. Smaller node capacities are set to expand fastest: seven-nanometer capacity is predicted to grow at a CAGR of 14 percent annually, 100-nanometer capacity at 4 percent. Varying levels of production reflect wider industry dynamics. Some companies want to add capacity: Taiwanese chipmaker TSMC, for example, plans to spend $32 billion to $36 billion in 2023 alone, despite expectations of softer demand. Other companies—both integrated device manufacturers (IDM) and foundries—are operating close to or at full utilization.

Global semiconductor chip shortage factors across metrics

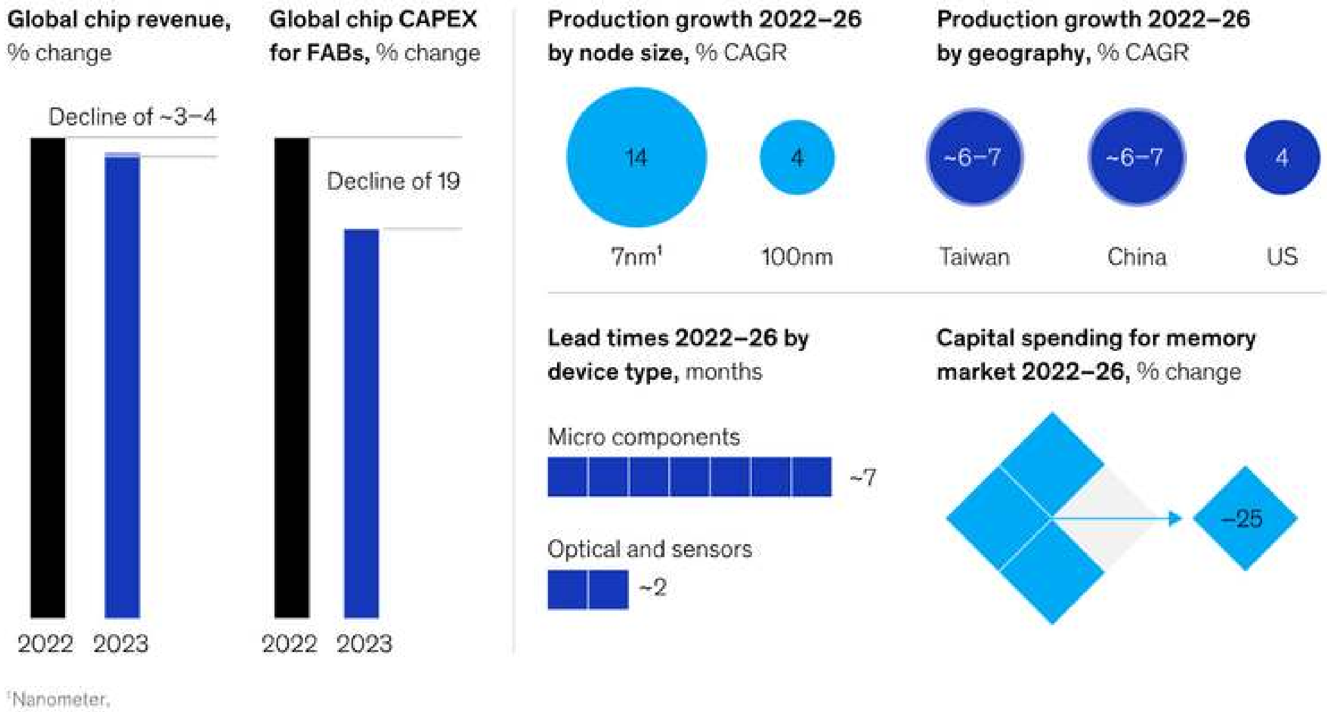


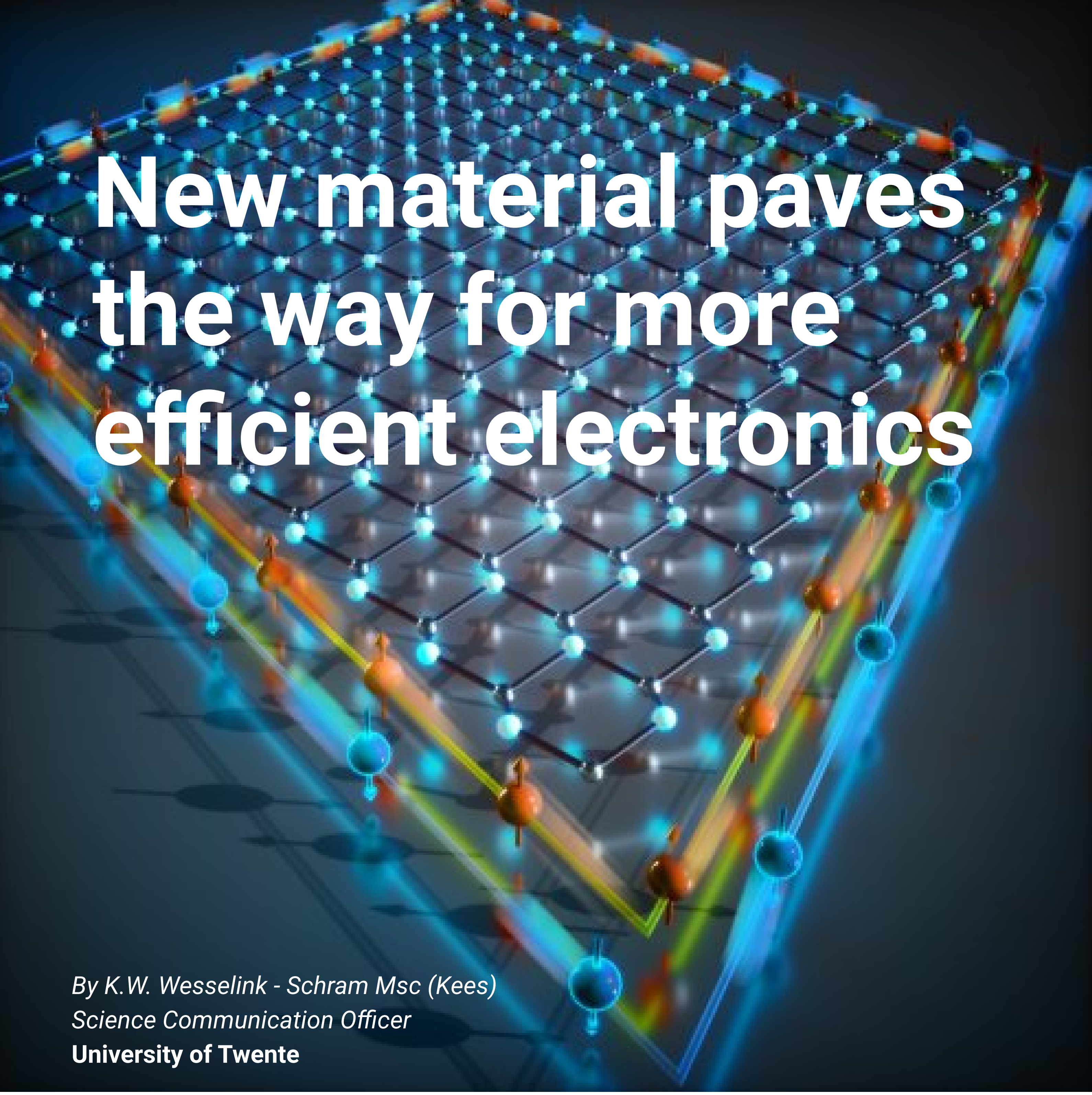
Figure 1: Global semiconductor chip shortage factors across metrics @ McKinsey & Company

If the recent past is any indication, supply challenges will remain high on C-suite agendas, with the most likely scenario involving waves of supply-and-demand mismatches across chips sizes, industries, and production centers.

Global semiconductor capacity grew at 7.6 percent a year on average from 2015 to 2022, but the growth is forecast to slow down to 4.9 percent a year from 2022 to 2026. Amid global macroeconomic headwinds, semiconductor industry revenues are predicted to fall by 3 to 4 percent in 2023. The biggest short-term capacity upgrades will take place in the Greater China area, including Taiwan. Elsewhere, new fabs in recently announced investments will take several years to come on line.

