THE LATEST IN SCIENCE AND TECHNOLOGY RESEARCH

Volume 12, Issue 7

S&T News Bulletin

August 2022

FEATURED ARTICLES

ARTICLE SUMMARIES

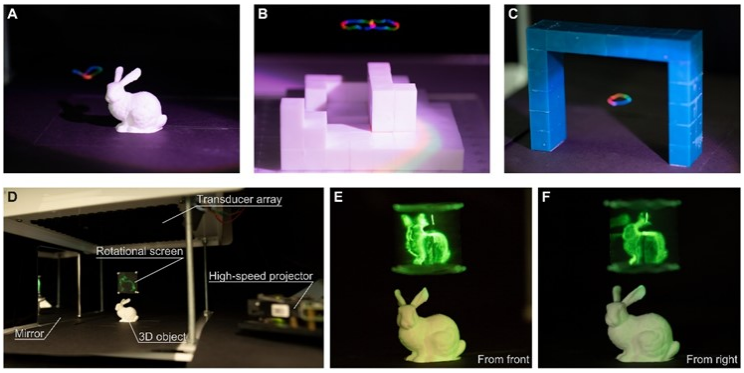
CRITICAL TECHNOLOGY AREAS:

OTHER AREAS OF INTEREST:

Featured Article 1

Acoustic Levitation Achieved in Complex Environments, Which Could Lead to Revolutions in Mixed Reality and 3D Printing

From: University College London, 17 June 2022 | Article DOI



Examples of mixed reality applications using high-speed acoustic holography in the presence of sound-scattering objects. Credit: University College London.

Using sound to levitate something when there are other objects in the way has been shown for the first time by UCL researchers and could lead to advances in the manufacturing and entertainment sectors.

The findings open up possibilities for more advanced interactive entertainment through virtual reality and mixed reality at theme parks, arcades and museums. Technology using 3D levitation could lead the way to fully immersive real-world simulations without the need for clunky headsets or goggles.

The technique could also improve 3D printing by allowing manufacturers to build more sophisticated, multi-material objects as opposed to the layer-by-layer, single material build approach that is currently used.

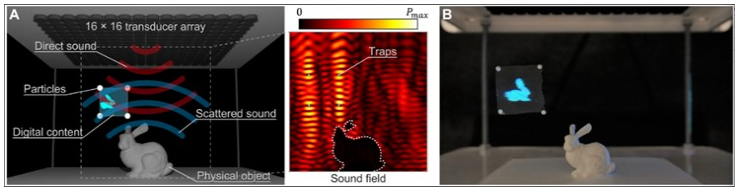
Previous research has already shown that levitation using soundwaves is possible. Objects can be held and moved in mid-air using the force from high intensity ultrasound waves (which have a frequency higher than humans can hear) to hold something in place, known as acoustic levitation. This technique also makes it possible to create interactive 3D images, such as holograms, in mid-air that you can see, feel and hear.

However, until now, this could only be done in an empty space; anything in the way of the soundwave would cause the levitated objects to fall.

For the paper, published in Science Advances, the research team has gone one step further by showing how acoustic levitation is possible outside of such a controlled environment, and can be achieved with objects nearby, such as walls, a car dashboard or other common appliances.

Co-author Dr. Diego Martinez Plasencia (UCL Computer Science) said: “In the past, our 3D displays had to exist in a vacuum, but now we can create 3D content right there in front of you. No eye-wear or tricks required, simply 3D shapes sharing the very space in which we live.”

Lead author Dr. Ryuji Hirayama (UCL Computer Science) said: “Until now, we’ve only been able to demonstrate acoustic levitation for virtual reality and holograms in controlled environments without any other objects nearby that could interrupt and scatter soundwaves. In this paper, we’ve shown how we can float objects and even create digital content such as holograms in real-world environments by accounting for nearby objects in real-time. It opens up the possibilities for fully immersive virtual reality experiences and interactive holograms.”



Diagrams of experimental levitation traps created in the presence of physical objects. Credit: University College London.

The team levitated different objects including polystyrene beads, water and fabric, by combining two new steps. Firstly, they computed how the soundwave's path looked at any time when different speakers are turned on, and how they bounce off objects in the environment.

