Making aircraft fuel from sunlight and air

AishwaryaPatil, KishorDhumale

Carbon-neutral fuels are crucial for making aviation and maritime transport sustainable. The plant developed in Zurich can be used to produce synthetic liquid fuels that release as much CO_2 during their combustion as was previously extracted from the air for their production. CO_2 and water are extracted directly from ambient air and split using solar energy. This process yields syngas, a mixture of hydrogen and carbon monoxide, which is then processed into kerosene, methanol, or other hydrocarbons.

A team of researchers led by Aldo Steinfeld, Professor of Renewable Energy Sources at ETH Zurich, have been operating the mini solar refinery on the roof of ETH's Machine Laboratory building in Zurich over the last two years. "This plant successfully demonstrates the technical feasibility of the entire thermochemical process for converting sunlight and ambient air into drop-in fuels. The system operates stably under real-world solar conditions and provides a unique platform for further research and development," says Steinfeld. The technology is now sufficiently mature for use in industrial applications.

Desert offers ideal conditions

Analyses of the entire process show that the fuel would cost 1.20 to 2 euros per litre if it were produced on an industrial scale. Desert regions with high solar resources are particularly suitable as production sites. "Unlike with biofuels, whose potential is limited due to the scarcity of agricultural land, this technology enables us to meet global demand for jet fuel by using less than one percent of the world's arid land and would not compete with the production of food or livestock feed," explains Johan Lilliestam, a research group leader at the Institute for Advanced Sustainability Studies (IASS Potsdam) and professor of energy policy at the University of Potsdam. If the materials used to build the production facilities, such as glass and steel, are manufactured using renewable energy and carbon-neutral methods, emissions can be further reduced to close to zero.

Supportive policies needed

However, given the high initial investment costs, solar fuels will need political support to secure their market entry. "The European Union's existing support instruments emissions trading and offsettingare not sufficient to stimulate market demand for solar fuels. In view of this, we propose the adoption of a European technology-specific quota system for aviation fuel. This would require airlines to acquire a specific share of their fuel from solar sources," explains Lilliestam.

The study's authors recommend a share of 0.1 percent in the earliest phase of market adoption, when the price of "solar kerosene" will be high and production capacities low. This would have little impact on the cost of flying, but would promote the construction of production facilities and set in motion a learning curve that could lead to technological enhancements and lower prices. The quota could then be gradually increased until solar kerosene achieves a market breakthrough without further support measures.

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Growing carbon footprint for plastics

Shraddha Mahadik, Shubham Kulkarni

Research into the global environmental impact of plastics has also focused primarily on the disposal phase. There are few studies into the production of plastics, which also affects the climate and air quality. In-depth analysis, however, requires detailed information on supply chains and processes in order to trace the relevant material and energy flows.

Assessing the global footprint of plastics

"So far, the simplistic assumption has been that the production of plastic requires roughly the same amount of fossil fuel as is contained in the raw materials in plastic -- above all petroleum," says Livia Cabernard, a doctoral student at the Institute of Science, Technology and Policy (ISTP) at ETH Zurich. The problem here, however, is that the relative significance of production versus disposal has been significantly underestimated.

Cabernard is part of a team of researchers led by Stephan Pfister, Senior Scientist at ISTP, and Stefanie Hellweg, ETH Professor of Ecological Systems Design at the Institute of Environmental Engineering. Through painstaking detective work, the team analysed the climate and health impact of the global plastics supply chain over a 20-year period.

In a study recently published in Nature Sustainability, the researchers show that the global carbon footprint of plastics has doubled since 1995, reaching 2 billion tonnes of CO2 equivalent (CO2e) in 2015. This represents 4.5 percent of global greenhouse gas emissions, and is more than previously thought. Over the same period, the global health footprint of plastics from fine particulate air pollution has increased by 70 percent, causing approximately 2.2 million disability-adjusted life years (DALYs) in 2015.

Coal for process heat, electricity and as a raw material

For their study, the team determined the greenhouse gas emissions generated across the life cycle of plastics -- from fossil resource extraction, to processing into product classes and use, through to end of life, including recycling, incineration and landfill.

The researchers identify booming plastic production in coal-based newly industrialised countries such as China, India, Indonesia and South Africa as the main cause of the growing greenhouse gas footprint of plastics. The energy and process heat for the production of plastics in these countries comes primarily from the combustion of coal. A small amount of coal is also used as a raw material for plastics.

"The plastics-related carbon footprint of China's transport sector, Indonesia's electronics industry and India's construction industry has increased more than 50-fold since 1995," explains Cabernard. Globally, carbon-based emissions in plastics production have quadrupled since 1995 and now account for nearly half of the global carbon footprint of plastics.

When coal is burned, it produces extremely fine particles that accumulate in the air. Such particulate matter is highly harmful to health and can cause asthma, bronchitis and cardiovascular disease. As more and more coal is used for process heat, electricity and as a raw material in plastic production, the negative consequences for health are also increasing.