Most chip shortfalls are in mature technologies used in everyday applications such as cars, home appliances, and electronics

Read the full report



New material paves the way for more efficient electronics

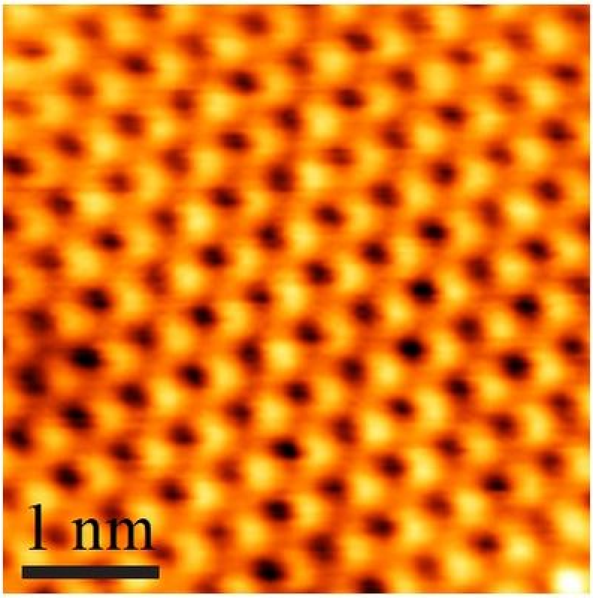
By K.W. Wesselink - Schram Msc (Kees)
Science Communication Officer
University of Twente

Researchers from the University of Twente proved that germanene, a two-dimensional material made of germanium atoms, behaves as a topological insulator. It is the first 2D topological insulator that consists of a single element. It also has the unique ability to switch between 'on' and 'off' states, comparable to transistors. This could lead to more energy-efficient electronics.

Topological insulators are materials with the unique property of insulating electricity in their interior while conducting electricity along their edges. The conductive edges allow electrical current to flow without energy loss. "At the moment, electronic devices lose a lot of energy in the form of heat, because defects in the material increase the resistance. As a result, your mobile phone can get uncomfortably hot", explains UT researcher Pantelis Bampoulis. While scattering at defects is allowed in normal materials, at the edges of 2D topological insulators, the scattering of electrons at defects is forbidden due to the unique topological protection mechanism. Therefore, electrical current in 2D topological insulators flows without dissipating energy. This makes them more energy-efficient than current electronic materials.

