Engineering research equips solar industry for improved performance

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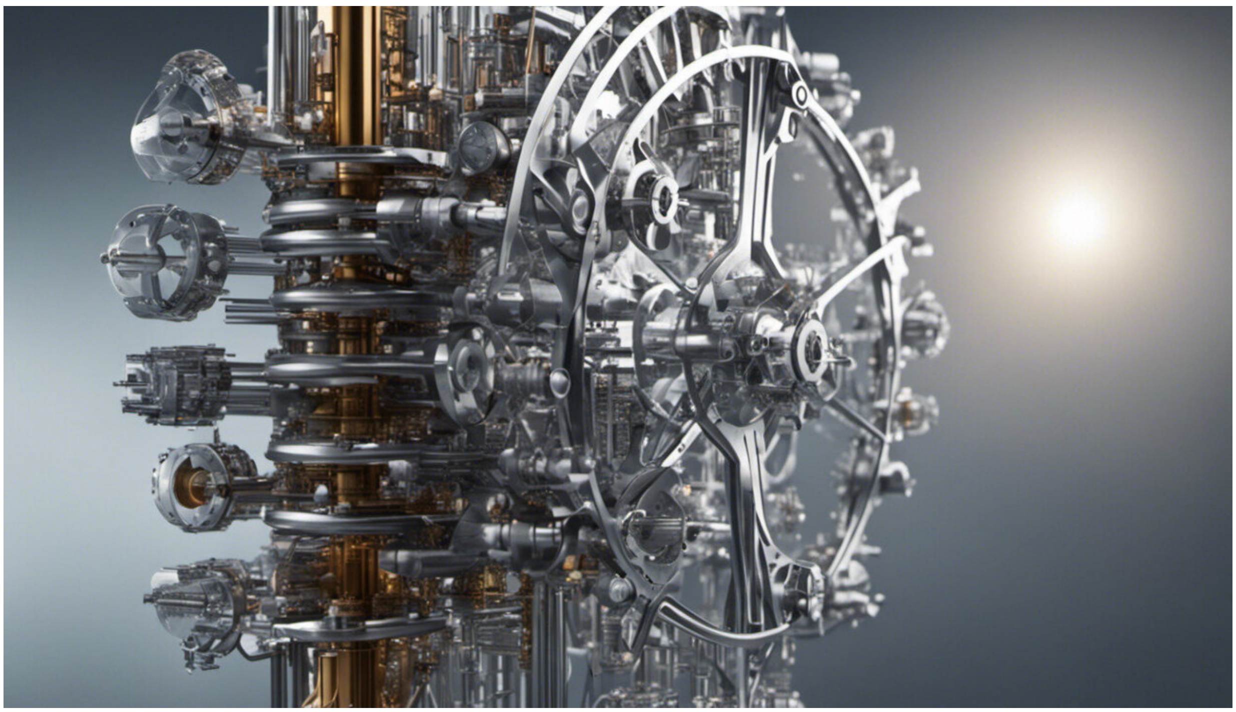

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Solar electricity is produced almost entirely by panels, or modules, constructed with light-absorbing cells made from silicon. Silicon is the industry standard because it is reliable and inexpensive, with structure and performance that are well understood.

But silicon cell modules are little more than 20% efficient in converting sunlight into electricity, and their production is relatively expensive and complicated. Efforts to lower technology costs relative to yield therefore include different materials or combinations of materials. One such mix is cadmium, selenium and telluride, abbreviated as CdSeTe and spoken colloquially as "CadTel."

"CadTel makes up only about 5% of the photovoltaics market, but it has significant potential," says Arthur Onno, an assistant research professor with the Holman Research Group in the Ira A. Fulton Schools of Engineering at Arizona State University. "For example, the absorbers are approximately 40 times thinner than those in silicon cells. Also, CadTel cells can be applied directly onto the front glass of a module through a more efficient production process called vapor transport deposition, which is the not the case for silicon. These differentiations can significantly change the manufacturing and cost structures for solar panels."

However, current CdSeTe devices display poorly understood voltage deficits that compromise their performance. Onno says the research community working with CdSeTe lacks the tools and techniques necessary to examine voltage losses and guide optimization in ways that are commonplace for improving silicon-based solar cells.