The second step involved working out a fast technique to turn the speakers quickly off or on so that after the soundwave had scattered, the environment was able to hold the object in air.

This technique could modernize how products are designed and built through multi-material 3D printers. Current printers use one dispenser to release each material in the object. This is particularly important to avoid material cross-contamination when chemicals or biological materials are used.

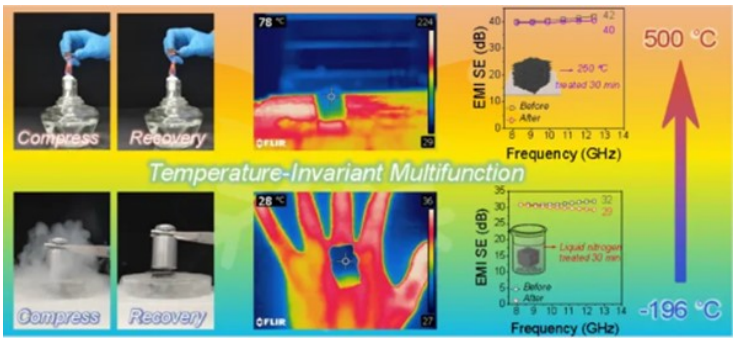
Acoustic levitation would enable numerous materials to be used without cross-contamination or moving the dispenser inside the fabrication space (contactless fabrication). The technique makes building the object more flexible, as material can be added from any direction, avoiding layer-by-layer fabrication and allowing for more sophisticated multi-material objects to be produced.

Lead researcher Sri Subramanian (UCL Computer Science) said: “I am excited for how this work opens the door for mixing many different materials in additive manufacturing and 3D printing. Acoustic levitation has huge potential in precision manufacturing and this work paves the way for realizing this opportunity.”

Featured Article 2

New Fabrication Technique for Carbon-Based Aerogel Material Preserves Functionality, Superelasticity at Extreme Temperatures

From: Sichuan University *via Tsinghua University Press*, 14 July 2022 | Article DOI



Diagrams and images showing the new aerogel’s resiliency in extreme conditions. Credit: Tsinghua University Press.

Aerogel materials serve a vital role as protective materials needed for many fields, including as electromagnetic interference shielding material for 5G technology, thermally insulating material in high-rise buildings and infrared stealth material for military applications. Current protective materials, however, often lose their protective functions under harsh conditions such as extreme temperatures, rendering them ineffective. Other protective materials lose their elasticity, leading to similar performance issues. Now, new aerogel materials that can maintain their functionality and superelasticity under extreme temperatures have been developed by a team of researchers from Sichuan University.

“We aimed to solve the problem that the performance of conventional protective aerogel materials deteriorates severely under harsh working conditions,” said corresponding author Hai-Bo Zhao, professor in the College of Chemistry at Sichuan University.

Prior to Zhao’s team’s developments, polymer-based foam materials were commonly used as protective materials. These materials exhibited the positive traits of superelasticity and high compressibility but were unable to maintain these properties after the melting temperatures of the polymers. Other commonly used materials were metallic and ceramic foams, which were stable across temperature ranges in a way that their polymer-based foam counterparts were not but did not have the elasticity needed to be practical.

An approach that came closer to a scalable solution involved using carbon aerogels, which have characteristics that lend themselves well to thermal insulation and electromagnetic interference, such as high specific surface area, low density, good electrical conductivity and chemical and thermal stability. However, carbon aerogels have limitations due to certain inherent properties.

Carbon nanotubes became a popular way to construct superelastic carbon aerogels, since they could maintain the needed properties at high temperatures, but because the preparation required so many steps, the methods were not scalable.

By focusing on the microstructure design, Zhao's team was able to develop a polymer aerogel with superelasticity that functioned in a temperature range of -320 to 932 degrees Fahrenheit (-196 to 500 degrees Celsius) with a process that was scalable and practical.