Creating Germanene

Germanene is such a 2D topological insulator. "Current topological insulators consist of complex structures from different types of elements. Germanene is unique in that it's made from just a single element", explains Bampoulis. To create this exciting material, the researchers melted germanium together with platinum. When the mixture cooled down, a tiny layer of germanium atoms arranged into a honeycomb lattice on top of the germanium-platinum alloy. This 2D layer of atoms is called germanene.



Scanning tunnelling microscopy topography of the honeycomb lattice of germanene

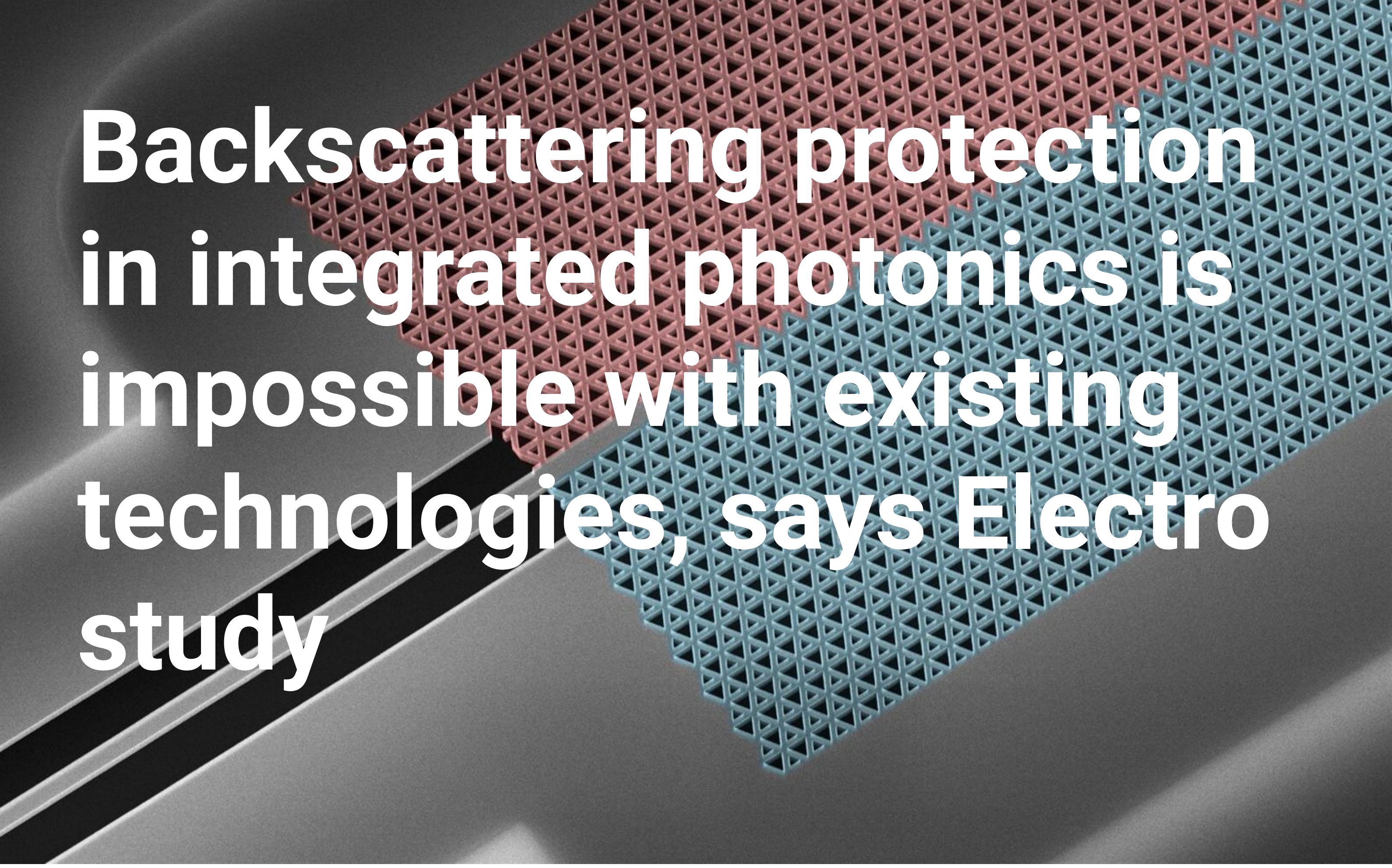
Topological Transistors

The researchers also discovered that the conducting properties of the material can be switched 'off' by applying an electric field. This property is unique for a topological insulator. "The possibility to switch between 'on' and 'off' states adds an exciting application case for germanene", says Bampoulis. It paves the way for designing topological field-effect transistors. These transistors could replace traditional transistors in electronic devices. Resulting in electronics that no longer heat up.