Underestimated plastic production

In contrast to earlier estimates, which assumed equal amounts of fuel and raw material for the production of plastics, the ETH researchers have now proven that twice as much fossil energy is burned for plastic production as is contained as a raw material in plastic.

This affects the assessment of the environmental consequences. "Even in a worst-case scenario in which all plastics are incinerated, their production accounts for the lion's share of total greenhouse gas and particulate matter emissions," says Cabernard.The overall production phase of plastics is responsible for the vast majority (96 percent) of the carbon footprint of plastics.

Insights thanks to new methodology

There had previously only been one publication that examined the global carbon footprint of plastics production. "This underestimated the greenhouse gas emissions, however, because it did not take into account the increasing dependence on coal due to the outsourcing of production processes to coal-based countries," Cabernard explains.

The researchers used a new method for their study that Cabernard had previously developed in her doctoral thesis under the supervision of Pfister and Hellweg. This approach involves a multi-regional input-output analysis that can accurately map global supply chains from production to consumption across industries, countries and regions.

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How organic neuromorphic electronics can think and act

OmkarKarangale, Rahul Shinde

Scientists working with Paschalis Gkoupidenis, group leader in Paul Blom's department at the Max Planck Institute for Polymer Research, have now applied this basic principle of learning through experience in a simplified form and steered a robot through a maze using a so-called organic neuromorphic circuit. The work was an extensive collaboration between the Universities of Eindhoven, Stanford, Brescia, Oxford and KAUST.

"We wanted to use this simple setup to show how powerful such 'organic neuromorphic devices' can be in real-world conditions," says ImkeKrauhausen, a doctoral student in Gkoupidenis' group and at TU Eindhoven (van de Burgt group), and first author of the scientific paper.

To achieve the navigation of the robot inside the maze, the researchers fed the smart adaptive circuit with sensory signals coming from the environment. The path of maze towards the exit is indicated visually at each maze intersects. Initially, the robot often misinterprets the visual signs, thus it makes the wrong "turning" decisions at the maze intersects and loses the way out. When the robot takes these decisions and follows wrong dead-end paths, it is being discouraged to take these wrong decisions by receiving corrective stimuli. The corrective stimuli, for example when the robot hits a wall, are directly applied at the organic circuit via electrical signals induced by a touch sensor attached to the robot. With each subsequent execution of the experiment, the robot gradually learns to make the right "turning" decisions at the intersects, i. e. to avoid receiving corrective stimuli, and after a few trials it finds the way out of the maze. This learning process happens exclusively on the organic adaptive circuit.

"We were really glad to see that the robot can pass through the maze after some runs by learning on a simple organic circuit. We have shown here a first, very simple setup. In the distant future, however, we hope that organic neuromorphic devices could also be used for local and distributed computing/learning. This will open up entirely new possibilities for applications in real-world robotics, human-machine interfaces and point-of-care diagnostics. Novel platforms for rapid prototyping and education, at the intersection of materials science and robotics, are also expected to emerge." Gkoupidenis says.

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A tool to speed development of new solar cells

Shraddha Hasure, SanjanaPatil

Now, researchers at MIT and Google Brain have developed a system that makes it possible not just to evaluate one proposed design at a time, but to provide information about which changes will provide the desired improvements. This could greatly increase the rate for the discovery of new, improved configurations.

The new system, called a differentiable solar cell simulator, is described in a paper published in the journal *Computer Physics Communications*, written by MIT junior Sean Mann, research scientist Giuseppe Romano of MIT's Institute for Soldier Nanotechnologies, and four others at MIT and at Google Brain.

Traditional solar cell simulators, Romano explains, take the details of a solar cell configuration and produce as their output a predicted efficiency -- that is, what percentage of the energy of incoming sunlight actually gets converted to an electric current. But this new simulator both predicts the efficiency and shows how much that output is affected by any one of the input parameters. "It tells you directly what happens to the efficiency if we make this layer a little bit thicker, or what happens to the efficiency if we for example change the property of the material," he says.

In short, he says, "we didn't discover a new device, but we developed a tool that will enable others to discover more quickly other higher performance devices." Using this system, "we are decreasing the number of times that we need to run a simulator to give quicker access to a wider space of optimized structures." In addition, he says, "our tool can identify a unique set of material parameters that has been hidden so far because it's very complex to run those simulations."

While traditional approaches use essentially a random search of possible variations, Mann says, with his tool "we can follow a trajectory of change because the simulator tells you what direction you want to be changing your device. That makes the process much faster because instead of exploring the entire space of opportunities, you can just follow a single path" that leads directly to improved performance.

Since advanced solar cells often are composed of multiple layers interlaced with conductive materials to carry electric charge from one to the other, this computational tool reveals how changing the relative thicknesses of these different layers will affect the device's output. "This is very important because the thickness is critical. There is a strong interplay between light propagation and the thickness of each layer and the absorption of each layer," Mann explains.

Other variables that can be evaluated include the amount of doping (the introduction of atoms of another element) that each layer receives, or the dielectric constant of insulating layers, or the bandgap, a measure of the energy levels of photons of light that can be captured by different materials used in the layers.