"Unlike most carbon aerogels reported previously that usually possess poor mechanical properties, the prepared aerogel materials exhibit temperature-invariant superelasticity while maintaining multifunctional protective performance," said Zhao, who is also affiliated with the National Engineering Laboratory for Eco-Friendly Polymeric Materials in Sichuan and with the Collaborative Innovation Center for Eco-Friendly and Fire-Safety Polymeric Materials.

Zhao's method uses bidirectionally oriented carbon/carbon aerogel composite multi-walled carbon nanotubes - in other words, a combination that allows for combining the positive traits of carbon aerogels with the positive traits of carbon nanotubes - with a highly ordered carbon skeleton, one of the key differentiators between this new method and previous methods. Their scalable method of achieving the desired microstructures - specifically, highly oriented arch structures - involves a bidirectional freezing and carbonization process to develop the carbon/carbon aerogels.

"The reported aerogel materials maintain superelasticity, high electromagnetic interference shielding effectiveness, thermal insulation and infrared stealth in a wide temperature range from -320 to 932 degrees Fahrenheit (-196 to 500 degrees Celsius) and after cyclic compression for hundreds of times," Zhao said. "The most exciting aspect is the economic and simple preparation process, which laid the foundation of the potential practical application of the material."

Zhao said that the next step is to make the aerogels available for use in commercial, military and other contexts. "We would like to promote the industrialization of the reported aerogel and further the application in 5G technology, high rise buildings, military use and more," he said.

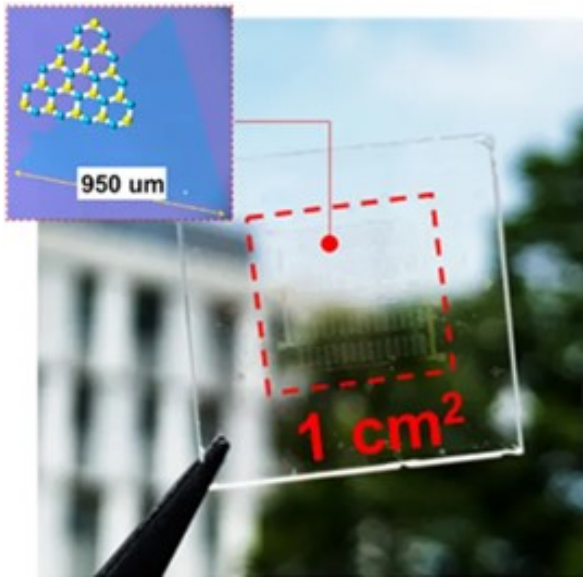
The other authors of the paper were Bo-Wen Liu, Min Cao, Yi-Ying Zhang and Yu-Zhong Wang, all of Sichuan University.

The National Natural Science Foundation of China, the Fundamental Research Funds for the Central Universities, the Young Elite Scientists Sponsorship Program by CAST and the 111 Project funded this work.

Featured Article 3

Highly Transparent Solar Cells, Fabricated Using Ultra-Thin 2D Conducting Layer, Could Vastly Expand Solar Panel Adoption

From: Tohoku University, 4 July 2022 | Article DOI



Prototype highly-transparent solar cell with schematic showing its 2D atomic sheet construction. Credit: Tohoku University.

Solar panels often get a bad rap for spoiling the appearance of homes and businesses. Yet, this may be about to change.

A research group has fabricated a highly transparent solar cell with a 2D atomic sheet. These near-invisible solar cells achieved an average visible transparency of 79%, meaning they can, in theory, be placed everywhere - building windows, the front panel of cars, and even human skin.

Scientists have long sought to develop transparent solar cells, but the suitable materials have not existed thus far.

To make the solar cell, the team controlled the contact barriers between indium tin oxide (ITO), one of the most widely used transparent conducting oxides, and a monolayer tungsten disulfide. They coated various thin metals onto the ITO and inserted a thin layer of tungsten oxide between the coated ITO and the tungsten disulfide.

"The way in which we formed the solar cell resulted in a power conversion efficiency over 1,000 times that of a device using a normal ITO electrode," pointed out Toshiaki Kato, corresponding author of the paper and associate professor at Tohoku University's Graduate School of Engineering.