Reference

Quantum Spin Hall States and Topological Phase Transition in Germanene
Phys. Rev. Lett. 130, 196401 – Published 12 May 2023

Image 1: Artistic illustration of the dissipationless edge channels in Germanene. Credits: Ella Marushchenko



Backscattering protection in integrated photonics is impossible with existing technologies, says Electro study

Published in Nature Photonics, a new paper from the Photonic Nanotechnology group at DTU Electro reports the conclusion of a very careful experimental investigation: topological waveguides do not work – at least not with known materials. Who said that modern science does not appreciate negative results?

Researchers: Measure your losses

Reducing losses in photonic waveguides is important for reducing the energy consumption in data centers, and losses are outright showstoppers for a wide range of envisioned quantum technologies.

The limiting factor is backscattering due to unavoidable structural defects, and this has motivated intense worldwide research efforts into a new class of photonic waveguides: so-called photonic topological insulator edge modes.

Numerous papers claim “topological protection” in such waveguides, but something important was forgotten: measuring the losses.

Background

The field of integrated photonics has taken off in recent years. These microchips utilize light particles (photons) in their circuitry as opposed to the electronic circuits that, in many ways, form the backbone of our modern age. Offering improved performance, reliability, energy efficiency, and novel functionalities, integrated photonics has immense potential and is fast becoming a part of the infrastructure in data centers and telecom systems while also being a promising contender for a wide range of sensors and integrated quantum technologies.

Significant improvements in nanoscale fabrication have made it possible to build photonic circuits with minimal defects, but defects can never be entirely avoided, and losses due to disorder remain a limiting factor in today's technology.

Minimizing these losses could, for example, reduce the energy consumption in communication systems and further improve the sensitivity of sensor technology. And since photonic quantum technologies rely on encoding information in fragile quantum states, minimizing losses is essential to scale quantum photonics to real applications. So the search is on for new ways to reduce the backscattering or even prevent it entirely.

A one-way street for photons is impossible today

One suggestion for minimizing the loss of photons in an integrated photonic system is to guide the light through the circuit using topological interfaces that prevent backscattering by design.

"It would be very nice if it were possible to reduce losses in these systems. But fundamentally, creating such a one-way street for photons is a tough thing to do. In fact, as of right now, it is impossible; to do this in the optical domain would require developing new materials that do not exist today," says Associate Professor Søren Stobbe, Group Leader at DTU Electro.

Circuitry built from topological insulators would, in theory, force photons to keep moving forward, never backwards. The backwards channel would simply not exist. While such effects are well-known in niche electronics and have been demonstrated with microwaves, they have yet to be shown in the optical domain.

But full topological protection is impossible in silicon and all other low-loss photonic materials because they are subject to time-reversal symmetry. This means that whenever a waveguide allows transmitting light in one direction, the backwards path is also possible. This means that there is no one-way street for photons in conventional materials, but researchers have hypothesized that a two-way street would already be good enough to prevent backscattering.

"There has been a lot of work trying to realize topological waveguides in platforms relevant to integrated photonics. One of the most interesting platforms is silicon photonics, which uses the same materials and technology that make up today's ubiquity of computer chips to build photonic systems, and even if disorder cannot be entirely eliminated, perhaps backscattering can," says Søren Stobbe.

New experimental results from DTU Electro recently published in Nature Photonics strongly suggest that with the materials available today, this likely will not happen.

State-of-the-art waveguides offer no protection

Although several previous studies have found that it may be possible to prevent backscattering based on various indirect observations, rigorous measurements of the losses and the backscattering in topological waveguides were so far missing. The central experiments conducted at DTU were performed on a highly well-characterized state-of-the-art type of silicon waveguide, showing that even in the best waveguides available, the topological waveguides show no protection against backscattering.

"We fabricated the best waveguide obtainable with current technology—reporting the smallest losses ever seen and reaching minute levels of structural disorder—but we never saw topological protection against backscattering. If the two-way topological insulators protect against backscattering, they would only be effective at disorder levels below what is possible today," says Ph.D.-student Christian Anker Rosiek.

He conducted most of the fabrication, experiments and data analysis along with postdoc Guillermo Arregui, both at DTU Electro.

"Measuring the losses alone is crucial, but not enough, because losses can also come from radiation out of the waveguide. We can see from our experiments that the photons get caught in little randomly located cavities in the waveguide as if many of tiny mirrors had been randomly placed in the light's path. Here, the light is reflected back and forth, scattering very strongly on those defects. It shows that the backscattering strength is high, even in a state-of-the-art system, proving that backscattering is the limiting factor," says Guillermo Arregui.

Waveguide-material should break time-reversal symmetry

The study concludes that, for a waveguide to offer protection against backscattering, you would need the topological insulator to be constructed from materials that break time-reversal symmetry without absorbing light. Such materials do not exist today.

"We are not ruling out that protection from backscattering can work, and absence of evidence must not be confused with evidence of absence. There is plenty of topological physics, but moving forward, I believe researchers should take great care in measuring losses when presenting new topological waveguides. That way, we will get a clearer picture of the true potential of these structures. Suppose someone does indeed develop new, exotic materials that allow only propagation in one direction; our study has established the tests needed to claim real protection against backscattering," says Christian Anker Rosiek.

