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NOESIS

Technical Magazine

Department of

Mechanical Engineering

Year 2022-23

Vol-1, Issue -1

Hon. Shri. Anil Bagane
Executive Director

Executive Director Message

I am very happy to know that Mechanical Engineering Department of Sharad Institute of Technology is bringing out the fifth edition of technical Magazine '**NOESIS**' for the year 2022- 2023. Sharad Institute of Technology has made all efforts towards the core areas of excellence in latest multidisciplinary technology with aidingefforts. I am sure that this technical magazine play important role to update students with latest technologies in the globe. Wish you all the best.

Shri. Anil Bagane

Executive Director
SITCoE, Yadrav

Dr. S. A. Khot
Principal

Principal Message

I am extremely pleasant to know that mechanical engineering department publish fifthtechnical magazine '**NOESIS**'. I congratulate HoD, faculty and students of mechanical engineering department to publish fifth edition of technical magazine. I appreciate all of you for working together as a team.

I wish a very best of luck to the team of Technical Magazine.

Dr. S. A. Khot

Principal
SITCoE, Yadrav

Dr. S. D. Patil
HOD, Mechanical

HoD's Message-

I feel happy to introduce fifth issue of technical magazine prepared by students of Mechanical EngineeringDepartment. We at SITCoE promise of increasing the knowledge, enhancing the critical thinking, ability to change information into knowledge and power of analyzing the things technically of each and every individual of ever changing society through students.

This magazine will reflect the intellectual as well as creative ideas of the students. Wish you all the best for NOESIS team.

Dr. S. D. Patil

Head of Mechanical Dept.
SITCoE, Yadrav

Mr. A. S. N. Husainy
Mechanical Engineering
Department

Editor's Message

It is my pleasure and great privilege to publish fifth issue of technical magazine 'NOESIS'.Fifth issue of technical magazine be a snapshot of the various multidisciplinary technologies associated with mechanical Engineering. We would like to place on record our gratitude and heartfelt thanks to all student and faculties from mechanical department, those who have contributed to make this effort in a successful one.

We profusely thank our Hon. Executive Director Mr. Anil Bagane, Principal Dr. S. A. Khot and head of mechanical engineering department Dr. S. D. Patil for giving support and encouragement and a free hand in this Endeavour.

Mr. A. S. N. Husainy
Assistant Professor
Mechanical Engineering Dept.

Solar cell keeps working long after sun sets

Mr. Ashish Magdum, Mr. Aditya Amane, Mr. Krishna Kupade, Mr. Ritwik Desai, Miss. Diya Sanadi

At night, solar cells radiate and lose heat to the sky, reaching temperatures a few degrees below the ambient air. The device under development uses a thermoelectric module to generate voltage and current from the temperature gradient between the cell and the air. This process depends on the thermal design of the system, which includes a hot side and a cold side.

"You want the thermoelectric to have very good contact with both the cold side, which is the solar cell, and the hot side, which is the ambient environment," said author Sid Assawaworrarit. "If you don't have that, you're not going to get much power out of it."

The team demonstrated power generation in their device during the day, when it runs in reverse and contributes additional power to the conventional solar cell, and at night.

The setup is inexpensive and, in principle, could be incorporated within existing solar cells. It is also simple, so construction in remote locations with limited resources is feasible.

"What we managed to do here is build the whole thing from off-the-shelf components, have a very good thermal contact, and the most expensive thing in the whole setup was the thermoelectric itself," said author Zunaid Omair.

Using electricity at night for lighting requires a few watts of power. The current device generates 50 milliwatts per square meter, which means lighting would require about 20 square meters of photovoltaic area.

"None of these components were specifically engineered for this purpose," said author Shanhui Fan. "So, I think there's room for improvement, in the sense that, if one really engineered each of these components for our purpose, I think the performance could be better."

The team aims to optimize the thermal insulation and thermoelectric components of the device. They are exploring engineering improvements to the solar cell itself to enhance the radiative cooling performance without influencing its solar energy harvesting capability.

Journal Reference:

Sid Assawaworrarit, Zunaid Omair, Shanhui Fan. Nighttime electric power generation at a density of 50 mW/m2 via radiative cooling of a photovoltaic cell. Applied Physics Letters, 2022; 120 (14): 143901 DOI: 10.1063/5.0085205

Using machine learning to find reliable and low-cost solar cells

Mr. Sanket Kinikar, Mr. Pranit Khurape, Miss. Rajeshree Shinde, Miss. Pallavi Kongnule, Mr. Aman Patel

Hybrid perovskites are organic-inorganic molecules that have received a lot of attention over the past 10 years for their potential use in renewable energy, said Marina Leite, associate professor of materials science and engineering at UC Davis and senior author on the paper. Some are comparable in efficiency to silicon for making solar cells, but they are cheaper to make and lighter, potentially allowing a wide range of applications, including light-emitting devices. A primary challenge in the field is that the perovskite devices tend to degrade way more readily than silicon when exposed to moisture, oxygen, light, heat, and voltage. The problem is to find which perovskites combine high-efficiency performance with resilience to environmental conditions. Perovskites have a general structure of ABX3, where A is an organic (carbon-based) or inorganic group, B is lead or tin, and X is a halide (based on chlorine, iodine or fluorine or a combination). Therefore, "the number of possible chemical combinations alone is enormous," Leite said. Further, they need to be assessed against multiple environmental conditions, alone and in combination, which results in a hyperparameter space that cannot be explored using conventional trial-and-error methods. "The chemical parameter space is enormous," Leite said. "To test them all would be very time consuming and tedious."

High throughput experiments and machine learning

As a first and key step towards solving thesechallenges, Leite and graduate students Meghna Srivastava and Abigail Hering decide to test whether machine learning algorithms could be effective when testing and predicting the effects of moisture on material degradation. Srivastava and Hering built an automated, high-throughput system to measure the photoluminescence efficiency of five different perovskite films against the conditions of summer days in Sacramento. They were able to collect over 7,000 measurements in a week, accumulating enough data for a reliable training set.

They used this data to train three different machine learning algorithms: a linear regression model, a neural network and a statistical model called SARIMAX. They compared the predictions of the models to physical results measured in the lab. The SARIMAX model showed best performance with a 90 percent match to observed results during a window of 50-plus hours. "These results demonstrate that we can make use of machine learning in identifying candidate materials and suitable conditions to prevent degradation in perovskites," Leite said. Next steps will be to expand the experiments to quantify combinations of multiple environmental factors. The perovskite film itself is only a part of a complete photovoltaic cell, Leite said. The same machine learning approach could also be used to forecast the behavior of a complete device. "Our paradigm is unique, and I am eager to see the upcoming measurements. Moreover, I am very proud of the students' diligence during the pandemic" Leite said.

Journal Reference:

Meghna Srivastava, Abigail R. Hering, Yu An, Juan-Pablo Correa-Baena, Marina S. Leite. Machine Learning Enables Prediction of Halide Perovskites' Optical Behavior with >90% Accuracy. ACS Energy Letters, 2023; 8 (4): 1716 DOI: 10.1021/acsenergylett.2c02555

A solar hydrogen system that co-generates heat and oxygen

Mr. Shubham Powar, Mr. Sameer Momin, Mr. Omkar Chougule, Mr. Prathamesh Jadhav, Mr. Arun Kgwade, Mr. Aditya Diwate

"This is the first system-level demonstration of solar hydrogen generation. Unlike typical lab-scale demonstrations, it includes all auxiliary devices and components, so it gives us a better idea of the energy efficiency you can expect once you consider the complete system, and not just the device itself," says Sophia Haussener, head of the Laboratory of Renewable Energy Science and Engineering (LRESE) in the School of Engineering.

"With an output power of over 2 kilowatts, we've cracked the 1-kilowatt ceiling for our pilot reactor while maintaining record-high efficiency for this large scale. The hydrogen production rate achieved in this work represents a really encouraging step towards the commercial realization of this technology."

The work builds on preliminary research demonstrating the concept on the laboratory scale, using LRESE's high-flux solar simulator, which was published in *Nature Energy* in 2019. Now, the team has published the results of their scaled-up, efficient, and multi-product process under real-world conditions in the same journal.