This simulator is now available as an open-source tool that can be used immediately to help guide research in this field, Romano says. "It is ready, and can be taken up by industry experts." To make use of it, researchers would couple this device's computations with an optimization algorithm, or even a machine learning system, to rapidly assess a wide variety of possible changes and home in quickly on the most promising alternatives.

At this point, the simulator is based on just a one-dimensional version of the solar cell, so the next step will be to expand its capabilities to include two- and three-dimensional configurations. But even this 1D version "can cover the majority of cells that are currently under production," Romano says. Certain variations, such as so-called tandem cells using different materials, cannot yet be simulated directly by this tool, but "there are ways to approximate a tandem solar cell by simulating each of the individual cells," Mann says.

The simulator is "end-to-end," Romano says, meaning it computes the sensitivity of the efficiency, also taking into account light absorption. He adds: "An appealing future direction is composing our simulator with advanced existing differentiable light-propagation simulators, to achieve enhanced accuracy."

Moving forward, Romano says, because this is an open-source code, "that means that once it's up there, the community can contribute to it. And that's why we are really excited." Although this research group is "just a handful of people," he says, now anyone working in the field can make their own enhancements and improvements to the code and introduce new capabilities.

"Differentiable physics is going to provide new capabilities for the simulations of engineered systems," says Venkat Viswanathan, an associate professor of mechanical engineering at Carnegie Mellon University, who was not associated with this work. "The differentiable solar cell simulator is an incredible example of differentiable physics, that can now provide new capabilities to optimize solar cell device performance," he says, calling the study "an exciting step forward."

In addition to Mann and Romano, the team included Eric Fadel and Steven Johnson at MIT, and Samuel Schoenholz and EkinCubuk at Google Brain. The work was supported in part by Eni S.p.A. and the MIT Energy Initiative, and the MIT Quest for Intelligence.

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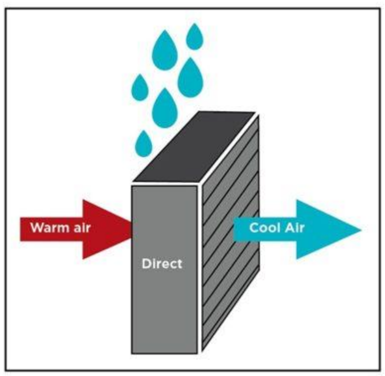
Direct, Indirect and Hybrid Evaporative Cooling

AsiyaPendhari, AmeyPanade

Direct evaporative cooling

Direct evaporative cooling (open circuit) is used to lower the temperature and increase the humidity of air by using latent heat of evaporation, changing liquid water to water vapor. In this process, the energy in the air does not change. Warm dry air is changed to cool moist air. The heat of the outside air is used to evaporate water. The RH increases to 70 to 90% which reduces the cooling effect of human perspiration. The moist air has to be continually released to outside or else the air becomes saturated and evaporation stops.

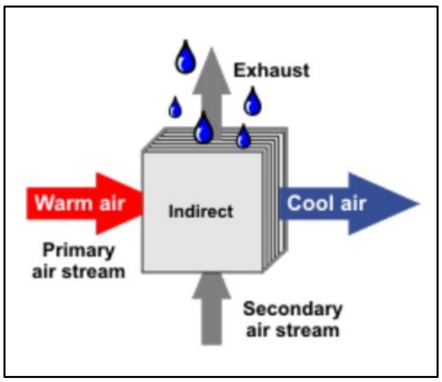


A mechanical direct evaporative cooler unit uses a fan to draw air through a wetted membrane, or pad, which provides a large surface area for the evaporation of water into the air. Water is sprayed at the top of the pad so it can drip down into the membrane and continually keep the membrane saturated. Any excess water that drips out from the bottom of the membrane is collected in a pan and recirculated to the top. Single-stage direct evaporative coolers are typically small in size as they only consist of the membrane, water pump, and centrifugal fan. The mineral content of the municipal water supply will cause scaling on the membrane, which will lead to clogging over the life of the membrane. Depending on this mineral content and the evaporation rate, regular cleaning and maintenance is required to ensure optimal performance. Generally, supply air from the single-stage evaporative cooler will need to be exhausted directly (one-through flow) because the high humidity of the supply air. A few design solutions have been conceived to utilize the energy in the air, like directing the exhaust air through two sheets of double glazed windows, thus reducing the solar energy absorbed through the glazing. Compared to energy required to achieve the equivalent cooling load with a compressor, single stage evaporative coolers consume less energy.