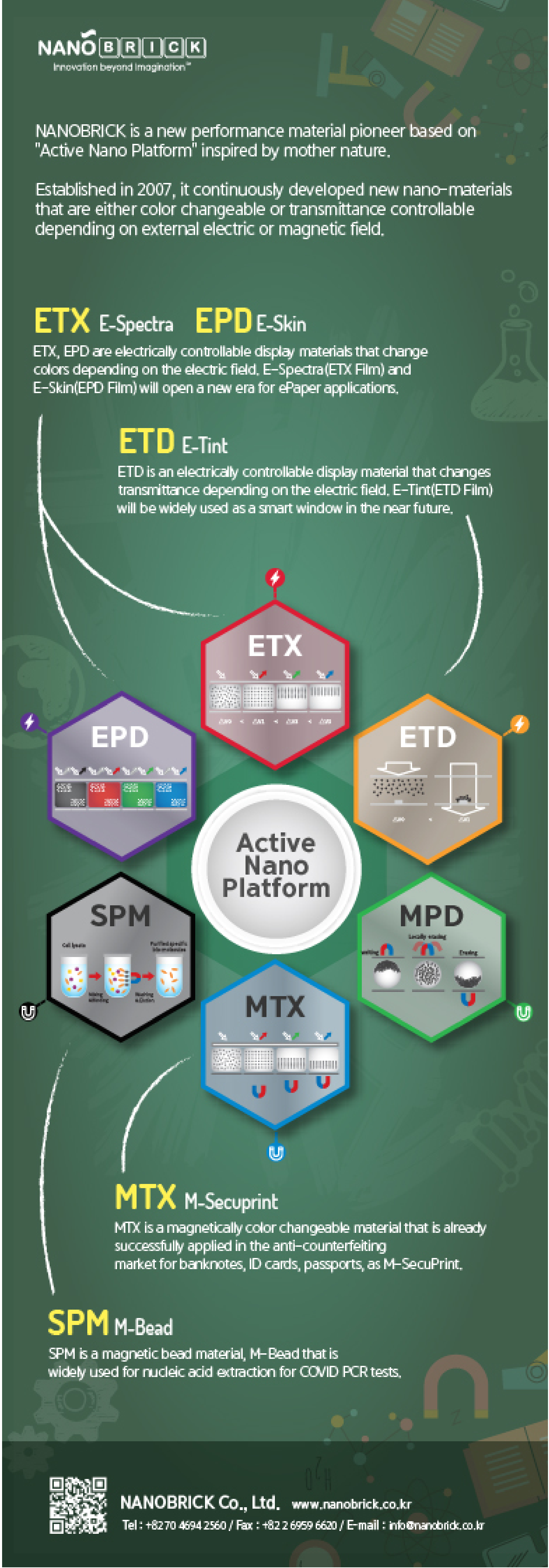
Reference

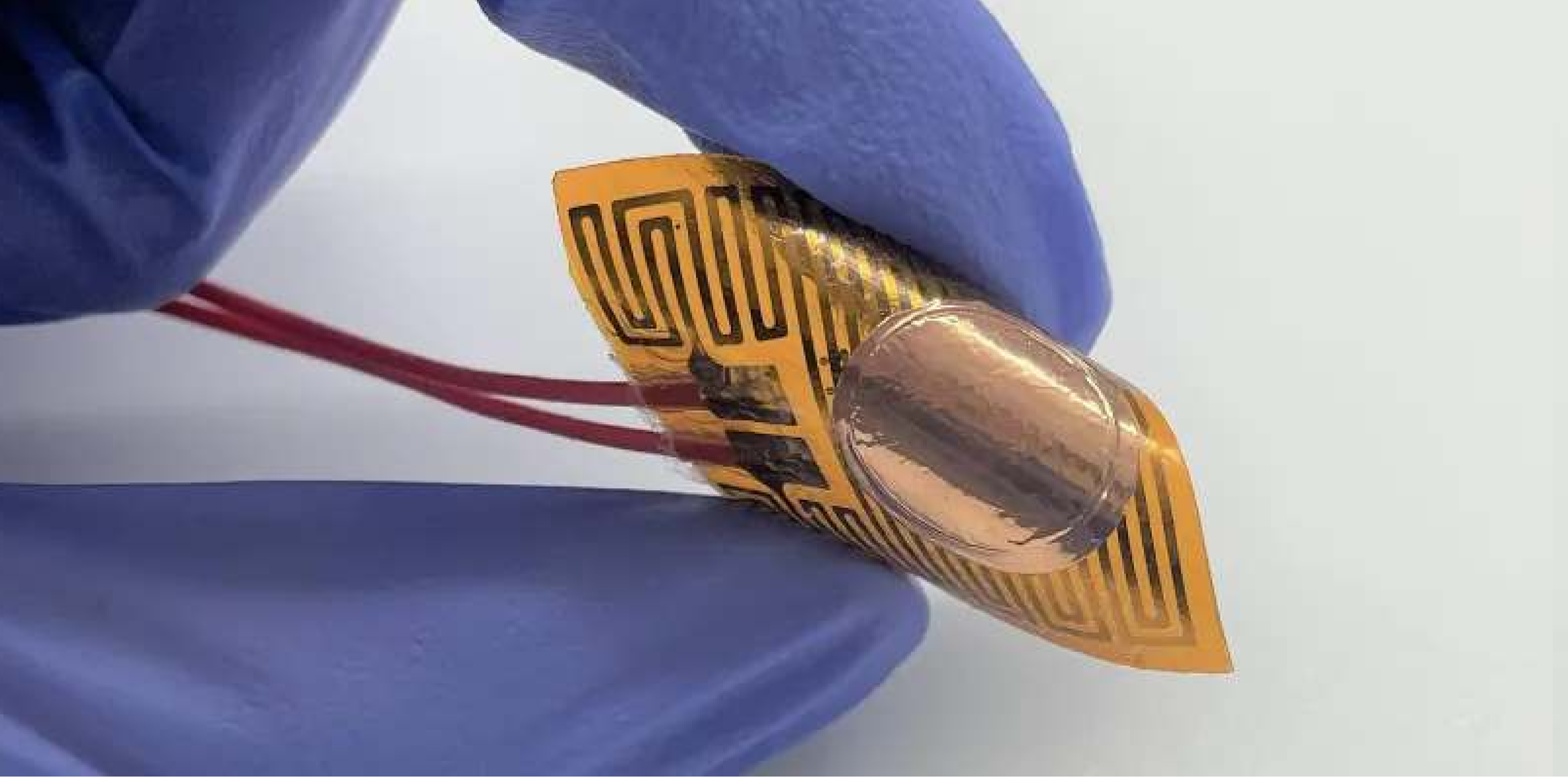
Observation of strong backscattering in valley-Hall photonic topological interface modes
Christian Anker Rosiek et al,
Nature Photonics (2023).
DOI: 10.1038/s41566-023-01189-x