Waste not, want not

Hydrogen production from water using solar energy is referred to as artificial photosynthesis, but the LRESE system is unique for its ability to also produce heat and oxygen at scale.

After the dish concentrates the sun's rays, water is pumped into its focus spot, where an integrated photoelectrochemical reactor is housed. Within this reactor, photoelectrochemical cells use solar energy to electrolyze, or split water molecules into hydrogen and oxygen. Heat is also generated, but instead of being released as a system loss, this heat is passed through a heat exchanger so that it can be harnessed -- for ambient heating, for example.

In addition to the system's primary outputs of hydrogen and heat, the oxygen molecules released by the photo-electrolysis reaction are also recovered and used.

"Oxygen is often perceived as a waste product, but in this case, it can also be harnessed -- for example for medical applications," Haussener says.

Industrial and residential energy

The system is suitable for industrial, commercial, and residential applications; in fact, LRESE-spinoff SoHHytec SA is already deploying and commercializing it. The EPFL start-up is working with a Swiss-based metal production facility to build a demonstration plant at the multi-100-kilowatt scale that will produce hydrogen for metal annealing processes, oxygen for nearby hospitals, and heat for the factory's hot-water needs.

"With the pilot demonstration at EPFL, we have achieved a major milestone by demonstrating unprecedented efficiency at high output power densities. We are now scaling up a system in an

artificial garden-like setup, where each of these 'artificial trees' is deployed in a modular fashion," says SoHHytec co-founder and CEO Saurabh Tembhurne.

The system could be used to provide residential and commercial central heating and hot water, and to power hydrogen fuel cells. At an output level of about half a kilogram of solar hydrogen per day, the EPFL campus system could power around 1.5 hydrogen fuel cell vehicles driving an average annual distance; or meet up to half the electricity demand and more than half of the annual heat demand of a typical four-person Swiss household.

With their artificial photosynthesis system well on its way to scale-up, Haussener is already exploring new technological avenues. In particular, the lab is working on a large-scale solar-powered system that would split carbon dioxide instead of water, yielding useful materials like syngas for liquid fuel, or the green plastic precursor ethylene.

Journal Reference:

Isaac Holmes-Gentle, Saurabh Tembhurne, Clemens Suter, Sophia Haussener. Kilowatt-scale solar hydrogen production system using a concentrated integrated photoelectrochemical device. Nature Energy, 2023; DOI: 10.1038/s41560-023-01247-2

Microwaves advance solar-cell production and recycling

Miss. Vaishnavi Bandgar, Miss Padma Jadhav, Mr. Suraj Lal, Mr. Prasad Mane, Prathamesh Mule, Jeevan Gurav, Bhargav Joshi

During the fabrication of solar panels, silicon goes through several high-temperature processes known as annealing. Currently the cells are cooked in an oven.

But in a paper published in the US Journal *Applied Physics Letters*, a team led by senior lecturer Dr Binesh Puthen Veettil of the School of Engineering has shown that heating using microwave radiation is nearly as efficient. Plus, it saves considerable time and energy and has other advantages.

Because microwave radiation selectively heats silicon, it leads to almost instantaneous effects with massive savings of energy. This is partly because the rest of the laminated panel of glass, plastic and aluminium is left largely unaffected. And that property that has led to an unexpected recycling benefit for which the group has a patent pending.

Recycling benefits

Under microwave treatment, the plastic (ethylene vinyl acetate) coating that protects the silicon plate from moisture and contamination softens to the point where it can be peeled off mechanically. That means the plate can be easily delaminated and its components reused without employing harsh chemicals.

"Until now it made economic sense to just dump the panels in the landfill," says Dr Veettil. "In the rare instances when they are recycled, you crush the panels, heat them to about 1400°C and wash them with chemicals to remove the plastic -- a highly energy-demanding process. But now, as the solar panels which began to be installed in vast numbers about 20-30 years ago are reaching the end of their life and being decommissioned, governments are demanding they be recycled."

Selective annealing

Microwave annealing has several other advantages. The ability to focus microwave radiation means the heating it induces can be selective and highly tuned. Some of the newer panels, for instance, employ what is known as heterojunction technology, where crystalline and amorphous silicon are interleaved. In these cells, faster, better-directed annealing is highly advantageous.

Precise focusing also means that annealing can be directed to specific parts of the solar panel, making it ideal for annealing solar panels with more intricate internal structures fabricated for special purposes.

And, in contrast to an oven where all sorts of chemical substances are shed from the walls, microwave annealing takes place in a clean environment. "So there is less contamination," says Dr Veettil. "And the whole process can all be undertaken at room temperature."

New materials

There are several other projects involving solar cells and sustainable energy underway at Macquarie. One of the co-authors of the annealing paper, Associate Professor Shujuan Huang, leads a group looking at microwave annealing in perovskite solar cells. Perovskites are a group of crystalline minerals with semiconductor properties that may, in future, be used for solar cells because they are flexible, lightweight and cheap to produce.

In this case, the microwave radiation produced more efficient solar cells as compared to conventional annealing methods, but the reason is not clear. The current work is being undertaken partly to answer that question.

Journal Reference:

Binesh Puthen Veettil, Yuchao Zhang, David Payne, Mattias Juhl, Shujuan Huang, Brett Hallam, Darren Bagnall. Microwave annealing of silicon solar cells. Applied Physics Letters, 2023; 122 (14): 142101 DOI: 10.1063/5.0127896

A neuromorphic visual sensor can recognize moving objects and predict their path

Miss. Pradnya Dhumal, Mr. Abhishek Funde, Mr. Prathamesh Hiremath, Mr. Tejas Jadhav, Mr. Idris Hydri, Mr. Sanmesh Shinde

Current motion detection systems need many components and complex algorithms doing frame-by-frame analyses, which makes them inefficient and energy-intensive. Inspired by the human visual system, researchers at Aalto University have developed a new neuromorphic vision technology that integrates sensing, memory, and processing in a single device that can detect motion and predict trajectories.

At the core of their technology is an array of photomemristors, electrical devices that produce electric current in response to light. The current doesn't immediately stop when the light is switched off. Instead, it decays gradually, which means that photomemristors can effectively 'remember' whether they've been exposed to light recently. As a result, a sensor made from an array of photomemristors doesn't just record instantaneous information about a scene, like a camera does, but also includes a dynamic memory of the preceding instants.

'The unique property of our technology is its ability to integrate a series of optical images in one frame,' explains Hongwei Tan, the research fellow who led the study. 'The information of each image is embedded in the following images as hidden information. In other words, the final frame in a video also has information about all the previous frames. That lets us detect motion earlier in the video by analysing only the final frame with a simple artificial neural network. The result is a compact and efficient sensing unit.'

To demonstrate the technology, the researchers used videos showing the letters of a word one at a time. Because all the words ended with the letter 'E', the final frame of all the videos looked similar. Conventional vision sensors couldn't tell whether the 'E' on the screen had appeared after the other letters in 'APPLE' or 'GRAPE'. But the photomemristor array could use hidden information in the final frame to infer which letters had preceded it and predict what the word was with nearly 100% accuracy. In another test, the team showed the sensor videos of a simulated person moving at three different speeds. Not only was the system able to recognize motion by analysing a single frame, but it also correctly predicted the next frames. Accurately detecting motion and predicting where an object will be are vital for self-driving technology and intelligent transport. Autonomous vehicles need accurate predictions of how cars, bikes, pedestrians, and other objects will move in order to guide their decisions. By adding a machine learning system to the photomemristor array, the researchers showed that their integrated system can predict future motion based on in-sensor processing of an all-informative frame.

'Motion recognition and prediction by our compact in-sensor memory and computing solution provides new opportunities in autonomous robotics and human-machine interactions,' says Professor Sebastiaan van Dijken. 'The in-frame information that we attain in our system using

photomemristors avoids redundant data flows, enabling energy-efficient decision-making in real time.'

Journal Reference:

1. Hongwei Tan, Sebastiaan van Dijken. **Dynamic machine vision with retinomorphic photomemristor-reservoir computing**. *Nature Communications*, 2023; 14 (1) DOI: 10.1038/s41467-023-37886-y

Shutting down nuclear power could increase air pollution

Mr. Sanmeh Shinde, Miss. Mansi Patil, Mr. Shahid Inamdar, Mr. Murli Choudhari, Mr. Akshay Madane, Mr. Rushikesh Naik

Policymakers are debating whether to retire the aging reactors or reinforce their structures to continue producing nuclear energy, which many consider a low-carbon alternative to climate-warming coal, oil, and natural gas.

