New robot boosts solar energy research

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Researchers have created a robot capable of conducting experiments more efficiently and sustainably to develop a range of new semiconductor materials with desirable attributes. The researchers have already demonstrated that the new technology, called RoboMapper, can rapidly identify new perovskite materials with improved stability and solar cell efficiency.

"RoboMapper allows us to conduct materials testing more quickly, while also reducing both cost and energy overhead—making the entire process more sustainable," says Aram Amassian, corresponding author of a paper on the work and a professor of materials science and engineering at North Carolina State University. The paper, "Sustainable Materials Acceleration Platform Reveals Stable and Efficient Wide Bandgap Metal Halide Perovskite Alloys," was published July 25 in the journal *Matter*.

Conventional materials research requires a researcher to prepare a sample and then go through multiple steps to test each sample using different instruments. This involves placing, aligning and calibrating samples as needed to collect the data. Think of it as an assembly line that is both time consuming and requires a lot of electricity to power the relevant instruments.

Previous efforts to automate this process have relied largely on automating the assembly line with one sample per chip moving through the entire data collection process. This improves speed, but each of the steps still has to be done with one sample at a time.

"RoboMapper also automates this process, but places dozens of samples on each chip by miniaturizing the material samples with the help of modern printing," Amassian says. "It still performs each step of the data collection process, but it does so for multiple materials in parallel, saving time and energy."

"This makes searching for new materials far more efficient, more cost effective, and more sustainable in terms of our carbon footprint," says Tonghui Wang, lead author of the paper and a Ph.D. student at NC State. "It's nearly 10 times faster than previous automated techniques."

To confirm this, the team evaluated the environmental impact of traditional materials research and data collection and compared it with the RoboMapper.

"It was remarkable to find that characterization is the major source of greenhouse gas emissions in materials research," says environmental economist Lucía Serrano-Luján, co-author of the paper and a researcher at Rey Juan Carlos University and the Technical University of Cartagena. "The RoboMapper's ability to streamline the data collection process by placing dozens of materials on the same chip reduced greenhouse gas emissions tenfold."

To demonstrate the utility of RoboMapper, the researchers focused first on perovskite materials. Perovskites, which are defined by their crystalline structure, are better than silicon at absorbing light. That means perovskite solar cells can be thinner and lighter than silicon solar cells without sacrificing the cell's ability to convert light into electricity—making them a focal point for research into next-generation solar technologies.

Specifically, the researchers focused on perovskite stability, which is one of the biggest challenges in the field.

"Basically, the challenge is that perovskite materials tend to degrade when exposed to light, losing the properties that made them desirable in the first place," Amassian says. "We're looking for ways to engineer these materials so that they are stable—meaning they retain their desirable properties for a long time, even when exposed to light."

And the researchers had their first significant finding with RoboMapper during the technology's proof-of-concept demonstration.

The researchers tasked RoboMapper with making alloys using a defined set of elements. RoboMapper then made samples with 150 different alloy compositions and conducted optical spectroscopy and X-ray structural assessments and stability tests of those samples.

RoboMapper's tests were designed to identify whether an alloy was suitable for tandem solar cells, meaning: whether it had the crystalline structure of a perovskite; whether it had a desirable set of optical characteristics, known as the band gap; and whether it was stable when exposed to intense light. This experimental data was then used to construct a computational model that identified a specific alloy composition that it predicted would have the best combination of desired attributes.

The researchers then made the desired alloy with RoboMapper and by using conventional laboratory techniques, and tested both.

"We are able to quickly identify the most stable composition from a possible set of perovskite alloys at a target band gap using the specific suite of elements we confined ourselves to for this proof-of-concept work," Amassian says. "The material we identified using RoboMapper also turned out to be more efficient at converting light into electricity in solar cell devices. Our conventional techniques validated the results from RoboMapper.

"One reason RoboMapper's experiments were able to produce such useful data is that the specific suite of experiments we used is based on previous work that informs our understanding of the relationship between what we can observe in optical tests and the stability of perovskite materials.

"Next steps for this work include expanding the range of potential alloys for testing in RoboMapper," Amassian says. "We're open to working with industry partners to identify new materials for photovoltaics or other applications. And with support from the Office of Naval Research, we are already using RoboMapper to advance our understanding of materials for both organic solar cells and printed electronics."

Ten of the paper's authors are part of the ORganic and Carbon Electronics Laboratories (ORaCEL) group at NC State, which is an interdisciplinary team of researchers focused on accelerating the development of new semiconductor materials for a wide range of applications.

More information: Aram Amassian, Sustainable Materials Acceleration Platform Reveals Stable and Efficient Wide Bandgap Metal Halide Perovskite Alloys, *Matter* (2023). DOI: 10.1016/j.matt.2023.06.040.
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