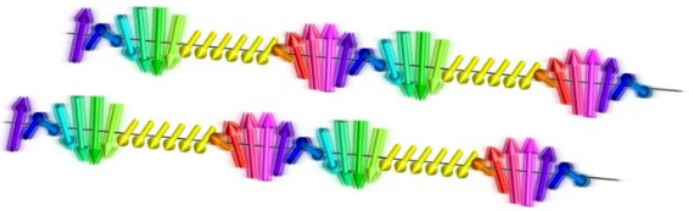
The group's efforts did not stop there. They also explored how their solar cell can be expanded for use in an actual solar panel. "We discovered the appropriate design modifications needed to avoid an unexpected voltage drop that accompanies increasing the device area," said Kato.

S&T Article Summaries

Future Generation Wireless Technology (FutureG)

Magnetic Superstructures Unlock Higher Frequencies Critical to Post-5G Wireless Networks

From: Osaka Metropolitan University, 17 June 2022 | Article DOI



Visualization of multiple resonance. Credit: Osaka Metropolitan University.

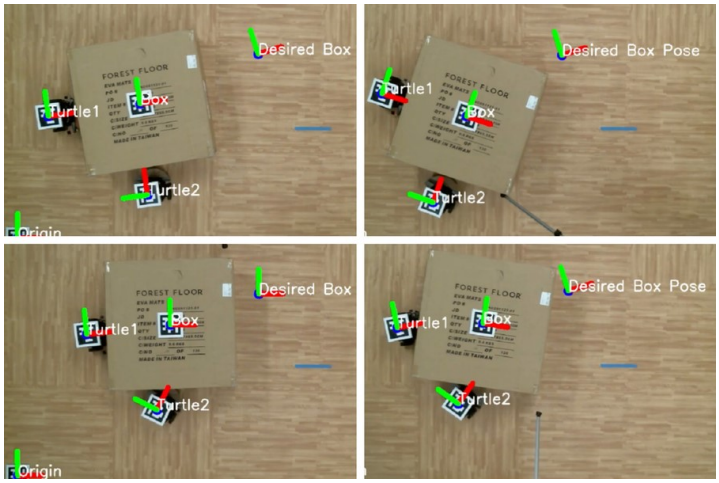
The technology that underpins 5G wireless communications systems needs to evolve beyond current limitations before 6G can become a reality. Specifically, the frequency band will need to expand from the current few Gigahertz (GHz) to over 100 GHz. Such high frequencies are not yet possible given that existing magnetic materials used in communication equipment can only resonate and absorb microwaves up to approximately 70 GHz within any practical-strength magnetic field. Using broadband microwave spectroscopy, scientists from Osaka Metropolitan University in Japan detected unprecedented collective resonance modes at remarkably high and broad frequency bands in chiral magnetic crystal $CrNb_3S_6$. They found that resonance could occur in this material at frequencies beyond 5G with a small change in the strength of the magnetic field. Utilizing a multiple resonance mode with this new material, the researchers discovered that the frequency spontaneously *increases* as the magnetic field strength *decreases*. This unprecedented phenomenon could allow a boost to over 100 GHz within a relatively weak magnetic field, critical for achieving practical post-5G operability.

Trusted AI & Autonomy | Robotics

General-Purpose Optimization Framework for Accelerating the Development of Virtually Any Autonomous Robotic System

From: Massachusetts Institute of Technology, 21 June 2022 | Article Paper

Autonomous robotic systems have historically been developed and optimized via an ad hoc process specific to a particular system or function through countless trial-and-error simulations. This approach could be summed up as, “given a design, what is the performance?” Massachusetts Institute of Technology (MIT) researchers have developed a general-purpose optimization framework that instead asks, “given a desired performance, what design is needed to achieve it?”



Hardware demonstration in which the tool automatically optimizes the performance of two robots working together to move a heavy box . Credit: Massachusetts Institute of Technology.

Compatible with virtually any autonomous robotic system, this optimization framework utilizes an automatic differentiation tool to quickly and efficiently analyze and optimize a robot’s underlying code. Originally created to train artificial neural networks, in MIT’s framework it is used to automatically evaluate each parameter of an autonomous robot’s code for potential tweaks which, if implemented, could improve its performance. In a relatively simple experiment it performed 3 times faster than conventional optimization techniques, but in a relatively complex experiment it performed 20 times faster, meaning the more complex the code, the greater the time savings.

