New solar energy conversion process could revamp solar power production

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A small PETE device made with cesium-coated gallium nitride glows while being tested inside an ultra-high vacuum chamber. The tests proved that the process simultaneously converted light and heat energy into electrical current. Credit: Photo courtesy of Nick Melosh, Stanford University

Stanford engineers have figured out how to simultaneously use the light and heat of the sun to generate electricity in a way that could make solar power production more than twice as efficient as existing methods and potentially cheap enough to compete with oil.

Unlike photovoltaic technology currently used in solar panels - which becomes less efficient as the temperature rises - the new process excels at higher temperatures.

Called 'photon enhanced thermionic emission,' or PETE, the process promises to surpass the efficiency of existing photovoltaic and thermal conversion technologies.

"This is really a conceptual breakthrough, a new energy conversion process, not just a new material or a slightly different tweak," said Nick Melosh, an assistant professor of materials science and engineering, who led the research group. "It is actually something fundamentally different about how you can harvest energy."

And the materials needed to build a device to make the process work are cheap and easily available, meaning the power that comes from it will be affordable.

Melosh is an assistant professor of materials science and engineering, and is senior author of a paper describing the tests the researchers conducted. It was published online August 1, in Nature Materials.

"Just demonstrating that the process worked was a big deal," Melosh said. "And we showed this physical mechanism does exist, it works as advertised."

Most photovoltaic cells, such as those used in rooftop solar panels, use the semiconducting material silicon to convert the energy from photons of light to electricity. But the cells can only use a portion of the light spectrum, with the rest just generating heat.

This heat from unused sunlight and inefficiencies in the cells themselves account for a loss of more than 50 percent of the initial solar energy reaching the cell.

If this wasted heat energy could somehow be harvested, solar cells could be much more efficient. The problem has been that high temperatures are necessary to power heat-based conversion systems, yet solar cell efficiency rapidly decreases at higher temperatures.

Until now, no one had come up with a way to wed thermal and solar cell conversion technologies.

Melosh's group figured out that by coating a piece of semiconducting material with a thin layer of the metal cesium, it made the material able to use both light and heat to generate electricity.

"What we've demonstrated is a new physical process that is not based on standard photovoltaic mechanisms, but can give you a photovoltaic-like response at very high temperatures," Melosh said. "In fact, it works better at higher temperatures. The higher the better."

While most silicon solar cells have been rendered inert by the time the temperature reaches 100 degrees Celsius, the PETE device doesn't hit peak efficiency until it is well over 200 degrees C.

Because PETE performs best at temperatures well in excess of what a rooftop solar panel would reach, the devices will work best in solar concentrators such as parabolic dishes, which can get as hot as 800 degrees C. Dishes are used in large solar farms similar to those proposed for the Mojave Desert in southern California and usually include a thermal conversion mechanism as part of their design, which offers another opportunity for PETE to help generate electricity, as well as minimizing costs by meshing with existing technology.

"The light would come in and hit our PETE device first, where we would take advantage of both the incident light and the heat that it produces, and then we would dump the waste heat to their existing thermal conversion systems," Melosh said. "So the PETE process has two really big benefits in energy production over normal technology."

Photovoltaic systems never get hot enough for their waste heat to be useful in thermal energy conversion, but the high temperatures at which PETE performs are perfect for generating usable high temperature waste heat. Melosh calculates the PETE process can get to 50 percent efficiency or more under solar concentration, but if combined with a thermal conversion cycle, could reach 55 or even 60 percent - almost triple the efficiency of existing systems.

The team would like to design the devices so they could be easily bolted on to existing systems, making conversion relatively inexpensive.

The researchers used a gallium nitride semiconductor in the 'proof of concept' tests. The efficiency they achieved in their testing was well below what they have calculated PETE's potential efficiency to be, which they had anticipated. But they used gallium nitride because it was the only material that had shown indications of being able to withstand the high temperature range they were interested in and still have the PETE process occur.

With the right material - most likely a semiconductor such as gallium arsenide, which is used in a host of common household electronics - the actual efficiency of the process could reach up to the 50 or 60 percent the researchers have calculated. They are already exploring other materials that might work.

Another advantage of the PETE system is that by using it in solar concentrators, the amount of semiconductor material needed for a device is quite small.

"For each device, we are figuring something like a six-inch wafer of actual material is all that is needed," Melosh said. "So the material cost in this is not really an issue for us, unlike the way it is for large solar panels of silicon."

The cost of materials has been one of the limiting factors in the development of the solar power industry, so reducing the amount of investment capital needed to build a solar farm is a big advance.

"The PETE process could really give the feasibility of solar power a big boost," Melosh said. "Even if we don't achieve perfect efficiency, let's say we give a 10 percent boost to the efficiency of solar conversion, going from 20 percent efficiency to 30 percent, that is still a 50 percent increase overall."

And that is still a big enough increase that it could make solar energy competitive with oil.

Provided by Stanford University