Passive direct evaporative cooling can occur anywhere that the evaporative cooled water can cool a space without the assist of a fan. This can be achieved through use of fountains or more architectural designs such as the evaporative downdraft cooling tower, also called a "passive cooling tower". The passive cooling tower design allows outside air to flow in through the top of a tower that is constructed within or next to the building. The outside air comes in contact with water inside the tower either through a wetted membrane or a mister. As water evaporates in the outside air, the air becomes cooler and less buoyant and creates a downward flow in the tower. At the bottom of the tower, an outlet allows the cooler air into the interior. Similar to mechanical evaporative coolers, towers can be an attractive low-energy solution for hot and dry climate as they only require a water pump to raise water to the top of the tower. Energy savings from using a passive direct evaporating cooling strategy depends on the climate and heat load. For arid climates with a great wet-bulb depression, cooling towers can provide enough cooling during summer design conditions to be net zero. For example, a 371 m2 (4,000 ft2) retail store in Tucson, Arizona with a sensible heat gain of 29.3 kJ/h (100,000 Btu/h) can be cooled entirely by two passive cooling towers providing 11890 m3/h (7,000 cfm) each.

For the Zion National Park visitors' center, which uses two passive cooling towers, the cooling energy intensity was 14.5 MJ/m2 (1.28 kBtu/ft;), which was 77% less than a typical building in the western United States that uses 62.5 MJ/m2 (5.5 kBtu/ft2). A study of field performance results in Kuwait revealed that power requirements for an evaporative cooler are approximately 75% less than the power requirements for a conventional packaged unit air-conditioner.

Indirect evaporative cooling



Indirect evaporative cooling (closed circuit) is a cooling process that uses direct evaporative cooling in addition to some heat exchanger to transfer the cool energy to the supply air. The cooled moist air from the direct evaporative cooling process never comes in direct contact with the conditioned supply air. The moist air stream is released outside or used to cool other external devices such as solar cells which are more efficient if kept cool. This is done to avoid excess humidity in enclosed spaces, which is not appropriate for residential systems.

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'Human-like' brain helps robot out of a maze

Akash Gangdhar, KamilMutwalli

Machine learning and neural networks have become all the rage in recent years, and quite understandably so, considering their many successes in image recognition, medical diagnosis, e-commerce and many other fields. Still though, this software-based approach to machine intelligence has its drawbacks, not least because it consumes so

Mimicking the human brain

This power issue is one of the reasons that researchers have been trying to develop computers that are much more energy efficient. And to find a solution many are finding inspiration in the human brain, a thinking machine unrivalled in its low power consumption due to how it combines memory and processing.

Neurons in our brain communicate with one another through so-called synapses, which are strengthened each time information flows through them. It is this plasticity that ensures that humans remember and learn.

"In our research, we have taken this model to develop a robot that is able to learn to move through a labyrinth," explains ImkeKrauhausen, PhD student at the department of Mechanical Engineering at TU/e and principal author of the paper.

"Just as a synapse in a mouse brain is strengthened each time it takes the correct turn in a psychologist's maze, our device is 'tuned' by applying a certain amount of electricity. By tuning the resistance in the device, you change the voltage that control the motors. They in turn determine whether the robot turns right or left."

So how does it work?

The robot that Krauhausen and her colleagues used for their research is a Mindstorms EV^3, a robotics kit made by Lego. Equipped with two wheels, traditional guiding software to make sure it can follow a line, and a number of reflectance and touch sensors, it was sent into a 2 m^2 large maze made up out of black-lined hexagons in a honeycomb-like pattern.

The robot is programmed to turn right by default. Each time it reaches a dead end or diverges from the designated path to the exit (which is indicated by visual cues), it is told to either return or turn left. This corrective stimulus is then remembered in the neuromorphic device for the next effort.

"In the end, it took our robot 16 runs to find the exit successfully," says Krauhausen. "And, what's more, once it has learned to navigate this specific route *(target path 1)*, it can navigate any other path that it is given in one go *(target path 2)*. So, the knowledge it has acquired is generalizable."

Part of the success of the robot's ability to learn and exit the maze lies in the unique integration of sensors and motors, according to Krauhausen, who cooperated closely with the Max Planck Institute for Polymer Research in Mainz for this research. "This sensorimotor integration, in which sense and movement reinforce one another, is also very much how nature operates, so this is what we tried to emulate in our robot."

Smart polymers

Another clever thing about the research is the organic material used for the neuromorphic robot. This polymer (known as p(g2T-TT)) is not only stable, but it also is able to 'retain' a large part of the specific states in which it has been tuned during the various runs through the labyrinth. This ensures that the learned behaviour 'sticks', just like neurons and synapses in a human brain remember events or actions.

The use of polymer instead of silicon in the field of neuromorphic computing was pioneered by Paschalis Gkoupidenis of the Max Planck Institute for Polymer Research in Mainz and Yoeri van de Burgt of TU/e, both co-authors of the paper.

In their research (dating from 2015 and 2017), they proved that the material can be tuned in a much larger range of conduction than inorganic materials, and that it is able to 'remember' or store learned states for extended periods. Since then, organic devices have become a hot topic in the field of hardware-based artificial neural networks.

Bionic hands

Polymeric materials also have the added advantage that they can be used in numerous biomedical applications. "Because of their organic nature, these smart devices can in principle be integrated with actual nerve cells. Say you lost your arm during an injury. Then you could potentially use these devices to link your body to a bionic hand," says Krauhausen.