Electroluminescent Artificial Muscles Allow Insect-Scale Robots to Fly, Be Tracked, and (Eventually) Communicate

From: Massachusetts Institute of Technology, 1 June 2022 | Article Paper

Tiny microscale robots, weighing barely more than a paper clip, are potentially useful in myriad applications such as searching for victims in the rubble of a collapsed building.

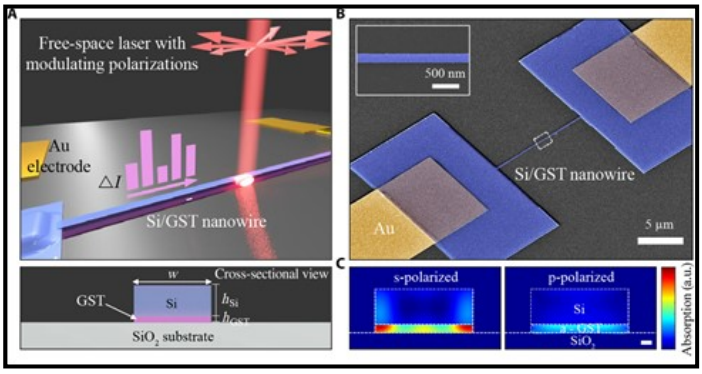
Prototype firefly-inspired insect-scale flying robot. Credit: Massachusetts Institute of Technology.

However, due to their size and weight restrictions microscale robots are unable to carry traditional components - such as radios and cameras - typically employed by larger robots. This makes it difficult to communicate and track the microscale robots in anything other than a tightly controlled and calibrated environment. Scientists at MIT, taking inspiration from fireflies, have designed and built soft, electro-luminescent artificial muscles that control the robots' wings while emitting colored light. The electroluminescent component, which increases the robot's weight by only 2.5 percent and has no effect on its flight performance, allows precise external tracking via basic smartphone cameras, obviating the need for bulky and expensive infrared cameras that are ill-suited to outdoor applications. Additionally, the electroluminescence could eventually enable the robots to communicate wirelessly among themselves and with their operators, for instance to relay their findings or request assistance during search and rescue operations.

Microelectronics

Novel Light Polarization Technique Powers Ultra-Fast Photonic Computing Processor

From: University of Oxford, 15 June 2022 | Article DOI Video



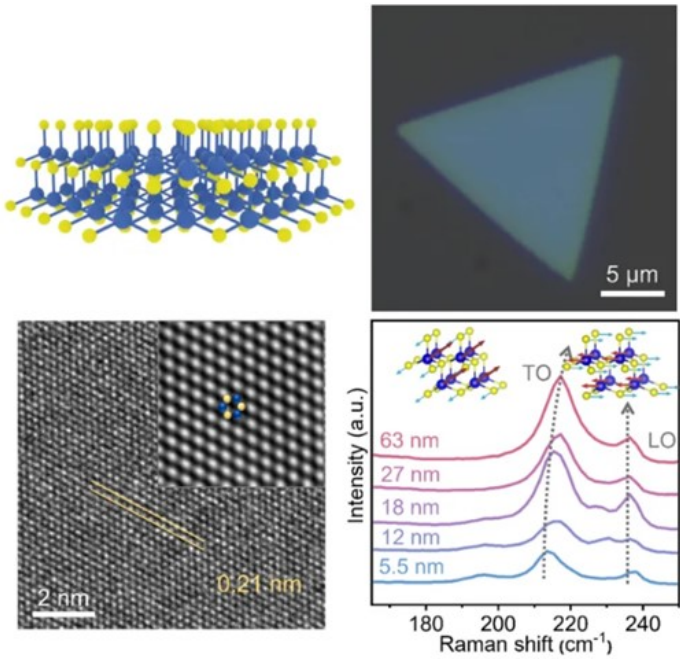
Schematics and scanning electron microscope view of the new technique. Credit: University of Oxford.