Image

A scanning electron microscope image of one of the photonic waveguides studied by the DTU researchers. The waveguide is formed at the edge between two photonic topological insulators (blue and red) which are realized in nanoscale silicon membranes. It has been predicted that light propagating in such topological waveguides is immune to backscattering on structural defects, but this was never investigated experimentally. For the first time, the DTU team checked this in an experiment and found the opposite: strong backscattering. ©C. A. Rosiek

DTU ELECTRO
Department of Electrical and Photonics Engineering





As devices get smaller and more powerful, the risk of overheating and burning out increases substantially. Despite advancements in cooling solutions, the interface between an electronic chip and its cooling system has remained a barrier for thermal transport due to the materials' intrinsic roughness.

Sheng Shen, a professor of mechanical engineering at Carnegie Mellon University, has fabricated a flexible, powerful and highly reliable material to efficiently fill the gap.

"At first glance, our solution looks like any ordinary copper film, but under a microscope the novelty of our material becomes clear," explained Lin Jing, a Ph.D. student in the Department of Mechanical Engineering.

The material, composed of two thin copper films with a graphene-coated copper nanowire array sandwiched between them, is extremely user-friendly.

"Other nanowires need to be in situ grown where the heat is designed to be dissipated, so that their application threshold and cost is high," said Rui Cheng, postdoctoral researcher in Shen's lab. "Our film isn't dependent on any substrate. It is a free-standing film that can be cut to any size or shape to fill the gap between various electrical components."

The "sandwich" builds out of Shen's "supersolder," a thermal interface material (TIM) that can be used similarly as conventional solders, but with twice the thermal conductance of current state-of-the-art TIMs.

How a sandwich is transforming electronics

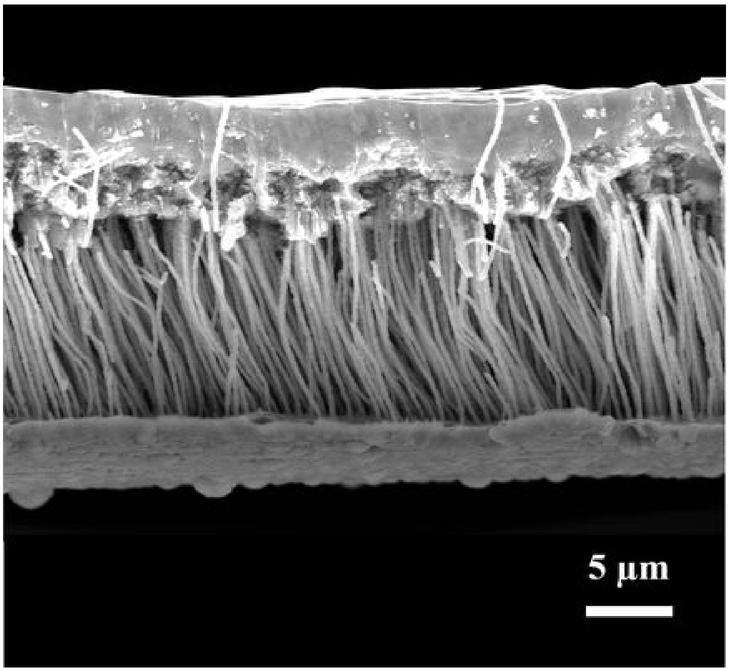
By: Kaitlyn Landram
College of Engineering
Carnegie Mellon University

By coating the "supersolder" in graphene, Shen's team enhanced its thermal transport capabilities and prevented the risk of oxidation, ensuring a longer service life. The "sandwich," compared to the thermal pastes/adhesives currently on the market, can reduce thermal resistance by more than 90% when considering the same thickness.