Another promising application of organic neuromorphic computing lies in small so-called edge computing devices where data from sensors is processed locally outside of the cloud. Van de Burgt: "This is where I see our devices going in the future, our materials will be very useful because they are easy to tune, use much less power, and are cheap to make."

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Engineers teach AI to navigate ocean with minimal energy

JagdishChoudhari, Anuj Birnale

"When we want robots to explore the deep ocean, especially in swarms, it's almost impossible to control them with a joystick from 20,000 feet away at the surface. We also can't feed those data about the local ocean currents they need to navigate because we can't detect them from the surface. Instead, at a certain point we need ocean-borne drones to be able to make decisions about how to move for themselves," says John O. Dabiri (MS '03, PhD '05), the Centennial Professor of Aeronautics and Mechanical Engineering and corresponding author of a paper about the research that was published by Nature Communications on December 8.

The AI's performance was tested using computer simulations, but the team behind the effort has also developed a small palm-sized robot that runs the algorithm on a tiny computer chip that could power seaborne drones both on Earth and other planets. The goal would be to create an autonomous system to monitor the condition of the planet's oceans, for example using the algorithm in combination with prosthetics they previously developed to help jellyfish swim faster and on command. Fully mechanical robots running the algorithm could even explore oceans on other worlds, such as Enceladus or Europa.

In either scenario, drones would need to be able to make decisions on their own about where to go and the most efficient way to get there. To do so, they will likely only have data that they can gather themselves information about the water currents they are currently experiencing.

To tackle this challenge, researchers turned to reinforcement learning (RL) networks. Compared to conventional neural networks, reinforcement learning networks do not train on a static data set but rather train as fast as they can collect experience. This scheme allows them to exist on much smaller computers -- for the purposes of this project, the team wrote software that can be installed and run on a Teensy -- a 2.4-by-0.7-inch microcontroller that anyone can buy for less than $30 on Amazon and only uses about a half watt of power.

Using a computer simulation in which flow past an obstacle in water created several vortices moving in opposite directions, the team taught the AI to navigate in such a way that it took advantage of low-velocity regions in the wake of the vortices to coast to the target location with minimal power used. To aid its navigation, the simulated swimmer only had access to information about the water currents at its immediate location, yet it soon learned how to exploit the vortices to coast toward the desired target. In a physical robot, the AI would similarly only have access to information that could be gathered from an onboard gyroscope and accelerometer, which are both relatively small and low-cost sensors for a robotic platform.

This kind of navigation is analogous to the way eagles and hawks ride thermals in the air, extracting energy from air currents to maneuver to a desired location with the minimum energy expended. Surprisingly, the researchers discovered that their reinforcement learning algorithm could learn navigation strategies that are even more effective than those thought to be used by real fish in the ocean.

"We were initially just hoping the AI could compete with navigation strategies already found in real swimming animals, so we were surprised to see it learn even more effective methods by exploiting repeated trials on the computer," says Dabiri.

The technology is still in its infancy: currently, the team would like to test the AI on each different type of flow disturbance it would possibly encounter on a mission in the ocean -- for example, swirling vortices versus streaming tidal currents -- to assess its effectiveness in the wild. However, by incorporating their knowledge of ocean-flow physics within the reinforcement learning strategy, the researchers aim to overcome this limitation. The current research proves the potential effectiveness of RL networks in addressing this challenge -- particularly because they can operate on such small devices. To try this in the field, the team is placing the Teensy on a custom-built drone dubbed the "CARL-Bot" (Caltech Autonomous Reinforcement Learning Robot). The CARL-Bot will be dropped into a newly constructed two-story-tall water tank on Caltech's campus and taught to navigate the ocean's currents.

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Engineers create 3D-printed objects that sense how a user is interacting with them

YuvrajKadage, Juned Pathan

"Metamaterials can support different mechanical functionalities. But if we create a metamaterial door handle, can we also know that the door handle is being rotated, and if so, by how many degrees? If you have special sensing requirements, our work enables you to customize a mechanism to meet your needs," says co-lead author Jun Gong, a former visiting PhD student at MIT who is now a research scientist at Apple.

Gong wrote the paper alongside fellow lead authors Olivia Seow, a graduate student in the MIT Department of Electrical Engineering and Computer Science (EECS), and Cedric Honnet, a research assistant in the MIT Media Lab. Other co-authors are MIT graduate student Jack Forman and senior author Stefanie Mueller, who is an associate professor in EECS and a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL). The research will be presented at the Association for Computing Machinery Symposium on User Interface Software and Technology next month.

"What I find most exciting about the project is the capability to integrate sensing directly into the material structure of objects. This will enable new intelligent environments in which our objects can sense each interaction with them," Mueller says. "For instance, a chair or couch made from our smart material could detect the user's body when the user sits on it and either use it to query particular functions (such as turning on the light or TV) or to collect data for later analysis (such as detecting and correcting body posture)."

Embedded electrodes

Because metamaterials are made from a grid of cells, when the user applies force to a metamaterial object, some of the flexible, interior cells stretch or compress.