Researchers at the University of Oxford in the United Kingdom have developed a method of combining polarized light with nanowires to maximize information storage density and computing performance. Polarization, like wavelength, is a fundamental property of light within which information can be encoded and (de)multiplexed. However, while wavelength-based systems have seen widespread adoption, polarization-based active photonics have not seen notable progress because tunable and polarization-selective nanostructures have been elusive. To address these challenges, the researchers developed a hybridized-active-dielectric nanowire, a hybrid glassy material which exhibits switchable material properties upon the illumination of optical pulses. Because each nanowire shows selective responses to a specific polarization direction information can be simultaneously processed using multiple polarizations in various directions.

Using this concept, the researchers developed the first photonic computing processor to utilize polarizations of light. This resulted in an enhancement in computing density by several orders of magnitude compared to that of conventional electronic chips due to the ultrafast optical pulses used to modulate data through the nanowires.

Controlled Synthesis of Crystal Flakes Could Lead to New High-Performance Semiconductors

From: Shanghai Jiao Tong University et al. *via Tsinghua University Press*, 3 June 2022 | Article DOI



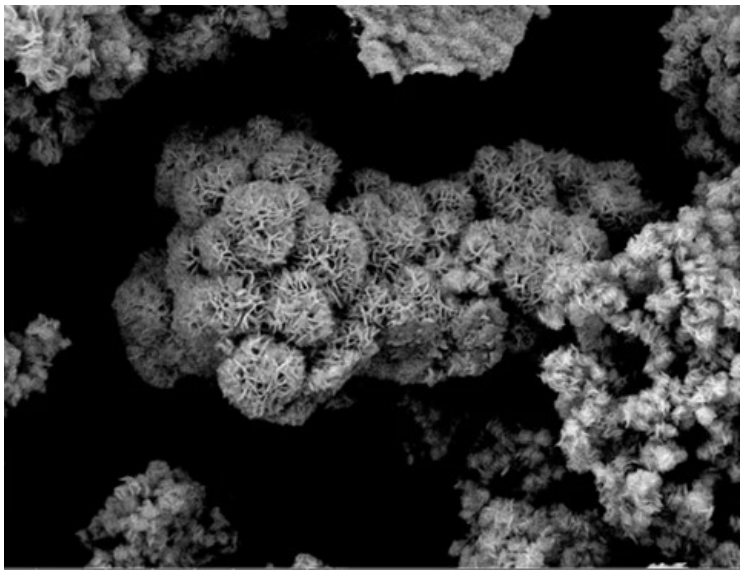
2D InAs single crystals. Credit: Tsinghua University Press.

Indium arsenide (InAs) is a narrow bandgap semiconductor with properties useful for high-speed electronics and highly sensitive infrared photodetectors. However, while most existing semiconductor materials are formed in 2D, layered structures, InAs typically has a 3D lattice structure which makes it challenging to transform into the ultrathin 2D films necessary for such intricate and complex applications. Researchers led by Lin Zhou of Shanghai Jiao Tong University in China utilized several techniques to fine-tune the synthesis of InAs to combine the advantages of InAs and typical 2D layered materials. The final 2D InAs material takes the form of triangular flakes, roughly five nanometers thick, or about 0.0007x the size of a single red blood cell. "Prior to this work, high-quality 2D InAs - meaning less than 10 nanometers thick - had not been reported, let alone a scalable synthesis of 2D InAs single crystals with unique optical and electronic properties," Zhou said. "Our work paves the way for miniaturization of InAs-based devices and integrations."

Renewable Energy Generation & Storage

Robust New Catalyst Combo Enables Conversion of Non-Purified Carbon Dioxide to Valuable Methanol on Industrial Scale

From: Vienna University of Technology, 28 June 2022 | Article



Molybdenum disulphide, a robust catalyst for converting CO_2 to methanol, seen here through a scanning electron microscope. Credit: Vienna University of Technology.