Now, MIT researchers say there's another factor to consider in weighing the future of nuclear power: air quality. In addition to being a low carbon-emitting source, nuclear power is relatively clean in terms of the air pollution it generates. Without nuclear power, how would the pattern of air pollution shift, and who would feel its effects?

The MIT team took on these questions in a new study appearing in *Nature Energy*. They lay out a scenario in which every nuclear power plant in the country has shut down, and consider how other sources such as coal, natural gas, and renewable energy would fill the resulting energy needs throughout an entire year.

Their analysis reveals that indeed, air pollution would increase, as coal, gas, and oil sources ramp up to compensate for nuclear power's absence. This in itself may not be surprising, but the team has put numbers to the prediction, estimating that the increase in air pollution would have serious health effects, resulting in an additional 5,200 pollution-related deaths over a single year.

If, however, more renewable energy sources become available to supply the energy grid, as they are expected to by the year 2030, air pollution would be curtailed, though not entirely. The team found that even under this heartier renewable scenario, there is still a slight increase in air pollution in some parts of the country, resulting in a total of 260 pollution-related deaths over one year.

When they looked at the populations directly affected by the increased pollution, they found that Black or African American communities -- a disproportionate number of whom live near fossil-fuel plants -- experienced the greatest exposure.

"This adds one more layer to the environmental health and social impacts equation when you're thinking about nuclear shutdowns, where the conversation often focuses on local risks due to accidents and mining or long-term climate impacts," says lead author Lyssa Freese, a graduate student in MIT's Department of Earth, Atmospheric and Planetary Sciences (EAPS).

"In the debate over keeping nuclear power plants open, air quality has not been a focus of that discussion," adds study author Noelle Selin, a professor in MIT's Institute for Data, Systems, and Society (IDSS) and EAPS. "What we found was that air pollution from fossil fuel plants is so damaging, that anything that increases it, such as a nuclear shutdown, is going to have substantial impacts, and for some people more than others."

The study's MIT-affiliated co-authors also include Principal Research Scientist Sebastian Eastham and Guillaume Chossière SM '17, PhD '20, along with Alan Jenn of the University of California at Davis.

Future phase-outs

When nuclear power plants have closed in the past, fossil fuel use increased in response. In 1985, the closure of reactors in Tennessee Valley prompted a spike in coal use, while the 2012 shutdown of a plant in California led to an increase in natural gas. In Germany, where nuclear power has almost completely been phased out, coal-fired power increased initially to fill the gap.

Noting these trends, the MIT team wondered how the U.S. energy grid would respond if nuclear power were completely phased out.

"We wanted to think about what future changes were expected in the energy grid," Freese says. "We knew that coal use was declining, and there was a lot of work already looking at the impact of what that would have on air quality. But no one had looked at air quality and nuclear power, which we also noticed was on the decline."

In the new study, the team used an energy grid dispatch model developed by Jenn to assess how the U.S. energy system would respond to a shutdown of nuclear power. The model simulates the production of every power plant in the country and runs continuously to estimate, hour by hour, the energy demands in 64 regions across the country.

Much like the way the actual energy market operates, the model chooses to turn a plant's production up or down based on cost: Plants producing the cheapest energy at any given time are given priority to supply the grid over more costly energy sources.

The team fed the model available data on each plant's changing emissions and energy costs throughout an entire year. They then ran the model under different scenarios, including: an energy grid with no nuclear power, a baseline grid similar to today's that includes nuclear power, and a grid with no nuclear power that also incorporates the additional renewable sources that are expected to be added by 2030.

They combined each simulation with an atmospheric chemistry model to simulate how each plant's various emissions travel around the country and to overlay these tracks onto maps of population density. For populations in the path of pollution, they calculated the risk of premature death based on their degree of exposure.

System response

Their analysis showed a clear pattern: Without nuclear power, air pollution worsened in general, mainly affecting regions in the East Coast, where nuclear power plants are mostly concentrated. Without those plants, the team observed an uptick in production from coal and gas plants, resulting in 5,200 pollution-related deaths across the country, compared to the baseline scenario.

They also calculated that more people are also likely to die prematurely due to climate impacts from the increase in carbon dioxide emissions, as the grid compensates for nuclear power's absence. The climate-related effects from this additional influx of carbon dioxide could lead to 160,000 additional deaths over the next century.

"We need to be thoughtful about how we're retiring nuclear power plants if we are trying to think about them as part of an energy system," Freese says. "Shutting down something that doesn't have direct emissions itself can still lead to increases in emissions, because the grid system will respond."

"This might mean that we need to deploy even more renewables, in order to fill the hole left by nuclear, which is essentially a zero-emissions energy source," Selin adds. "Otherwise we will have a reduction in air quality that we weren't necessarily counting on."

Story Source:

Materials provided by **Massachusetts Institute of Technology**. Original written by Jennifer Chu. *Note: Content may be edited for style and length.*

Physicists find unusual waves in nickel-based magnet

Mr. Shoeb Pathan, Mr. Pranav Patil, Mr. Somesh Patil, Me. Vaibhav Patil, Mr. Aniket Fulari, Mr. Adnan Jamadar, Mr. Nikhil Kamble

In a study published in *Nature Communications*, the researchers reported finding unusual properties in nickel molybdate, a layered magnetic crystal. Subatomic particles called electrons resemble miniscule magnets, and they typically orient themselves like compass needles in relation to magnetic fields. In experiments where neutrons were scattered from magnetic nickel ions inside the crystals, the researchers found that two outermost electrons from each nickel ion behaved differently. Rather than aligning their spins like compass needles, the two canceled one another in a phenomenon physicists call a spin singlet.

"Such a substance should not be a magnet at all," said Rice's Pengcheng Dai, corresponding author of the study. "And if a neutron scatters off a given nickel ion, the excitations should remain local and not propagate through the sample."

Dai and his collaborators were therefore surprised when instruments in the neutron-scattering experiments detected not one, but two families of propagating waves, each at dramatically different energies.

To understand the waves' origins, it was necessary to delve into the atomic details of the magnetic crystals. For instance, electromagnetic forces from atoms in crystals can compete with the magnetic field and affect electrons inside neighboring atoms. This is called the crystal field effect, and it can force electron spins to orient themselves along directions distinct from the orientation of the magnetic field. Probing crystal field effects in the nickel molybdate crystals required additional experiments and theoretical interpretation of the data from the experiments.

"The collaboration between experimental groups and theory is paramount to painting a full picture and understanding the unusual spin excitations observed in this compound," said Rice co-author Emilia Morosan.

Morosan's group probed the thermal response of the crystals to changes in temperature using specific heat measurements. From those experiments, the researchers concluded that two kinds of crystal field environments occurred in the layered nickel molybdate, and the two affected nickel ions very differently.

"In one, the field effect is rather weak and corresponds to a thermal energy of about 10 Kelvin," said study co-author Andriy Nevidomskyy, a theoretical physicist at Rice who helped interpret the experimental data. "It is perhaps not surprising to see, at few-Kelvin temperatures, that neutrons can excite magnetic spin waves from nickel atoms that are subject to this first type of crystal field effect. But it is most puzzling to see them coming from nickel atoms that are subject to the second type. Those atoms have a tetrahedral arrangement of oxygens around them, and the electric field effect is nearly 20-fold stronger, meaning the excitations are that much harder to create."

Nevidomskyy said this can be understood as if the spins on the corresponding nickel ions had different "mass."

"The analogy is that of heavy basketballs that are intermixed with tennis balls," he said. "To excite the spins of the second type, the heavier basketballs, one must administer a stronger 'kick' by shining more energetic neutrons at the material."

The resulting effect on the nickel spin is called a spin exciton, and one would normally expect the effect of the exciton-producing "kick" to be confined to a single atom. But measurements from the experiments indicated "basketballs" were moving in unison, creating an unexpected sort of wave. Even more surprising, the waves appeared to persist at relatively high temperatures where the crystals no longer behaved as magnets.

