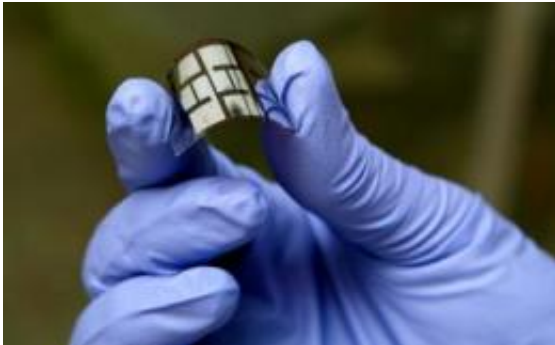


Folding light: Wrinkles and twists boost power from solar panels

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Microscopic folds increase the power output and durability of solar cells. Credit: Frank Wojciechowski

Taking their cue from the humble leaf, researchers have used microscopic folds on the surface of photovoltaic material to significantly increase the power output of flexible, low-cost solar cells.

The team, led by scientists from Princeton University, [reported](#) online April 22 in the journal [Nature Photonics](#) that the folds resulted in a 47 percent increase in [electricity generation](#). Yueh-Lin (Lynn) Loo, the principal investigator, said the finely calibrated folds on the surface of the panels channel [light](#) waves and increase the photovoltaic material's exposure to light.

"On a [flat surface](#), the light either is absorbed or it bounces back," said

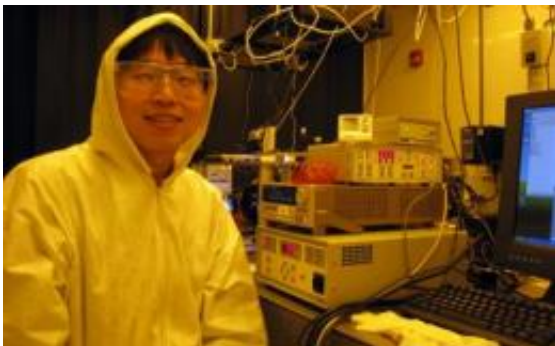
Loo, a professor of chemical and [biological engineering](#) at Princeton.
 "By adding these curves, we create a kind of wave guide. And that leads to a greater chance of the light's being absorbed."

The research team's work involves photovoltaic systems made of relatively cheap plastic. Current solar panels are typically made of silicon, which is both more brittle and more expensive than [plastics](#). So far, plastic panels have not been practical for widespread use because their [energy production](#) has been too low. But researchers have been working to increase that efficiency with the goal of creating a cheap, tough and flexible source of [solar power](#).

If researchers can increase the plastic panels' efficiency, the material could produce power from an array of surfaces from inserts in window panels to overlays on exterior walls or backpacks.

"It is flexible, bendable, light weight and low cost," Loo said.

In most cases, researchers have focused on increasing the efficiency of the plastic photovoltaic material itself. Recent developments have been promising: a team from UCLA [recently announced](#) a system with a 10.6 percent efficiency. That approaches the 10 to 15 percent level seen as the [target](#) for commercial development.



Jong Bok Kim was part of a team of researchers who found that microscopic folds significantly boosted the power of solar cells. Credit: Courtesy of Jong Bok Kim

Loo said the folding method promises to increase those numbers. Because the technique works with most types of plastic photovoltaic materials, it should provide a boost to efficiency across the board.

"This is a very simple process that you can use with any material," she said. "We have tested it with other polymers and it works as well."

Jong Bok Kim, a postdoctoral researcher in chemical and biological engineering and the paper's lead author, explained in the *Nature Photonics* paper that the folds on the surface of the panels channel [light waves](#) through the material in much the same way that canals guide water through farmland. By curving the light through the material, the researchers essentially trap the light inside the photovoltaic material for a longer time, which leads to greater absorption of light and generation of energy.

"I expected that it would increase the photocurrent because the folded surface is quite similar to the morphology of leaves, a natural system with high light harvesting efficiency," said Kim, a postdoctoral researcher in chemical and biological engineering. "However, when I actually constructed [solar cells](#) on top of the folded surface, its effect was better than my expectations."

Although the technique results in an overall increase in efficiency, the results were particularly significant at the red side of the light spectrum, which has the longest wavelengths of visible light. The efficiency of conventional solar panels drops off radically as light's wavelength

increases, and almost no light is absorbed as the spectrum approaches the infrared. But the folding technique increased absorption at this end of the spectrum by roughly 600 percent, the researchers found.

"If you look at the solar spectrum, there is a lot of sunlight out there that we are wasting," Loo said. "This is a way to increase efficiency."

The research team created the folded surface in Howard Stone's laboratory in the mechanical and aerospace engineering department by carefully curing a layer of liquid photographic adhesive with ultraviolet light. By controlling how fast different sections of the adhesive cured, the team was able to introduce stresses in the material and generate ripples in the surface. The shallower ripples were classified as wrinkles and the deeper ones are called folds. The team found that a surface containing a combination of wrinkles and folds produced the best results.

Although the math underlying the process is complex, the actual production is straightforward. Loo said it would be quite practical for industrial purposes.

"Everything hinges on the fact that you can reproduce the wrinkles and folds," Loo said. "By controlling the stresses, we can introduce more or fewer wrinkles and folds."

Another benefit of the process is that it increases the durability of the [solar panels](#) by relieving mechanical stresses from bending. The researchers found the panels with folded surfaces were able to retain their effectiveness after bending. A standard plastic panel's energy production would be diminished by 70 percent after undergoing bending.

Loo said the researchers drew their inspiration from leaves. Seemingly a simple object, the leaf is a miracle of natural engineering. Its green surface is perfectly constructed to bend and control light to ensure that a

maximum amount of solar energy is absorbed to create energy and nutrients for the tree. Recent work by Pilnam Kim, a postdoctoral researcher in Stone's lab, provided insight into how these microscopic structures could be applied to synthetic devices.

"If you look at leaves very closely, they are not smooth, they have these sorts of structures," said Loo, who is deputy director of Princeton's Andlinger Center for Energy and the Environment. "We'd like to mimic this geometric effect in synthetic, man-made light-harvesting systems."

Provided by Princeton University

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