The researchers took advantage of this by creating "conductive shear cells," flexible cells that have two opposing walls made from conductive filament and two walls made from nonconductive filament. The conductive walls function as electrodes.

When a user applies force to the metamaterial mechanism -- moving a joystick handle or pressing the buttons on a controller -- the conductive shear cells stretch or compress, and the distance and overlapping area between the opposing electrodes changes. Using capacitive sensing, those changes can be measured and used to calculate the magnitude and direction of the applied forces, as well as rotation and acceleration.

To demonstrate this, the researchers created a metamaterial joystick with four conductive shear cells embedded around the base of the handle in each direction (up, down, left, and right). As the user moves the joystick handle, the distance and area between the opposing conductive walls changes, so the direction and magnitude of each applied force can be sensed. In this case, those values were converted to inputs for a "PAC-MAN" game.

By understanding how joystick users apply forces, a designer could prototype unique handle shapes and sizes for people with limited grip strength in certain directions.

The researchers also created a music controller designed to conform to a user's hand. When the user presses one of the flexible buttons, conductive shear cells within the structure are compressed and the sensed input is sent to a digital synthesizer.

This method could enable a designer to quickly create and tweak unique, flexible input devices for a computer, like a squeezable volume controller or bendable stylus.

A software solution

MetaSense, the 3D editor the researchers developed, enables this rapid prototyping. Users can manually integrate sensing into a metamaterial design or let the software automatically place the conductive shear cells in optimal locations.

"The tool will simulate how the object will be deformed when different forces are applied, and then use this simulated deformation to calculate which cells have the maximum distance change. The cells that change the most are the optimal candidates to be conductive shear cells," Gong says.

The researchers endeavored to make MetaSense straightforward, but there are challenges to printing such complex structures.

"In a multimaterial 3D printer, one nozzle would be used for nonconductive filament and one nozzle would be used for conductive filament. But it is quite tricky because the two materials may have very different properties. It requires a lot of parameter-tuning to settle on the ideal speed, temperature, etc. But we believe that, as 3D printing technology continues to get better, this will be much easier for users in the future," he says.

In the future, the researchers would like to improve the algorithms behind MetaSense to enable more sophisticated simulations.

They also hope to create mechanisms with many more conductive shear cells. Embedding hundreds or thousands of conductive shear cells within a very large mechanism could enable high-resolution, real-time visualizations of how a user is interacting with an object, Gong says.

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Smoke from nuclear war would devastate ozone layer, alter climate

Nikita Walave, KalyaniBadade

The international study paints an even grimmer picture of a global nuclear war's aftermath than previous analyses. The research team used newly developed computer climate modeling techniques to learn more about the effects of a hypothetical nuclear exchange, including complex chemistry interactions in the stratosphere that influence the amounts of ultraviolet (UV) radiation that reach the planet's surface.

"In addition to all the fatalities that would happen almost immediately, the climate effects and the UV effects would be widespread," said lead author Charles Bardeen, a scientist at the National Center for Atmospheric Research (NCAR). "These aren't local to where the war occurs. They're global, so they would affect all of us."

Bardeen and his co-authors found that smoke from a global nuclear war would destroy much of the ozone layer over a 15-year period, with the ozone loss peaking at an average of about 75% worldwide. Even a regional nuclear war would lead to a peak ozone loss of 25% globally, with recovery taking about 12 years.

Since the ozone layer protects Earth's surface from harmful UV radiation, such impacts would be devastating to humans and the environment. High levels of UV radiation have been linked to certain types of skin cancer, cataracts, and immunological disorders. The ozone layer also protects terrestrial and aquatic ecosystems, as well as agriculture.

"Although we suspected that ozone would be destroyed after nuclear war and that would result in enhanced ultraviolet light at the Earth's surface, if there was too much smoke, it would block out the ultraviolet light," said study co-author Alan Robock, a professor of climate science at Rutgers University. "Now, for the first time, we have calculated how this would work and quantified how it would depend on the amount of smoke."

The study was funded by the Open Philanthropy Project with computational support from the National Science Foundation, which is NCAR's sponsor, as well as from the University of Colorado Boulder and Colorado State University. It was published in the *Journal of Geophysical Research -- Atmospheres*, a publication of the American Geophysical Union.

Shifting atmospheric response to global war

Scientists in the 1980s found that the enormous amounts of smoke from a nuclear war would cool the planet by blocking incoming sunlight, an outcome known as a "nuclear winter." They also found that a nuclear war would destroy ozone because of chemical reactions involving nitrogen oxides produced from the fireball created by a nuclear weapon explosion.

Subsequent research, however, suggested that the smoke would also cause ozone loss by heating the stratosphere, which changes chemical reaction rates, and by reducing photochemistry (chemical reactions caused by sunlight).

In the new study, the authors explored how much the reduced photochemistry would affect ozone destruction, as well as the extent to which the smoke would protect the surface from UV radiation. They calculated, for the first time, the combined effects of nitrogen oxides, stratospheric heating, and reduced photochemistry on stratospheric ozone chemistry and surface UV resulting from a global nuclear war.

