Graphene shows unusual thermoelectric response to light

October 7 2011, by David L. Chandler

Photo: Len Rubenstein

Graphene, an exotic form of carbon consisting of sheets a single atom thick, exhibits a novel reaction to light, MIT researchers have found: Sparked by light's energy, the material can produce electric current in unusual ways. The finding could lead to improvements in photodetectors and night-vision systems, and possibly to a new approach to generating electricity from sunlight.

This current-generating effect had been observed before, but researchers had incorrectly assumed it was due to a photovoltaic effect, says Pablo Jarillo-Herrero, an assistant professor of physics at MIT and senior author of a new paper published in the journal *Science*. The paper's lead author is postdoc Nathaniel Gabor; co-authors include four MIT students, MIT physics professor Leonid Levitov and two researchers at the National Institute for Materials Science in Tsukuba, Japan.

Instead, the MIT researchers found that shining light on a sheet of graphene, treated so that it had two regions with different electrical properties, creates a temperature difference that, in turn, generates a current. Graphene heats inconsistently when illuminated by a laser, Jarillo-Herrero and his colleagues found: The material's electrons, which carry current, are heated by the light, but the lattice of carbon nuclei that forms graphene's backbone remains cool. It's this difference in temperature within the material that produces the flow of electricity. This mechanism, dubbed a "hot-carrier" response, "is very unusual," Jarillo-Herrero says.

Such differential heating has been observed before, but only under very special circumstances: either at ultralow temperatures (measured in thousandths of a degree above absolute zero), or when materials are blasted with intense energy from a high-power laser. This response in graphene, by contrast, occurs across a broad range of temperatures all the way up to room temperature, and with light no more intense than ordinary sunlight.

The reason for this unusual thermal response, Jarillo-Herrero says, is that graphene is, pound for pound, the strongest material known. In most materials, superheated electrons would transfer energy to the lattice around them. In the case of graphene, however, that's exceedingly hard to do, since the material's strength means it takes very high energy to vibrate its lattice of carbon nuclei — so very little of the electrons' heat is transferred to that lattice.

Because this phenomenon is so new, Jarillo-Herrero says it is hard to know what its ultimate applications might be. “Our work is mostly fundamental physics,” he says, but adds that “many people believe that graphene could be used for a whole variety of applications.”

But there are already some suggestions, he says: Graphene “could be a good photodetector” because it produces current in a different way than other materials used to detect light. It also “can detect over a very wide energy range,” Jarillo-Herrero says. For example, it works very well in infrared light, which can be difficult for other detectors to handle. That could make it an important component of devices from night-vision systems to advanced detectors for new astronomical telescopes.

The new work suggests graphene could also find uses in detection of biologically important molecules, such as toxins, disease vectors or food contaminants, many of which give off infrared light when illuminated. And graphene, made of pure and abundant carbon, could be a much cheaper detector material than presently used semiconductors that often include rare, expensive elements.

The research also suggests graphene could be a very effective material for collecting solar energy, Jarillo-Herrero says, because it responds to a broad range of wavelengths; typical photovoltaic materials are limited to specific frequencies, or colors, of light. But more research will be needed, he says, adding, “It is still unclear if it could be used for efficient energy generation. It’s too early to tell.”

“This is the absolute infancy of graphene photodetectors,” Jarillo-Herrero says. “There are many factors that could make it better or faster,” which will now be the subject of further research.

Philip Kim, an associate professor of physics at Columbia University who was not involved in this research, says the work represents “extremely important progress toward optoelectric and energy-harvesting applications” based on graphene. He adds that because of this team’s work, “we now have better understanding of photo-generated hot electrons in graphene, excited by light.”

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

Provided by Massachusetts Institute of Technology

Citation: Graphene shows unusual thermoelectric response to light (2011, October 7) retrieved 10 April 2024 from https://phys.org/news/2011-10-graphene-unusual-thermoelectric-response.html