"At first glance, our solution looks like any ordinary copper film, but under a microscope the novelty of our material becomes clear."
— Lin Jing

Thanks to its ultrahigh mechanical flexibility, the "sandwich" can enable a wide range of applications in flexible electronics and microelectronics, including flexible LEDs and lasers for lighting and display, wearable sensors for communication, implantable electronics for monitoring health and imaging, and soft robotics.

Moving forward, Shen's team will explore ways to scale the material at an industrial level and lower its cost, while continuing to seek improvements.



Cross-section of the material under scanning electron microscope. @CMU

"We are very excited about this material's potential," Shen shared. "We believe that a wide variety of electronic systems can benefit from it by allowing them to operate at a lower temperature with higher performance."

This research first published in ACS Nano and is a collaborative effort with Tzahi Cohen-Karni, a professor of biomedical engineering and materials science and engineering, and Xu Zhang, a professor of electrical and computer engineering, both of Carnegie Mellon University.

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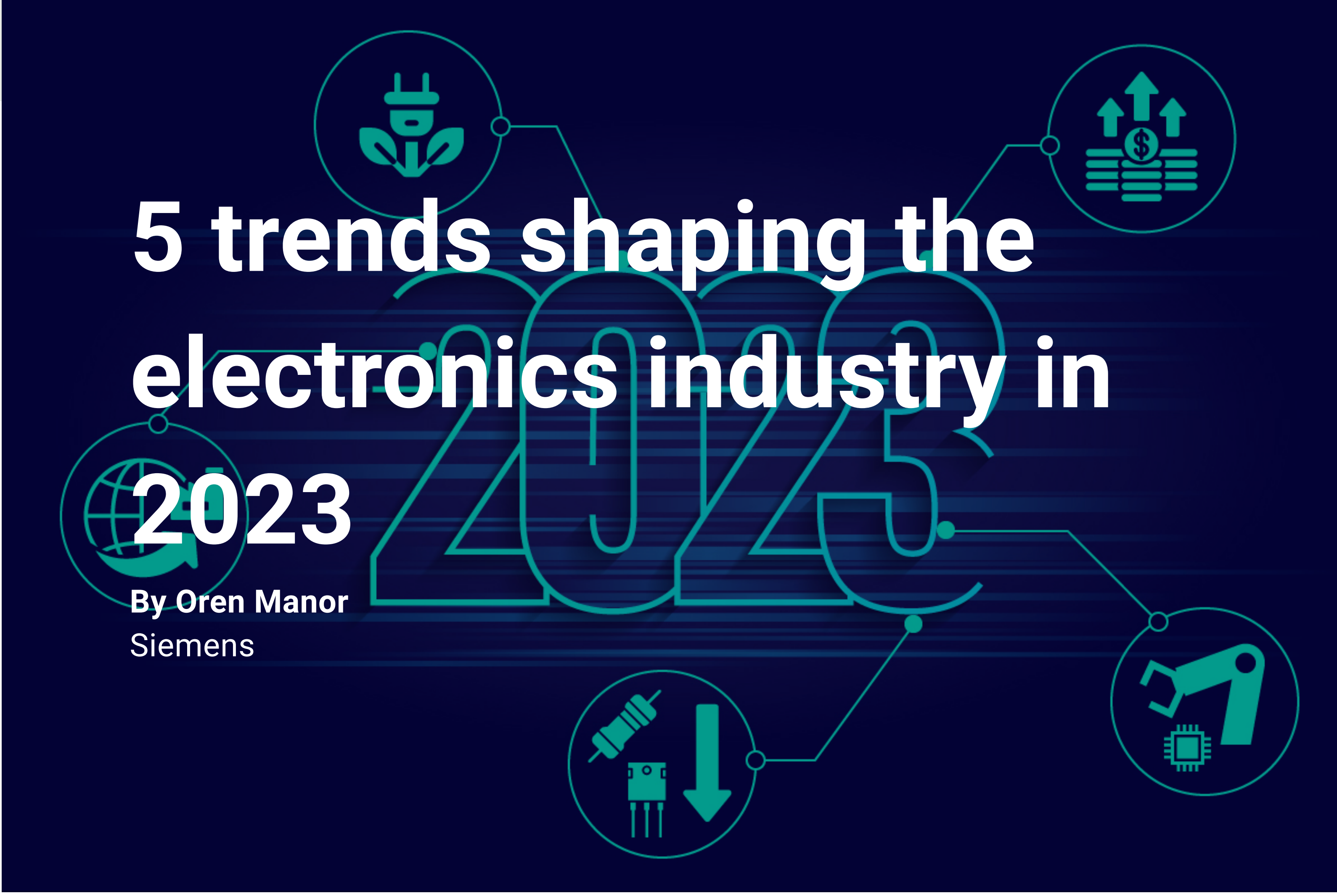
3D Graphene-Nanowire “Sandwich” Thermal Interface with Ultralow Resistance and Stiffness
Lin Jing, Rui Cheng, Raghav Garg, Wei Gong, Inkyu Lee, Aaron Schmit, Tzahi Cohen-Karni, Xu Zhang, and Sheng Shen
ACS Nano 2023, 17, 3, 2602–2610

Carnegie Mellon University



5 trends shaping the electronics industry in 2023

By Oren Manor
Siemens

What electronics manufacturers need to plan for in 2023

2022 was a year of global shifts. The Ukraine-Russia war, lingering COVID-19, the soaring cost of living and rising inflation have all had a major impact on the global economy, creating a sense of uncertainty and concern about the future. How are these affecting the electronics manufacturing industry? And what can we expect in 2023? We've broken it down and outlined the most important trends for electronics manufacturers to consider when building their business strategies for 2023 and beyond.