The explanation offered by Nevidomskyy and theorist co-author Leon Balents from the University of California, Santa Barbara was: Heavier spin excitons -- basketballs in the analogy -- bob in response to the fluctuations of the surrounding, lighter magnetic excitons -- the analogous tennis balls -- and if the interactions between the two types of balls are sufficiently strong, the heavier spin excitons participate in a coherent motion akin to a wave.

"What is particularly interesting," Dai said, "is that the two kinds of nickel atoms each form a triangular lattice, and the magnetic interactions within this lattice are therefore frustrated."

In magnetism on triangular lattices, frustration refers to the difficulty in aligning all the magnetic moments anti-parallel (up-down) with respect to their three immediate, nearest neighbors.

Understanding the role of magnetic frustrations in triangular lattices is one of the long-standing challenges that Dai and Nevidomskyy have both been working to address for a number of years.

"It is very exciting to find a puzzle, against one's expectations, and then feel a sense of satisfaction of having understood its origin," said Nevidomskyy.

Dai, Morosan and Nevidomskyy are members of the Rice Quantum Initiative. Dai is the Sam and Helen Worden Professor of Physics and Astronomy. Morosan is a professor of physics and astronomy, and of chemistry. Nevidomskyy is an associate professor of physics and astronomy. The neutron scattering experiments were carried out by Bin Gao and Tong Chen in Dai's group in collaboration with instrument scientists at Oak Ridge National Laboratory and ISIS Neutron and Muon Source at Rutherford Appleton Laboratory. Chien-Lung Huang, a research scientist in Morosan's group, performed the specific heat measurements and analysis.

Journal Reference:

Bin Gao, Tong Chen, Xiao-Chuan Wu, Michael Flynn, Chunruo Duan, Lebing Chen, Chien-Lung Huang, Jesse Liebman, Shuyi Li, Feng Ye, Matthew B. Stone, Andrey Podlesnyak, Douglas L. Abernathy, Devashibhai T. Adroja, Manh Duc Le, Qingzhen Huang, Andriy H. Nevidomskyy, Emilia Morosan, Leon Balents, Pengcheng Dai. Diffusive excitonic bands from frustrated triangular sublattice in a singlet-ground-state system. Nature Communications, 2023; 14 (1) DOI: 10.1038/s41467-023-37669-5

'Green' hydrogen: How photoelectrochemical water splitting may become competitive

Mr. Wasim Mujawar, Mr. Atharva Simfal, Mr. Rushikesh Kumbhar, Mr. Prajwal Kadam, Mr. Sairam Patil, Mr. Ajeem Attar

The direct approach

At the HZB Institute for Solar Fuels, several teams are working on a direct approach to solar water splitting: they are developing photoelectrodes that convert sunlight into electrical energy, are stable in aqueous solutions, and catalytically promote water splitting. These photoelectrodes consist of light absorbers that are intimately coupled to catalyst materials to form the active component of a photoelectrochemical cell (PEC). The best PEC cells based on low-cost and stable metal oxide absorbers already achieve efficiencies close to 10%. Although PEC cells are still less efficient than PV-driven electrolyzers, they also have important advantages: in PEC cells, for example, the heat from sunlight can be used to further accelerate the reactions. And because current densities are ten to a hundred times lower with this approach, it is possible to use abundant and very inexpensive materials as catalysts.

Not yet competitive

So far, techno-economic analyses (TEA) and net energy assessments (NEA) have shown that the PEC approach is not yet competitive for large-scale implementation. Hydrogen from PEC systems today costs about 10 USD/kg, about 6 times more than hydrogen from fossil methane steam reforming (1.5 USD/kg). Moreover, the cumulative energy demand for PEC water splitting is estimated to be 4 -- 20 times higher than for hydrogen production with wind turbines and electrolysers.

The idea: co-production of valuable chemicals

"This is where we wanted to bring a new approach," says Dr Fatwa Abdi from the HZB Institute for Solar Fuels. Within the framework of the UniSysCat excellence network collaboration between Prof Reinhard Schomäcker and Prof Roel van de Krol, Abdi's group investigated how the balance changes when some of the hydrogen produced reacts further with itaconic acid (IA) in the same reactor (*in situ*) to form methyl succinic acid (MSA).

Energy payback times

They first calculated how much energy is needed to produce the PEC cell from light absorbers, catalyst materials and other materials such as glass, and how long it has to function to produce this energy in the form of chemical energy as hydrogen or MSA. For hydrogen alone, this 'energy payback time' is around 17 years assuming a modest 5% solar-to-hydrogen efficiency. If only 2% of the hydrogen produced is used to convert IA into MSA, the energy payback time is halved, and if 30% of the hydrogen is converted into MSA, the production energy can be regained after just 2 years. "This makes the process much more sustainable and competitive,"

says Abdi. One reason: the energy needed to synthesise MSA in such a PEC cell is only one-seventh of the energy need of conventional MSA production processes.

A flexible system

"The system is flexible and can also produce other valuable chemicals that are currently needed at the site," explains Abdi. The advantage is that the fixed components of the PEC unit, which account for most of the investment costs, remain the same; only the hydrogenation catalyst and the feedstock need to be exchanged. "This approach offers a way to significantly reduce the production cost of green hydrogen and increases the economic feasibility of PEC technology," Abdi says. "We have carefully thought through the process, and the next step is to test in the laboratory how well the simultaneous production of hydrogen and MSA works in practice."

Journal Reference:

Xinyi Zhang, Michael Schwarze, Reinhard Schomäcker, Roel van de Krol, Fatwa F. Abdi. Life cycle net energy assessment of sustainable H2 production and hydrogenation of chemicals in a coupled photoelectrochemical device. Nature Communications, 2023; 14 (1) DOI: 10.1038/s41467-023-36574-1

Team designs four-legged robotic system that can walk a balance beam

Mr. Suraj Patil, Mr. Prathamesh Shishte, Mr. Pankaj Patil, Omkar Patil, Mr. Varad Joshi, Mr. Rahul Mane

"This experiment was huge," said Zachary Manchester, an assistant professor in the RI and head of the Robotic Exploration Lab. "I don't think anyone has ever successfully done balance beam walking with a robot before."

By leveraging hardware often used to control satellites in space, Manchester and his team offset existing constraints in the quadruped's design to improve its balancing capabilities.

The standard elements of most modern quadruped robots include a torso and four legs that each end in a rounded foot, allowing the robot to traverse basic, flat surfaces and even climb stairs. Their design resembles a four-legged animal, but unlike cheetahs who can use their tails to control sharp turns or falling cats that adjust their orientation in mid-air with the help of their flexible spines, quadruped robots do not have such instinctive agility. As long as three of the robot's feet remain in contact with the ground, it can avoid tipping over. But if only one or two feet are on the ground, the robot can't easily correct for disturbances and has a much higher risk of falling. This lack of balance makes walking over rough terrain particularly difficult.

"With current control methods, a quadruped robot's body and legs are decoupled and don't speak to one another to coordinate their movements," Manchester said. "So how can we improve their balance?"

The team's solution employs a reaction wheel actuator (RWA) system that mounts to the back of a quadruped robot. With the help of a novel control technique, the RWA allows the robot to balance independent of the positions of its feet.

RWAs are widely used in the aerospace industry to perform attitude control on satellites by manipulating the angular momentum of the spacecraft.

"You basically have a big flywheel with a motor attached," said Manchester, who worked on the project with RI graduate student Chi-Yen Lee and mechanical engineering graduate students Shuo Yang and Benjamin Boksor. "If you spin the heavy flywheel one way, it makes the satellite spin the other way. Now take that and put it on the body of a quadruped robot."

The team prototyped their approach by mounting two RWAs on a commercial Unitree A1 robot -- one on the pitch axis and one on the roll axis -- to provide control over the robot's angular momentum. With the RWA, it doesn't matter if the robot's legs are in contact with the ground or not because the RWAs provide independent control of the body's orientation.

Manchester said it was easy to modify an existing control framework to account for the RWAs because the hardware doesn't change the robot's mass distribution, nor does it have the joint limitations of a tail or spine. Without needing to account for such constraints, the hardware can

be modeled like a gyrostat (an idealized model of a spacecraft) and integrated into a standard model-predictive control algorithm.