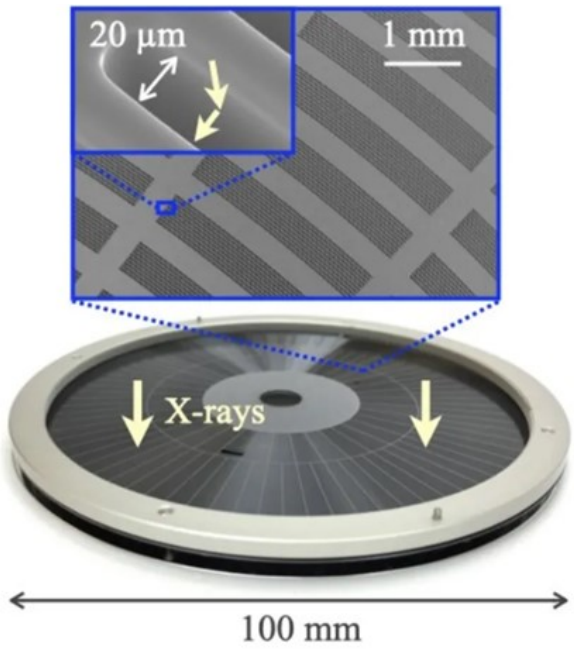
Carbon dioxide (CO_2) is a potent greenhouse gas, and its removal or isolation from Earth's atmosphere is considered a viable method of partially mitigating the effects of climate change. Methanol is a valuable chemical with numerous industrial applications that is normally produced from raw fossil fuels. With the help of special catalysts, captured CO_2 can be converted into liquid methanol, simultaneously reducing atmospheric CO_2 and sustainably generating more fuel. The copper-based catalysts in current use for these processes quickly lose their effectiveness unless the CO_2 is pre-treated and purified of foreign materials. This has historically precluded efficient conversion efforts in such locations where CO_2 is most concentrated, such as the exhaust of large industrial plants.

A research team from Vienna University of Technology in Austria was able to show that a new catalyst based on sulfur and molybdenum is robust enough to allow the methanol conversion in these types of environments without costly pre-treatment or filtration. "Methanol is an attractive product. It is liquid at room temperature, so it can be stored without any problems. It is needed in industry; up to now it has normally been produced from fossil raw materials," says Karin Föttinger from the University's Institute of Materials Chemistry. The method has now been patented, and it will now be scaled up in collaboration with commercial partners hoping for a cost-effective reduction in harmful industrial greenhouse gas emissions.

Space Technology

Microscopic Mechanical Construction Technology Repurposed to Drastically Reduce Weight of X-Ray Space Telescopes

From: Tokyo Metropolitan University, 27 June 2022 | Article DOI



Microscopic construction of the X-ray sensor shown in increasing detail. Credit: Tokyo Metropolitan University.

Angular resolution, or the angle that two light sources can make with a detector and still be distinguished, is a key factor in optical sensors such as the X-ray telescopes used for astronomical observation. With common fabrication methods, any increase in resolution incurs a significant increase in weight, which can make launching the optics to space (where X-rays are not yet absorbed by Earth's atmosphere) prohibitively expensive. A team led by scientists from Tokyo Metropolitan University in Japan have overcome this limitation by using a technology originally designed to build microscopic mechanical actuators to instead etch intricate patterns into silicon wafers which collect and direct incoming X-rays. The team is aiming for a finished sensor with a total weight of only 110 pounds (50 kilograms), a fraction of the weight of comparable existing telescopes, which could drastically reduce the cost of launching into space.

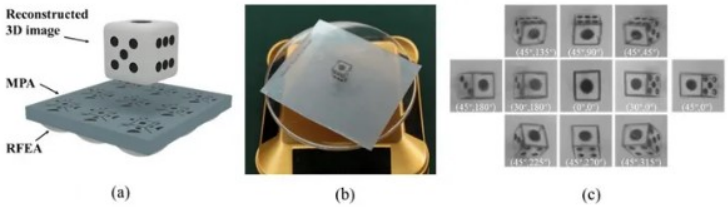
Human-Machine Interfaces

Ultra-Thin Film Enables Display of Detailed 3D Images, Viewable from All Angles Without Special Reading Devices

From: Soochow University *via Optica Publishing Group*, 23 June 2022 | Article DOI

Researchers at Soochow University in China have developed a new ultra-thin film that creates detailed 3D images viewable under normal illumination without any special reading devices.