1. **Effects of inflation on electronics production**
2. **High-mix, low-volume manufacturing**
3. **Component shortages made worse by the shift away from China**
4. **Reshoring electronics production**
5. **Demand for sustainable electronics**

In today's ever-changing global manufacturing landscape, the need for digitalization is more acute than ever. Digitalized processes provide opportunities for optimization and efficiency even in times of strain and tension, and help manufacturers gain control of their operations across lines and production sites.

Read more

Continued from page 49

technology. The new inkjet module will be complementary to EVG's existing spin-coating modules and will be offered as an alternative option for dispensing NIL photoresists on substrates for high-volume-manufacturing (HVM) applications for NIL that have unique film deposition and uniformity needs. Through this partnership, EVG further cements its leadership in NIL with inkjet capabilities in a fully integrated and automated NIL solution.

"As both a pioneer and the established market leader in NIL, EVG partners with companies across the nanoimprint supply chain within its NILPhotonics® Competence Center to continually innovate NIL to support new applications and provide greater benefits for our customers," stated Dr. Thomas Glinsner, corporate technology director at EV Group. "By teaming up with Notion Systems, a specialized supplier of industrial, high-volume-production inkjet systems with an established and field-proven solution for the optical/display, electronics and semiconductor markets, we can reduce the time to market for incorporating this unique additive manufacturing approach to our own NIL portfolio, and more quickly bring the performance benefits of inkjet-based nanoimprint to our customers."

Inkjet coating enables new opportunities for NIL

Inkjet deposition can enable fine tuning of the resist amount and placement on a substrate to achieve uniform residual layer thicknesses after the NIL process, which in turn allows for high-quality pattern transfer. Inkjet deposition also allows for selective area resist coating, independent of the fill factor and structure size and height, making it ideal for applications like augmented/virtual reality (AR/VR) gratings with narrow spaces and unique topographies. This unique deposition approach can also reduce material consumption, resulting in significant cost savings associated with nanoimprint resists.

"We are pleased to be partnering with EV Group on this important development for the NIL market," stated Dr. Kai Keller, VP Business Development, Notion Systems. "With its high precision, drop placement accuracy and uniformity, our n.jet inkjet deposition technology in combination with EVG's SmartNIL technology provides the perfect match for supporting new NIL applications that cannot be met with current spin coating approaches. This collaboration provides EVG with a powerful new and unique additive manufacturing capability to support its customers' growing needs, while at the same time providing us with first-mover status in the rapidly growing NIL market."

Demonstrations of EVG's HERCULES SmartNIL UV-NIL system in conjunction with standalone inkjet deposition capabilities are available at the company's NILPhotonics Competence Center located at EVG's corporate headquarters. More information on EVG's HERCULES NIL system can be found at https://www.evgroup.com/products/nanoimprint-lithography/uv-nil-smartnil/hercules-nil/.

About Notion Systems

Notion Systems is a leading supplier of industrial ink jet coating systems. The n.jet inkjet platform from Notion Systems is used to produce printed circuit boards, OLED & QLED displays, sensors and high-quality 3D parts. Notion Systems relies on decades of experience bringing precise inkjet systems to customers and scaling up digital printing processes for functional materials. Notion Systems is based in Schwetzingen close to Heidelberg - Germany and works together with leading sales and service organizations worldwide with focus on Asia, Europe and North America. For more information, visit www.notion-systems.com.

SEOUL SEMICONDUCTOR

Seoul Semiconductor Unveils 2nd-generation LED Technology for Future Displays at Display Week 2023

About EV Group (EVG)

EV Group (EVG) is a leading supplier of equipment and process solutions for the manufacture of semiconductors, microelectromechanical systems (MEMS), compound semiconductors, power devices and nanotechnology devices. Key products include wafer bonding, thin-wafer processing, lithography/nanoimprint lithography (NIL) and metrology equipment, as well as photoresist coaters, cleaners and inspection systems. Founded in 1980, EV Group services and supports an elaborate network of global customers and partners all over the world. More information about EVG is available at www.EVGroup.com.

nature

Excitons in mesoscopically reconstructed moiré heterostructures

Shen Zhao, Zhijie Li, Xin Huang, Anna Rupp, Jonas Göser, Ilia A. Vovk, Stanislav Yu. Kruchinin, Kenji Watanabe, Takashi Taniguchi, Ismail Bilgin, Anvar S. Baimuratov & Alexander Högele
Nature Nanotechnology (2023)

Open Access
Published: 27 March 2023

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