The team tested their system with a series of successful experiments that demonstrated the robot's enhanced ability to recover from sudden impacts. In simulation, they mimicked the classic falling-cat problem by dropping the robot upside down from nearly half a meter, with the RWAs enabling the robot to reorient itself mid-air and land on its feet. On hardware, they showed the robot's ability to recover from disturbances -- as well as the system's balancing capability -- with an experiment where the robot walked along a 6-centimeter-wide balance beam.

Manchester predicts that quadruped robots will soon transition from being primarily research platforms in labs to widely available commercial-use products, similar to where drones were about 10 years ago. And with continued work to enhance a quadruped robot's stabilizing capabilities to match the instinctual four-legged animals that inspired their design, they could be used in high-stakes scenarios like search-and-rescue in the future.

Story Source:

Materials provided by **Carnegie Mellon University**. Original written by Kayla Papakie. *Note: Content may be edited for style and length.*

Eco-efficient cement could pave the way to a greener future

Mr. Ashish Patil, Mr, Vaibhav Patil, Mr. Rohan Buchade, Mr. Atharva Kulkarni, Pratik Bhosale, Mr. Avadhut Mane, Mr. Aniket Mhetar

The production of cement, an ingredient in concrete, accounts for roughly 8% of the world's annual carbon dioxide emissions, making it a significant target of greenhouse gas emissions reduction goals. Toward those efforts, the Rice lab of chemist James Tour used flash Joule heating to remove toxic heavy metals from fly ash, a powdery byproduct of coal-based electric power plants that is used frequently in concrete mixtures. Using purified coal fly ash reduces the amount of cement needed and improves the concrete's quality.

In the lab's study, replacing 30% of the cement used to make a batch of concrete with purified coal fly ash improved the concrete's strength and elasticity by 51% and 28%, respectively, while reducing greenhouse gas and heavy metal emissions by 30% and 41%, respectively, according to the paper published in the Nature journal *Communications Engineering*.

"Reducing emissions from cement production is very important to mitigate global greenhouse emissions," said lead author Bing Deng, a postdoctoral research associate in the Tour lab. "This is the big picture of this study."

Rice engineer Satish Nagarajaiah pointed out that "cement production is a significant source of carbon dioxide emissions. Reducing cement content in concrete will help reduce emissions."

"You can use less concrete if you use coal fly ash. However, fly ash contains heavy metals," Tour said. "Often, we try to fix one thing and we mess something else up. In our effort to do something with this waste, namely coal fly ash, we were polluting our environment because the heavy metals were leaching out. Water carried it into our environment and contaminated our soil along roadways, etc."

Roughly 750 million tons of coal fly ash are produced worldwide each year. Rice scientists developed a rapid and water-free process based on flash Joule heating that can remove up to 90% of the heavy metals in it, making it more fit for infrastructure use.

"Basically, we mix the fly ash with carbon black, because fly ash does not conduct electricity, and the carbon black makes the mixture conductive," Deng said. "Next, we place the mixture between two graphite or copper electrodes and use a capacitor to supply a short current pulse to the sample. This current input brings the sample temperature up to about 3,000 degrees Celsius (5,432 Fahrenheit). The high temperature makes the heavy metals evaporate into a volatile stream which is then captured.

"By using this method, we can eliminate the heavy metals from coal fly ash with very high efficiency," he continued. "For different heavy metals like arsenic, cadmium, cobalt, nickel and lead, the removal efficiency is up to 70% to 90% in just one second. This is a very rapid discharging process."

Flash Joule heating was shown to work on different coal fly ash compositions resulting from the combustion of coal extracted from various geographical locations.

"There are two main classes of fly ash with different inorganic compositions, Class C and Class F," Deng said. "We found that our method works for both kinds of coal fly ash. It also works for other hazardous wastes like red mud or bauxite residue. This shows that the process can become a generalized approach for large-scale industrial solid waste decontamination."

"The purified coal fly ash is not only better for the environment, but it also increases concrete strength and quality," said Wei Meng, a Rice civil and environmental engineering postdoctoral research associate and co-lead author on the study. "We have found that by replacing 30% of the cement in a concrete mixture with the purified coal fly ash, the compressive strength and the elastic modulus of the composite increased significantly.

"This is very meaningful for structural engineering and the construction industry because stronger structures can be built with less cement," he continued. "That is why this research is valuable to civil engineers."

The Tour lab's process allows for the evaporated heavy metals to be collected in a vacuum chamber rather than released into the environment. Moreover, the energy consumed during the process is relatively low.

"We calculated that energy consumption is about 532 kilowatts per ton," Meng said. "If we convert this to Texas electricity prices it comes out at about $21 per ton. The life cycle analysis shows we can actually extract value from these waste materials."

"It's a big win for the environment," Tour said. "You're reducing emissions, and you're not leaching heavy metals in the process."

Satish Nagarajaiah, a Rice professor of civil and environmental engineering and mechanical engineering, and Tour, the T. T. and W. F. Chao Professor of Chemistry and a professor of materials science and nanoengineering in Rice's George R. Brown School of Engineering, are co-authors on the study.

Other co-authors are Rice alumnus Paul Advincula, Weiyin Chen, Robert Carter, and Gang Li; graduate students Lucas Eddy, Kevin Wyss and Yi Cheng, and U.S. Army Engineer Research and Development Center chemist Mine Ucak-Astarlioglu.

The Air Force Office of Scientific Research (FA9550-22-1-0526) and the U.S. Army Corps of Engineers Engineer Research and Development Center (W912HZ-21-2-0050) and the Shared Equipment Authority (SEA) at Rice University supported the research.

Journal Reference:

1. Bing Deng, Wei Meng, Paul A. Advincula, Lucas Eddy, Mine G. Ucak-Astarlioglu, Kevin M. Wyss, Weiyin Chen, Robert A. Carter, Gang Li, Yi Cheng, Satish Nagarajaiah, James M. Tour. **Heavy metal removal from coal fly ash for low carbon footprint cement**. *Communications Engineering*, 2023; 2 (1) DOI: 10.1038/s44172-023-00062-7

Eco-efficient cement could pave the way to a greener future

Miss, Pallavi Patil, Miss. Shruti Desai, Mr. Sourabh Kadole, Mr. Karan Patil, Mr. Samir Mujawar, Mr. Aftab Desai, Mr. Anil Sutar

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Photonic filter separates signals from noise to support future 6G wireless communication

Miss. Sharmeen Takawade, Miss. Komal Patil, Mr. Bhosale Pratik, Mr. Rahul Patil, Mr. Pise Tejas, Mr. Rahul Mane, Aakib Nadaf

"This new microwave filter chip has the potential to improve wireless communication, such as 6G, leading to faster internet connections, better overall communication experiences and lower costs and energy consumption for wireless communication systems," said researcher Xingjun Wang from Peking University. "These advancements would directly and indirectly affect daily life, improving overall quality of life and enabling new experiences in various domains, such as mobility, smart homes and public spaces."

In the *Photonics Research* journal co-published by Chinese Laser Press and Optica Publishing Group, the researchers describe how their new photonic filter overcomes the limitations of traditional electronic devices to achieve multiple functionalities on a chip-sized device with low power consumption. They also demonstrate the filter's ability to operate across a broad radio frequency spectrum extending to over 30 GHz, showing its suitability for envisioned 6G technology.

"As the electro-optic bandwidth of optoelectronic devices continues to increase unstoppably, we believe that the integrated microwave photonics filter will certainly be one of the important solutions for future 6G wireless communications," said Wang. "Only a well-designed integrated microwave photonics link can achieve low cost, low power consumption and superior filtering performance."

Stopping interference

6G technology is being developed to improve upon currently-deployed 5G communications networks. To convey more data at a faster rate, 6G networks are expected to use millimeter wave and even terahertz frequency bands. As this will distribute signals over an extremely wide frequency spectrum with increased data rate, there is a high likelihood of interference between different communication channels.

To solve this problem, researchers have sought to develop a filter that can protect signal receivers from various types of interference across the full radio frequency spectrum. To be cost-effective and practical for widespread deployment, it is important for this filter to be small, consume little power, achieve multiple filtering functions and be able to be integrated on a chip. However, previous demonstrations have been limited by their few functions, large size, limited bandwidth or requirements associated with electrical components.

