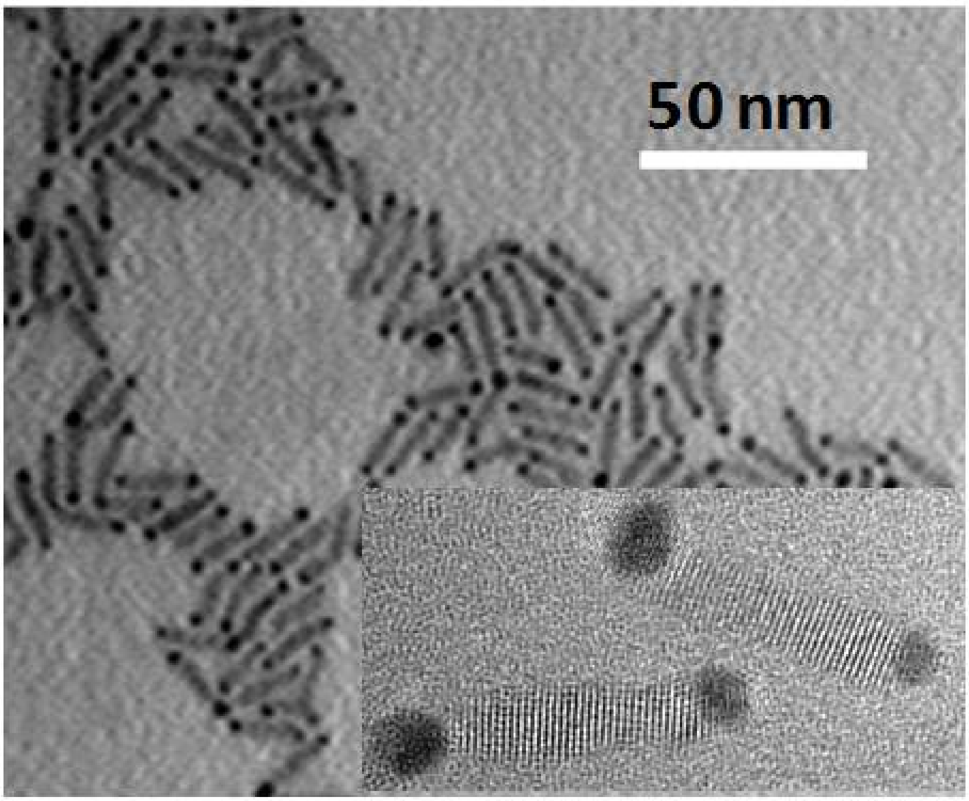
Chemists find new way to do light-driven reactions in solar energy quest

August 6 2015



Transmission electron micrograph image of cadmium selenide nanorods with gold tips. Inset shows a high-resolution TEM image of two nanorods. Credit: James R. McBride

Chemists have found a new, more efficient method to perform light-driven reactions, opening up another possible pathway to harness sunlight for energy. The journal *Science* is publishing the new method, which is based on plasmon - a special motion of electrons involved in the optical properties of metals.

"We've discovered a new and unexpected way to use plasmonic metal that holds potential for use in solar energy conversion," says Tim Lian, professor of physical chemistry at Emory University and the lead author of the research. "We've shown that we can harvest the high energy electrons excited by light in plasmon and then use this energy to do chemistry."

Plasmon is a collective motion of free electrons in a metal that strongly absorbs and scatters light. One of the most vivid examples of surface plasmon can be seen in the intricate stained glass windows of some medieval cathedrals, an effect achieved through gold nano-particles that absorb and scatter visible light. Plasmon is highly tunable: Varying the size and shape of the gold nano-particles in the glass controls the color of the light emitted.

Modern-day science is exploring and refining the use of these plasmonic effects for a range of potential applications, from electronics to medicine and renewable energy.

Lian's lab, which specializes in exploring light-driven charge transfer for solar energy conversion, experimented with ways to use plasmon to make that process more efficient and sustainable.

Gold is often used as a catalyst, a substance to drive chemical reactions, but not as a photo catalyst: a material to absorb light and then do chemistry with the energy provided by the light.

During photocatalysis, a metal absorbs light strongly, rapidly exciting a lot of electrons. "Imagine electrons sloshing up and down in the metal," Lian says. "Once you excite them at this level, they crash right down. All the energy is released as heat really fast - in picoseconds."

The researchers wanted to find a way to capture the energy in the excited electrons before it was released as heat and then use hot electrons to fuel reactions.

Through experimentation, they found that coupling nano-rods of cadmium selenide, a semi-conductor, to a plasmonic gold nanoparticle tip allowed the excited electrons in the gold to escape into the semi-conductor material.

"If you use a material with a certain energy level that can strongly bond to plasmon, then the excited electrons can escape into the material and stay at the high energy level," Lian says. "We showed that you can harvest electrons before they crash down and relax, and combine the catalytic property of plasmon with its light absorbing ability."

Instead of using heat to do chemistry, this new process uses metals and light to do photochemistry, opening a new, potentially more efficient, method for exploration.

"We are now looking at whether we can find other electron acceptors that would work in this same process, such as a molecule or molecular catalyst instead of cadmium selenide," Lian says. "That would make this process a general scheme with many different potential applications."

The researchers also want to explore whether the method can drive light-driven water oxidation more efficiently. Using sunlight to split water to generate hydrogen is a major goal in the quest for affordable and sustainable solar energy.

"Using unlimited sunlight to move electrons around and tap catalytic power is a difficult challenge, but we have to find ways to do this," Lian says. "We have no choice. Solar power is the only energy source that can sustain the growing human population without catastrophic environmental impact."

More information: Efficient hot-electron transfer by a plasmon-induced interfacial charge-transfer transition" *Science*, www.sciencemag.org/lookup/doi/ … 1126/science.aac5443

Provided by Emory University