The research team combined four advanced NCAR-based computer models: the Community Earth System Model, which simulates global climate; the Whole Atmosphere Community Climate Model, which simulates higher regions of the atmosphere; the Tropospheric Ultraviolet and Visible Radiation Model, which calculates the light available for photolysis and the amount of UV radiation that reaches the surface; and the Community Aerosol and Radiation Model for Atmospheres, which provides an advanced treatment of smoke particles.

They used this modeling approach to study two scenarios. In one, a regional nuclear war between India and Pakistan produces 5 megatons of smoke. In the other, a global nuclear war between the United States and Russia produces 150 megatons of smoke.

The results highlighted the importance of using sophisticated modeling techniques to flesh out the complexities of the atmosphere. In the case of the global nuclear war, for example, the simulations showed that massive injection of smoke into the stratosphere would initially cool surface temperatures by blocking sunlight, alter precipitation patterns, shield the planet from incoming UV radiation, while also destroying the protective ozone layer. Within a few years, however, the smoke would begin to dissipate and far more UV radiation would reach the surface through the diminished ozone layer.

"Conditions would switch dramatically, and adaptations that may work at first won't help as temperatures warm back up and UV radiation increases," Bardeen said. "Just as the smoke is clearing up, you would get this blast of UV with completely different impacts on human health and agriculture."

In contrast, a regional nuclear war that generated less smoke would result in a more straightforward pattern, with UV increasing right away while surface temperatures are decreasing and the ozone layer gradually recovering as the smoke dissipates.

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Affordable policy which could stop fossil fuels causing global warming

SurajHaswal, BharteshAmbade

A ground-breaking study by the Universities of Oxford and Edinburgh, published Tuesday in the international energy journal *Joule,* explores the economic implications of imposing a carbon takeback obligation on the global fossil fuel industry, and shows it provides an affordable and low-risk route to net zero emissions, particularly if complemented by conventional measures to reduce near-term fossil fuel demand.

Oxford researcher Stuart Jenkins, lead author of the study, explains, 'Despite the perceived high cost of carbon dioxide capture and storage, we show that the cost to the world economy of a Carbon Takeback Obligation, even if entirely passed on to fossil fuel consumers, is no higher than the cost of mitigation in conventional scenarios meeting similar goals driven by a global carbon price.'

Professor Stuart Haszeldine of the University of Edinburgh, a report co-author, says, 'Investment in carbon dioxide capture and geological storage has, to date, been dependent on state subsidies, and consistently far below what is required to meet Paris climate goals. Carbon Takeback provides the fossil fuel industry itself with the strongest possible incentive to make amends: survival.'

Oxford's Professor Myles Allen, another co-author adds, 'Carbon Takeback has consistently been dismissed by the climate policy establishment as much more expensive and risky than the alternative of driving down consumption by changing consumer behaviour or through a global carbon price. But these options are hardly risk-free. Getting to net zero means carbon prices rising to $1000 per tonne of CO_2 by 2050: 100 times the hike that brought out the gilets jaunes.'

MargrietKuijper, an independent expert in carbon capture and storage who reviewed the work, comments, 'A Carbon Takeback policy as proposed in this paper will provide a safety net to make sure we achieve net zero emissions even if we don't manage to reduce the use of fossil fuels quickly enough. It extends the responsibility of producers to take care of the waste generated by the use of their products. The polluter pays to clean up. And the costs are included in the product price. As it should be.'

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Free green services could substantially reduce emissions

Ashwini Patil, MayuriNirmal

Carbon taxes on home energy and motor fuel often place a greater burden on low-income households because the same tax rate applies to every taxpayer, regardless of income. However, they contribute much less to climate change than high income households.

The researchers compared two ways of using revenue from carbon taxes to reduce emissions and fuel and transport poverty. They found that providing free green services would be more effective than redistributing the tax revenue among the population to address the regressive impacts of the taxes on lower earners.

The study was led by Dr Milena Buchs, Associate Professor in Sustainability, Economics and Low Carbon Transitions in Leeds' Sustainability Research Institute. She said: "Stringent climate policies, including carbon taxes on home energy and motor fuels, are likely to be part of government strategies to achieve climate targets, but they put higher burdens on low-income households than on rich households. Governments urgently need to make climate policies fairer by finding ways that can compensate disadvantaged people.

"Providing people with green living options, like free green electricity and free public transport, is promising because it's re-distributive, saves emissions and reduces fuel and transport poverty."

The research team examined household expenditure data on home energy and motor fuel from 275,614 households across 27 European countries, provided by the European Household Budget Surveys (HBS). The expenditure data were combined with emission factors to estimate annual greenhouse gas emissions per household for home energy and motor fuels.

They then examined the impact of introducing two different compensation strategies to mitigate the impact of new carbon taxes on low-income households.

They found that giving cash back through tax rebates, without bringing in additional low carbon investments such as renewable electricity or public transport, would result in only small reductions in home energy and motor fuel emissions.

In contrast, introducing universal green vouchers with expanded renewable electricity generation and public transport would reduce home energy emissions by 13.4%, and motor fuel emissions by 23.8%.