For the new filter, researchers created a simplified photonic architecture with four main parts. First, a phase modulator serves as the input of the radio frequency signal, which modulates the electrical signal onto the optical domain. Next, a double-ring acts as a switch to shape the

modulation format. An adjustable microring is the core unit for processing the signal. Finally, a photodetector serves as the output of the radio frequency signal and recovers the radio frequency signal from the optical signal.

"The greatest innovation here is breaking the barriers between devices and achieving mutual collaboration between them," said Wang. "The collaborative operation of the double-ring and microring enables the realization of the intensity-consistent single-stage-adjustable cascaded-microring (ICSSA-CM) architecture. Owing to the high reconfigurability of the proposed ICSSA-CM, no extra radio frequency device is needed for the construction of various filtering functions, which simplifies the whole system composition."

Demonstrating performance

To test the device, researchers used high-frequency probes to load a radio frequency signal into the chip and collected the recovered signal with a high-speed photodetector. They used an arbitrary waveform generator and directional antennas to simulate the generation of 2Gb/s high-speed wireless transmission signals and a high-speed oscilloscope to receive the processed signal. By comparing the results with and without the use of the filter, the researchers were able to demonstrate the filter's performance.

Overall, the findings show that the simplified photonic architecture achieves comparable performance with lower loss and system complexity compared with previous programmable integrated microwave photonic filters composed of hundreds of repeating units. This makes it more robust, more energy-efficient and easier to manufacture than previous devices.

The researchers plan to further optimize the modulator and improve the overall filter architecture to achieve a high dynamic range and low noise while ensuring high integration at both the device and system levels.

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Wonder material Graphene claims yet another superlative

Mr. Samartha Nanekar, Mr. Suraj Patil, Mr. Shubham Sangale, Mr. Chetan Kumbhoje, Mr. Rahil Mujawar, Mr.Saurabh Koli

Materials that strongly change their resistivity under magnetic fields are highly sought for various applications and, for example, every car and every computer contain many tiny magnetic sensors. Such materials are rare, and most metals and semiconductors change their electrical resistivity only by a tiny fraction of a percent at room temperature and in practically viable magnetic fields (typically, by less than a millionth of 1 %). To observe a strong magnetoresistance response, researchers usually cool materials to liquid-helium temperatures so that electrons inside scatter less and can follow cyclotron trajectories.

Now a research team led by Professor Sir Andre Geim has found that good old graphene that seemed to be studied in every detail over the last two decade exhibits a remarkably strong response, reaching above 100% in magnetic fields of standard permanent magnets (of about 1,000 Gauss). This is a record magnetoresistivity among all the known materials.

Speaking about this latest graphene discovery, Sir Andre Geim said: "People working on graphene like myself always felt that this gold mine of physics should have been exhausted long ago. The material continuously proves us wrong finding yet another incarnation. Today I have to admit again that graphene is dead, long live graphene."

To achieve this, the researchers used high-quality graphene and tuned it to its intrinsic, virgin state where there were only charge carriers excited by temperature. This created a plasma of fast-moving "Dirac fermions" that exhibited a surprisingly high mobility despite frequent scattering. Both high mobility and neutrality of this Dirac plasma are crucial components for the reported giant magnetoresistance.

"Over the last 10 years, electronic quality of graphene devices has improved dramatically, and everyone seems to focus on finding new phenomena at low, liquid-helium temperatures, ignoring what happens under ambient conditions. This is perhaps not so surprising because the cooler your sample the more interesting its behaviour usually becomes. We decided to turn the heat up and unexpectedly a whole wealth of unexpected phenomena turned up," says Dr Alexey Berdyugin, the corresponding authors of the paper.

In addition to the record magnetoresistivity, the researchers have also found that, at elevated temperatures, neutral graphene becomes a so-called "strange metal." This is the name given to materials where electron scattering becomes ultimately fast, being determined only by the Heisenberg uncertainty principle. The behaviour of strange metals is poorly understood and remains a mystery currently under investigation worldwide.

The Manchester work adds some more mystery to the field by showing that graphene exhibits a giant linear magnetoresistance in fields above a few Tesla, which is weakly temperature dependent. This high-field magnetoresistance is again record-breaking.

The phenomenon of linear magnetoresistance has remained an enigma for more than a century since it was first observed. The current Manchester work provides important clues about origins of the strange metal behaviour and of the linear magnetoresistance. Perhaps, the mysteries can now be finally solved thanks to graphene as it represents a clean, well-characterised and relatively simple electronic system.

"Undoped high-quality graphene at room temperature offers an opportunity to explore an entirely new regime that in principle could be discovered even a decade ago but somehow was overlooked by everyone. We plan to study this strange-metal regime and, surely, more of interesting results, phenomena and applications will follow," adds Dr Leonid Ponomarenko, one of the leading *Nature* paper authors.

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Physicists discover transformable Nano-scale electronic devices

Mr. Atish Chavan, Mr. Suraj Wagh, Mr. Pranav Lagare, Mr. Avinash Londhe, Mr. Shreyash Nagavkar, Mr. Tushar Aswale, Mr. Amey Shendage

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.

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.

"The initial story is more about the basic science of it, although it is an idea which could one day have an effect on industry," said Sanchez-Yamagishi. "This germinates the idea of it."

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.

Journal Reference:

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Nanophysics: The right twist

Mr. Aman Bagwan, Mr. Atharva Joshi, Mr. Chetan Patil, Miss. Pragati Naik, Mr. Sanket Chougule, Mr. Sumit Mangave, Mr. Ritesh Naik

Novel, ultrathin nanomaterials exhibit remarkable properties. If you stack individual atomically thin layers of crystals in a vertical assembly, for example, fascinating physical effects can occur. For instance, bilayers of the wonder material graphene twisted by the magic angle of 1.1 degrees may exhibit superconductivity. And researchers are also focusing their attention on bilayer semiconducting heterostructures made of so-called transition metal dichalcogenides, which are held together weakly by van der Waals forces.

The research group led by Alexander Högele investigates such novel heterostructures, which do not occur in nature. "The combination of materials, the number of layers, and their relative orientation give rise to a wide variety of novel phenomena," says the LMU physicist. "In the lab, we can tailor physical phenomena for various applications in electronics, photonics, or quantum technology with properties that are unknown in naturally occurring crystals." Experimentally observed phenomena are not always easy to interpret, however, as a new paper published in the journal *Nature Nanotechnology* demonstrates.

Högele's team investigated a heterobilayer system held together by van der Waals forces and fabricated from semiconductor monolayers of molybdenum diselenide (MoSe2) and tungsten diselenide (WSe2). Depending on the orientation of the individual layers, moiré effects can emerge. These effects, which we are familiar with from everyday life, also arise in the nano-world when two different atomic lattices are stacked upon each other, or two identical lattices are twisted with respect to each other. The difference in the nano case is that it is not an optical effect. In the quantum mechanical world of atomically thin crystal heterostructures, moiré interference dramatically affects the properties of the composite system, also impacting electrons and strongly bound electron-hole pairs, or excitons, explains Högele.

"Our work shows that the naïve notion of a perfect moiré pattern in heterobilayer MoSe2-WSe2 does not necessarily hold true, particularly for small angles of rotation. Therefore, the interpretation of the phenomenology observed to date will have to be partially revised," says Högele. Instead of periodic moiré patterns, there are laterally extended areas that are free from moiré interferences. Moreover, there are zones with interesting quantum mechanical effects such as one-dimensional quantum wires or quasi zero-dimensional quantum dots that are potentially viable for applications in quantum communication based on spatially localized excitons with single-photon emission characteristics. In the latter case, ideal moiré patterns presumably transform into periodic patterns with triangular or hexagonal tiling.

The reason seems to lie in an elastic deformation of the lattice structure that depends on the orientation of the layers. The atoms are displaced out of their equilibrium positions, which comes at the expense of increased strain in individual layers but promotes better adhesion among the layers. The result is an energy landscape in the heterobilayer system that can be engineered and potentially exploited by means of rational design. "We also observe collective phenomena in synthetic crystals, where periodic moiré patterns have a dramatic effect on the motion of electrons as well as their mutual interactions," says Högele.

