# Measurement of 'hot' electrons could have solar energy payoff

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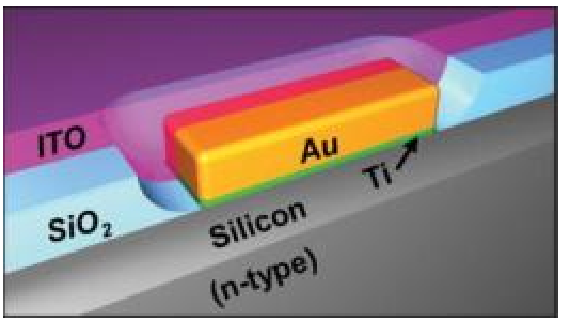


An optical antenna-diode for photodetection. Representation of a single Au resonant antenna on an n-type silicon substrate. For more information, please see Figure 1 in the manuscript. Credit: Science/AAAS

(PhysOrg.com) -- Basic scientific curiosity paid off in unexpected ways when Rice University researchers investigating the fundamental physics of nanomaterials discovered a new technology that could dramatically improve solar energy panels.

The research is described in a new paper this week in the journal *Science*.

"We're merging the optics of nanoscale antennas with the electronics of semiconductors," said lead researcher Naomi Halas, Rice's Stanley C. Moore Professor in Electrical and Computer Engineering. "There's no practical way to directly detect infrared light with silicon, but we've shown that it is possible if you marry the semiconductor to a nanoantenna. We expect this technique will be used in new scientific instruments for infrared-light detection and for higher-efficiency solar cells."

More than a third of the solar energy on Earth arrives in the form of infrared light. But silicon -- the material that's used to convert sunlight into electricity in the vast majority of today's solar panels -- cannot capture infrared light's energy. Every semiconductor, including silicon, has a "bandgap" where light below a certain frequency passes directly through the material and is unable to generate an electrical current. By attaching a metal nanoantenna to the silicon, where the tiny antenna is specially tuned to interact with infrared light, the Rice team showed they could extend the frequency range for electricity generation into the infrared. When infrared light hits the antenna, it creates a "plasmon," a wave of energy that sloshes through the antenna's ocean of free electrons . The study of plasmons is one of Halas' specialties, and the new paper resulted from basic research into the physics of plasmons that began in her lab years ago.

It has been known that plasmons decay and give up their energy in two ways; they either emit a photon of light or they convert the light energy into heat. The heating process begins when the plasmon transfers its energy to a single electron -- a 'hot' electron. Rice graduate student Mark Knight, lead author on the paper, together with Rice theoretical physicist Peter Nordlander, his graduate student Heidar Sobhani, and Halas set out to design an experiment to directly detect the hot electrons resulting from plasmon decay.

Patterning a metallic nanoantenna directly onto a semiconductor to create a "Schottky barrier," Knight showed that the infrared light striking the antenna would result in a hot electron that could jump the barrier, which creates an electrical current. This works for infrared light at frequencies that would otherwise pass directly through the device.

"The nanoantenna-diodes we created to detect plasmon-generated hot electrons are already pretty good at harvesting infrared light and turning it directly into electricity," Knight said. "We are eager to see whether this expansion of light-harvesting to infrared frequencies will directly result in higher-efficiency solar cells."

**More information:** Photodetection with Active Optical Antennas, Science 6 May 2011: Vol. 332 no. 6030 pp. 702-704 DOI: 10.1126/science.1203056
www.sciencemag.org/content/332/6030/702.abstract

**ABSTRACT**
Nanoantennas are key optical components for light harvesting; photodiodes convert light into a current of electrons for photodetection. We show that these two distinct, independent functions can be combined into the same structure. Photons coupled into a metallic nanoantenna excite resonant plasmons, which decay into energetic, "hot" electrons injected over a potential barrier at the nanoantenna-semiconductor interface, resulting in a photocurrent. This dual-function structure is a highly compact, wavelength-resonant, and polarization-specific light detector, with a spectral response extending to energies well below the semiconductor band edge.

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