If green vouchers and infrastructure were provided without introducing carbon taxes, emission savings would be slightly lower, but 4.1% and 2.2% of households would be lifted out of fuel and transport poverty respectively.

However, combining carbon taxes with cash compensation would increase fuel and transport poverty by 4.1% and 1.8%.

DrBuchs said: "These findings demonstrate that policies that aim to compensate for unfair distributional impacts of carbon taxes need to be combined with additional environmental interventions.

"The provision of green goods and services needs to be expanded, and fuel and transport poverty minimised, so that social and environmental objectives can both be met."

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Stretchy, washable battery brings wearable devices closer to reality

AnkushGurav, Akash Kirtane

The battery developed by Dr. Nguyen and his colleagues offers a number of engineering advances. In normal batteries, the internal layers are hard materials encased in a rigid exterior. The UBC team made the key compoundsin this case, zinc and manganese dioxide -- stretchable by grinding them into small pieces and then embedding them in a rubbery plastic, or polymer. The battery comprises several ultra-thin layers of these polymers wrapped inside a casing of the same polymer. This construction creates an airtight, waterproof seal that ensures the integrity of the battery through repeated use.

It was team member BaharIranpour, a PhD student, who suggested throwing the battery in the wash to test its seal. So far, the battery has withstood 39 wash cycles and the team expects to further improve its durability as they continue to develop the technology.

"We put our prototypes through an actual laundry cycle in both home and commercial-grade washing machines. They came out intact and functional and that's how we know this battery is truly resilient," says Iranpour.

The choice of zinc and manganese dioxide chemistry also confers another important advantage. "We went with zinc-manganese because for devices worn next to the skin, it's a safer chemistry than lithium-ion batteries, which can produce toxic compounds when they break," says Nguyen.

An affordable option

Ongoing work is underway to increase the battery's power output and cycle life, but already the innovation has attracted commercial interest. The researchers believe that when the new battery is ready for consumers, it could cost the same as an ordinary rechargeable battery.

"The materials used are incredibly low-cost, so if this is made in large numbers, it will be cheap," says electrical and computer engineering professor Dr. John Madden, director of UBC's Advanced Materials and Process Engineering Lab who supervised the work. In addition to watches and patches for measuring vital signs, the battery might also be integrated with clothing that can actively change colour or temperature.

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Atom laser creates reflective patterns similar to light

Akash Kamble, AnisNadaf

In experiments at Washington State University, scientists have developed a technique to see these matter wave caustics by placing attractive or repulsive obstacles in the path of a cold atom laser. The results are curving cusps or folds, upward or downward "V" shapes, which the researchers describe in a paper for *Nature Communications.*

While it is foundational research, these caustics have potential applications for highly precise measurement or timing devices such as interferometers and atomic clocks.

"It's a beautiful demonstration of how we can manipulate matter waves in a way that is very similar to how one would manipulate light," said Peter Engels, WSU Yount distinguished professor and the paper's senior author. "An atom is accelerated by gravity, so therefore, we can mimic effects that would be very difficult to see with light. Also, since atoms respond to many different things, we can potentially exploit this for new types of sensors that are particularly good at detecting magnetic fields, gradients in electric fields or in gravity."

To achieve these effects, first the scientists had to create one of the coldest places on Earth, which they were able to accomplish in the Fundamental Quantum Physics lab at WSU. Engels and his colleagues used optical lasers to take energy out of an atomic cloud trapped inside a vacuum chamber, cooling it very close to absolute zero (?273.15 degrees Celsius or ?459.67 degrees Fahrenheit).

This extreme cold makes atoms behave quantum mechanically in ways very different from the familiar laws of nature. In these conditions, instead of behaving like particles of matter, the atoms move like waves. Clouds formed of such atoms are known as Bose-Einstein condensates, named after the theorists whose work first predicted this state of matter, Albert Einstein and SatyendraNath Bose.

In the process of exploring these condensates, the researchers at WSU created a cold atom laser, meaning the wave-like atoms started lining up in a column and moving together.

"A light laser is a collimated, coherent stream of photons, and we're essentially doing that with atoms," said Maren Mossman, the paper's first author who worked on the project as a WSU post-doctoral fellow and is now the Clare BootheLuce assistant professor of physics at the University of San Diego. "The atoms sort of walk together and behave as one object. So then, we decided to see what happens if we poked this."

For this study, the researchers 'poked' at the atom laser by putting optical obstacles in its path, essentially shining specific wavelengths of laser lights onto the accelerating stream of atoms. One obstacle type repelled the atoms and made caustics in downward fold shapes; another attracted them making caustics in upward cusp shapes.

The system is also very tunable, the researchers said, meaning they can change how fast the atoms accelerate.

"Caustics in atom lasers have never really been studied with this flexibility," said Engels.

In addition to Engels and Mossman, the co-authors include Michael Forbes, WSU associate professor in the Department of Physics and Astronomy and Thomas Bersano, a former WSU post-doctoral fellow now at Los Alamos National Laboratory.

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