Of decisive importance is the understanding of excitons -electron-hole pairs -- that are characteristic for the distinct types of atomic registries in bilayer crystal heterostructures and which could potentially be utilized in future opto-electronic applications. These excitons are generated in semiconducting transition metal dichalcogenides by means of light absorption, and convert back into light again. "Excitons thus act as mediators of light-matter interaction in semiconductor crystals," says Högele. As the current paper shows, different types of excitons arise depending on the actual structure of the heterobilayer systems in parallel or antiparallel alignment. "We want to learn how to manufacture van der Waals heterostructures with customized properties in a deterministic approach to control the rich emergent phenomenology of correlated effects such as magnetism or superconductivity."

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Shining new light on solar cell development

Mr. Omkar Radde, Mr. Ritesh Patil, Miss. Rajnandini Parit, Mr. Ajay Singh, Miss, Vaishnavi Khot, Mr. Sahil Chougule, Mr. Aditya havan

ANU researchers have found a way to improve the performance of silicon photovoltaic (PV) or solar cells. This is done through the addition of 'passivating contacts' between the metal and silicon parts of the solar cell, making it more productive.

"These findings will help push the performance of silicon solar cells closer to their theoretical limit," Mohamed Ismael, lead ANU researcher and PhD candidate said.

"Each day, the sun produces significantly more energy than needed to power the whole planet. The only limitation is our ability to economically convert it to electricity," he said.

Solar cells are devices that convert light energy in the form of photons into electrical energy. As it stands, solar cells aren't operating at their maximum capacity due to substantial electrical losses associated with the direct contact of metals with silicon.

"Transition metal oxides such as titanium oxide have many qualities that make them ideal as passivating contact layers," Dr Lachlan Black said. "This isn't a new idea, but the way in which we combined these layers has produced better results and higher operating voltages than anything previously reported." The research team is hoping to develop the technology to a point where it can be applied to industrial solar cells on a large scale. The PV market is a multi-billion-dollar industry, with silicon solar cells contributing to 95 per cent of all commercial solar cells. They are predicted to remain dominant for the foreseeable future given their advantageous properties compared to competitors. "If successful, we could see our technology in almost all new solar panels installed on your roof or utility-scale solar plants," Dr Black said.

Some practical issues still need to be addressed before the technology can be implemented, but the PV community is already working to solve these challenges.

"Improving the efficiency of solar cells guarantees more clean energy at a reduced cost. This not only helps to address climate change, but opens up new economic opportunities for this low-cost clean energy," Ismael said.

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World's climate plans make for a worrying read

Mr. Om patel, Mr. ABhishek Chougule, Mr. Vinit Patil, Mr. Sudesh Mane

Every year, the world's oceans absorb twelve gigatons of CO_2 from the atmosphere. Twelve gigatons is also the amount of CO_2 that countries will rely on new technologies and nature restoration to remove from the atmosphere annually by 2050.

This is a key finding by an international research team. In a new study published in *Nature Climate Change*, the researchers went through the so-called "long term low emission plans" of 50 countries submitted to the UN Intergovernmental Panel on Climate Change.

The plans outline how CO_2 emissions will be reduced, as well as each country's expected residual emissions in 2050, they year when they expect to reach the point of net zero emissions.

"Our analysis looked at the most ambitious scenarios advanced by countries, as many countries used several different projections, meaning that actual residual emissions may be much larger," says first author of the study, assistant professor Holly Jean Buck of the University at Buffalo.

Co-author, Professor Jens Friis Lund from the University of Copenhagen adds:

"We have been kind to the countries and taken their most conservative emissions estimates by the year 2050. Even then, we are left with 12 gigatons of CO_2, an unrealistically large amount to remove. Therefore, as they stand today, the countries' plans make for a worrying read," says Professor Jens Friis Lund of the University of Copenhagen's Department of Food and Resource Economics, one of the new study's authors.

Afforestation will impact food security

Only 18 out of the 50 countries that submitted climate plans supplied figures for how large their residual emissions would be in 2050. The researchers used these figures to calculate an average, which was then applied to the other countries.

Despite the large amount of CO_2 expected to remain in 2050, the 18 countries still plan to attain net zero emissions that year. This is to be achieved by planting new forests and conserving large tracts of nature, among other techniques.

But according to Professor Jens Friis Lund, this will likely compoundother challenges, for instance increased competition for land for biodiversity protection and food production.

"These very large areas that need to be set aside to remove CO_2, will compete with agricultural land and food security. The sheer speed at which forests or biocrops must be planted will pose a risk to people around the world, because there won't be time to ensure that people are properly heard or compensated," says Jens Friis Lund, an assertion based on a report on the need and potential for removing CO_2 that he co-published prior to last year's COP27.

Rapid reductions, here and now

New technology that can capture atmospheric CO_2 also plays a major role in the future plans of countries to reduce their emissions. These technologies include carbon capture and storage (CCS) technology applied to biomass energy and in direct air capture.

"We'll need negative emissions technologies, but we also need to be aware of the risks. This is not the first time the prospect of new technologies have been relied upon to deal with the climate crisis, without being followed up by strong enough policy or enough investment. We've seen the same thing for e.g. CCS technology applied fossil energy. Scrutinising our reliance on residual emissions is a way to keep the pressure on decision makers up," says Nils Markusson, a senior lecturer at Lancaster University, who also contributed to the research.

There are already a handful of direct air capture systems around the planet that remove a few thousand tons of CO2 annually. By 2050, plants like these will be many times larger than they are today and require huge amounts of energy. Energy that needs to be green energy before it makes sense.

"Today, technology allows us to remove a few thousand tons of CO_2 every year. This capacity must increase a thousandfold if we are to eliminate the emissions that countries currently expect to have in 2050. This means huge demands on how land is used and the expansion of renewable energy with the sole purpose of removing CO_2 from the atmosphere. And this must be added to everything else we already need to do to reduce emissions. It's a huge bill that we're leaving to future generations," says Jens Friis Lund.

Therefore, the new study also comes with a clear and not too surprising recommendation:

"We strongly recommend accelerating efforts to reduce emissions. Faster reductions here and now are far more preferable to investing in an uncertain technological fix, in a future where the climate crisis has worsened, with even more severe weather phenomena and subsequent climate damage," says Jens Friis Lund.

"Ultimately, our research demonstrates that we need a much more open discussion about all of this. Countries and companies that set net zero targets need to enable a democratic debate about the kind of climate futures that we collectively want, and not hide behind seemingly neutral claims about the kind of emissions they think are "necessary," says senior lecturer Wim Carton of Lund University.

The study was conducted in collaboration between the University of Buffalo, Lund University, Lancaster University and the University of Copenhagen.

Journal Reference:

Holly Jean Buck, Wim Carton, Jens Friis Lund, Nils Markusson. Why residual emissions matter right now. Nature Climate Change, 2023; 13 (4): 351 DOI: 10.1038/s41558-022-01592-2

Next decade decisive for PV growth on the path to 2050

Mr. Vasim Mullani, Miss. Pradnya Mallade, Mr. Abdulhasi Khan, Mr. Saad Bairagdar

The consensus reached by participants in the 3rd Terawatt Workshop last year follows increasingly large projections from multiple groups around the world on the need for large-scale PV to drive electrification and greenhouse gas reduction. The increasing acceptance of PV technology has prompted the experts to suggest that about 75 terawatts or more of globally deployed PV will be needed by 2050 to meet decarbonization goals.

The workshop, led by representatives from the National Renewable Energy Laboratory (NREL), the Fraunhofer Institute for Solar Energy in Germany, and the National Institute of Advanced Industrial Science and Technology in Japan, gathered leaders from around the world in PV, grid integration, analysis, and energy storage, from research institutions, academia, and industry. The first meeting, in 2016, addressed the challenge of reaching at least 3 terawatts by 2030.

The 2018 meeting moved the target even higher, to about 10 TW by 2030, and to three times that amount by 2050. The participants in that workshop also successfully predicted the global generation of electricity from PV would reach 1 TW within the next five years. That threshold was crossed last year.

"We have made great progress, but the targets will require continued work and acceleration," said Nancy Haegel, director of the National Center for Photovoltaics at NREL. Haegel is lead author of the new article in the journal *Science*, "Photovoltaics at Multi-Terawatt Scale: Waiting Is Not an Option." The coauthors represent 41 institutions from 15 countries.