The images appear to float on top of the film and can be clearly viewed from all angles. With additional development, the new glass-free approach could be used as a visual security feature or incorporated into virtual or augmented reality devices.



Researchers created a 3D image of a six-sided die with 360-degree visibility. Credit: Soochow University.

"Our ultra-thin, integrated reflective imaging film creates an image that can be viewed from a wide range of angles and appears to have physical depth," said researcher Su Shen. "It can be easily laminated to any surface as a tag or sticker or integrated into a transparent substrate, making it suitable for use as a security feature on banknotes or identification cards."

Integrated Sensing & Cyber

Prototype Biometric Sensor Identifies and Authenticates Users by Analyzing Chemical Composition of Their Breath

From: Kyushu University, 22 June 2022 | Article DOI

Biometric authentication, such as fingerprint or iris scans, is commonly used in security systems to protect access to sensitive devices, areas, or information. These techniques all rely on the physical uniqueness of each individual person, but each method has inherent weaknesses. A malicious actor could replicate a trusted person's fingerprint to gain unauthorized access, or a legitimate user may become unrecognizable due to an injury or other factor. In an effort to overcome such limitations, researchers from Kyushu University in Japan have developed an artificial nose that acts as a biometric sensor. It uses a 16-channel sensor array to detect the chemical composition of a user's breath. A machine learning algorithm then analyzes the results to create a profile, unique to that individual, for implementation in identification and authentication systems. This prototype achieved a 97% success rate in a group of 20 test subjects, but only with pre-experiment fasting. They are now investigating increasing the number of sensors in order to achieve similar results regardless of diet or fasting, a necessary step to real-world use.

Dual-Shutter Optical Microphone Captures Isolated Sound from Multiple Sources Without Interference

From: Carnegie Mellon University, 21 June 2022 | Article Paper Multimedia Site

Even the most high-powered and directional microphones are unable to eliminate nearby sounds, ambient noise, and acoustic interference when capturing audio, and existing optical microphones require prohibitively expensive, high-framerate cameras to function. A novel system designed by Carnegie Mellon University researchers combines a laser with two relatively inexpensive, low-framerate cameras to detect sound by analyzing subtle surface vibrations. The laser is aimed at a surface being vibrated by a sound, producing a reflection pattern that each camera captures. A computer vision algorithm then analyzes and compares the differences between the two cameras to reconstruct the original sound. By using relatively low-framerate cameras, both the cost and bandwidth requirements are reduced compared to existing systems, potentially enabling new applications for computer vision. For example, sound engineers could monitor the performance of individual instruments within a full orchestra or manufacturers could continuously monitor machines on a factory floor to spot early signs of potentially costly malfunctions or mechanical failures.

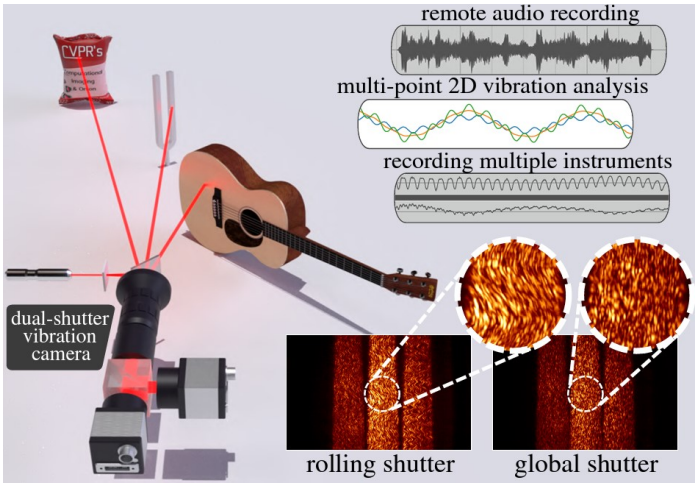


Diagram and detail images showing the dual-shutter technique. Credit: Carnegie Mellon University.

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