"It means issues are often associated with 'this part' or 'that part' of a device without any clear quantification of the losses or the mechanisms at play," Onno says. "It's sort of 'flying blind,'' so there is a real opportunity to bring important contributions to this field."

To seize that opportunity, Onno has been running a three-year project to develop a means of understanding why CdSeTe solar cell voltages are not higher—and thereby illuminate the way forward to improved performance.

The effort has been led by the Holman Research Group, which is part of the School of Electrical, Computer and Energy Engineering, one of the seven Fulton Schools at ASU, in partnership with the Center for Next Generation Photovoltaics at Colorado State University, the National Renewable Energy Laboratory in Golden, Colorado, and First Solar Inc. of Tempe, Arizona. Their research has been supported by a $1.5 million grant from the Solar Energy Technologies Office within the U.S. Department of Energy.

"We have succeeded in identifying a technique that works. The measurement is called external radiative efficiency, or ERE," Onno says. "We started using it on solar cells produced by our project partners, and we found a lot of hidden potential.

"We also learned that the main mechanism limiting voltage is not necessarily linked to defects within the bulk of the cell nor at the interfaces between different materials comprising the cell," he says. "That's usually what is assumed in the CadTel community. But instead, it's an issue with selectivity, which is when electrons within the cell go the wrong way and cancel each other."

Selectivity losses correspond to a drop between the internal and external voltages of the cell. Internal voltage is a measure of how defects within the bulk of the absorber and at its interfaces reduce voltage below an ideal thermodynamic limit. External voltage corresponds to internal voltage minus losses due to non-ideal behavior in the semipermeable membranes that sandwich or wrap the cell absorber and direct the electron flow in and out of the cell to generate an electric current.

The very presence of selectivity losses means these semipermeable membranes are imperfect, and Onno says the CdSeTe community has long assumed that semipermeable membranes were not an issue and therefore overlooked these losses.

The team's new research shows that things are more complicated than assumed, and more precise accounting is required because different devices exhibit different types of voltage losses. Consequently, the ability to measure internal voltage through ERE is an important innovation.

Onno says that the "doping" of absorbers through the addition of elements like arsenic helps to reduce selectivity losses. It does so because absorbers engineered in this way can support the role of the semipermeable membrane by letting electrons flow only one way through them.

This means altering the fabrication of the absorber with doping can change overall selectivity even when semipermeable membranes are left unchanged. Onno says this is important because it shows that there are multiple ways to achieve low selectivity losses and improve the efficiency of CdSeTe devices.

These new findings are revealed in "Understanding what limits the voltage of polycrystalline CdSeTe solar cells," a new paper written by Onno with his colleagues and published in the research journal *Nature Energy*.

Moving forward, the team will apply the measurement technique to help improve solar cells produced from other advanced materials such as perovskites, a class of compounds that absorb light from a different portion of the electromagnetic spectrum than the range for silicon.

The research results will also be applied to work with traditional silicon solar cells. The Holman Research Group is supporting a project led by Mariana Bertoni, an associate professor of electrical engineering in the Fulton Schools, to monitor device degradation in the field. The ERE technique works through glass, so solar cells already packaged inside commercial modules can be evaluated in ways that are not currently possible using a standard method known as quasi-steady-state photoconductance, or QSSPC.

"We're also focused on getting this technology into the hands of industry," says Zachary Holman, director of the Holman Research Group and an associate professor of electrical engineering in the Fulton Schools. "We have already built replicates of this measurement technique for a couple of domestic solar cell and module manufacturers."

Each company purchased components from a list supplied by the Holman Research Group. The ASU team then assembled the ERE unit and conducted lab training with an engineer from the manufacturer before shipping everything to their site.

Holman says his group plans to continue distribution of the new capability, with added drive from the launch of Arizona's New Economy Initiative, or NEI, to position Phoenix and the state for success in cultivating high-tech industry.

"The NEI's Science and Technology Center for Advanced Materials, Processes and Energy Devices, or AMPED, has photovoltaics as a thrust area," he says. "And it has recently extended support for further commercialization of this innovation, which is really going to help us get it out in the world and create impact."

More information: Arthur Onno et al, Understanding what limits the voltage of polycrystalline CdSeTe solar cells, *Nature Energy* (2022). DOI: 10.1038/s41560-022-00985-z