"Time is of the essence, so it's important that we set ambitious and achievable goals that have significant impact," said Martin Keller, director of NREL. "There has been so much progress in the realm of photovoltaic solar energy, and I know we can accomplish even more as we continue to innovate and act with urgency."

Incident solar radiation can easily provide more than enough energy to meet the Earth's energy needs, but only a small percentage is actually put to use. The amount of electricity supplied globally by PV significantly increased from a negligible amount in 2010 to 4-5% in 2022.

The report from the workshop noted the "window is increasingly closing to take action at scale to cut greenhouse gas emissions while meeting global energy needs for the future." PV stands out as one of very few options that can be immediately used to replace fossil fuels. "A major risk for the next decade would be to make poor assumptions or mistakes in modeling the required growth in the PV industry, and then realize too late that we were wrong on the low side and need to ramp up manufacturing and deployment to unrealistic or unsustainable levels."

Reaching the 75-terawatt target, the authors predicted, will place significant demands on both PV manufacturers and the scientific community. For example:

- Makers of silicon solar panels must reduce the amount of silver used in order for the technology to be sustainable at a multi-terawatt scale.
- The PV industry must continue to grow at a rate of about 25% per year over the next critical years.
- The industry must continuously innovate to improve material sustainability and reduce its environmental footprint.

Workshop participants also said solar technology must be redesigned for ecodesign and circularity, although recycling materials is not an economically viable solution at present for material demands given the relatively low installations to date compared to the demands of the next two decades.

As the report noted, the target of 75 terawatts of installed PV "is both a major challenge and an available path forward. Recent history and the current trajectory suggest that it can be achieved."

Story Source:

Materials provided by DOE/National Renewable Energy Laboratory. Note: Content may be edited for style and length.

Students use machine learning in lesson designed to reveal issues, promise of A.I.

Mr. Harsh Magdum, Mr. Rohan Thomake, Mr. Harshavardhan Kamat, Kumbhar Rushikesh

The study was conducted in conjunction with a high school journalism class in the Northeast. Since then, researchers have expanded the program to high school classrooms in multiple states, including North Carolina. NC State researchers are looking to partner with additional schools to collaborate in bringing the curriculum into classrooms.

"We want students, from a very young age, to open up that black box so they aren't afraid of AI," said the study's lead author Shiyan Jiang, assistant professor of learning design and technology at NC State. "We want students to know the potential and challenges of AI, and so they think about how they, the next generation, can respond to the evolving role of AI and society. We want to prepare students for the future workforce."

For the study, researchers developed a computer program called StoryQ that allows students to build their own machine-learning models. Then, researchers hosted a teacher workshop about the machine learning curriculum and technology in one-and-a-half hour sessions each week for a month. For teachers who signed up to participate further, researchers did another recap of the curriculum for participating teachers, and worked out logistics.

"We created the StoryQ technology to allow students in high school or undergraduate classrooms to build what we call 'text classification' models," Jiang said. "We wanted to lower the barriers so students can really know what's going on in machine-learning, instead of struggling with the coding. So we created StoryQ, a tool that allows students to understand the nuances in building machine-learning and text classification models."

A teacher who decided to participate led a journalism class through a 15-day lesson where they used StoryQ to evaluate a series of Yelp reviews about ice cream stores. Students developed models to predict if reviews were "positive" or "negative" based on the language.

"The teacher saw the relevance of the program to journalism," Jiang said. "This was a very diverse class with many students who are under-represented in STEM and in computing. Overall, we found students enjoyed the lessons a lot, and had great discussions about the use and mechanism of machine-learning."

Researchers saw that students made hypotheses about specific words in the Yelp reviews, which they thought would predict if a review would be positive, or negative. For example, they expected reviews containing the word "like" to be positive. Then, the teacher guided the students to analyze whether their models correctly classified reviews. For example, a student who used the word "like" to predict reviews found that more than half of reviews containing the word were actually negative. Then, researchers said students used trial and error to try to improve the accuracy of their models.

"Students learned how these models make decisions, and the role that humans can play in creating these technologies, and the kind of perspectives that can be brought in when they create AI technology," Jiang said.

From their discussions, researchers found that students had mixed reactions to AI technologies. Students were deeply concerned, for example, about the potential to use AI to automate processes for selecting students or candidates for opportunities like scholarships or programs.

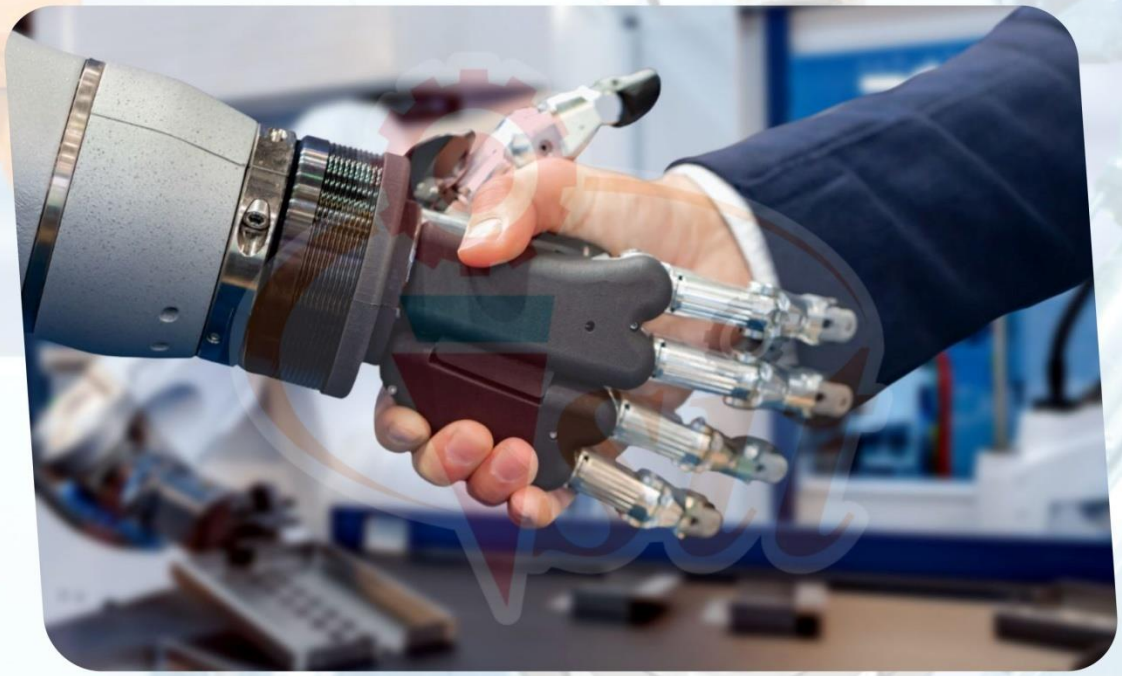
For future classes, researchers created a shorter, five-hour program. They've launched the program in two high schools in North Carolina, as well as schools in Georgia, Maryland and Massachusetts. In the next phase of their research, they are looking to study how teachers across disciplines collaborate to launch an AI-focused program and create a community of AI learning.

"We want to expand the implementation in North Carolina," Jiang said. "If there are any schools interested, we are always ready to bring this program to a school. Since we know teachers are super busy, we're offering a shorter professional development course, and we also provide a stipend for teachers. We will go into the classroom to teach if needed, or demonstrate how we would teach the curriculum so teachers can replicate, adapt, and revise it. We will support teachers in all the ways we can."

The study, "High school students' data modeling practices and processes: From modeling unstructured data to evaluating automated decisions," was published online March 13 in the journal *Learning, Media and Technology*. Co-authors included Hengtao Tang, Cansu Tatar, Carolyn P. Rosé and Jie Chao. The work was supported by the National Science Foundation under grant number 1949110.

Journal Reference:

Shiyan Jiang, Hengtao Tang, Cansu Tatar, Carolyn P. Rosé, Jie Chao. High school students' data modeling practices and processes: From modeling unstructured data to evaluating automated decisions. Learning, Media and Technology, 2023; 1 DOI: 10.1080/17439884.2023.2189735



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