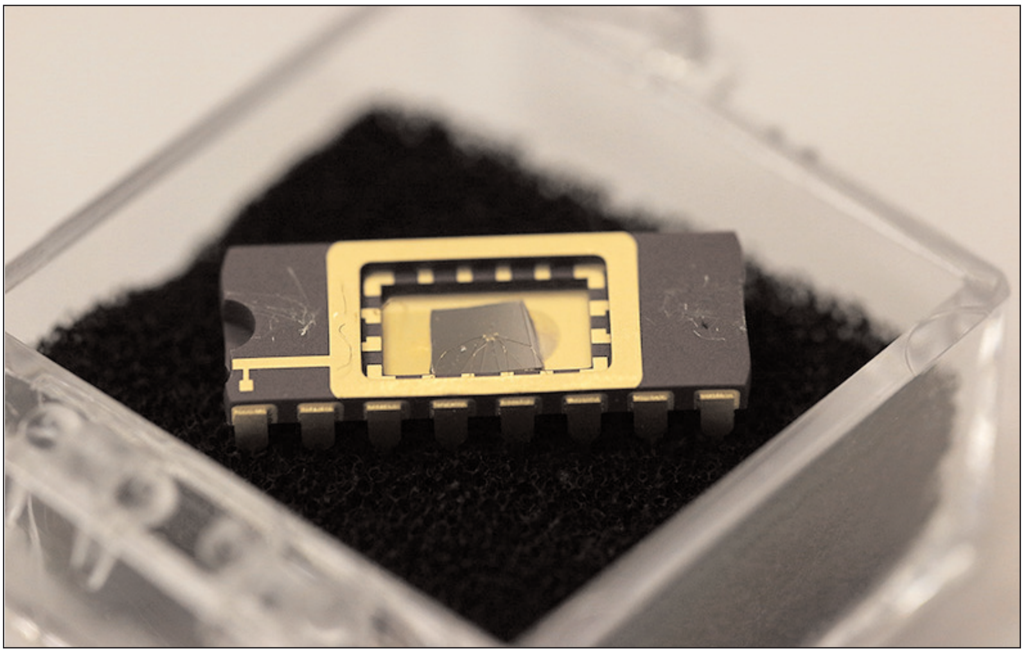
Graphene phototransistor promises high-performance optoelectronics

Position-dependent and millimeter-range photodetection has been achieved using micron-scale graphene on SiC.

A team of researchers at Purdue University, the University of Michigan and Pennsylvania State University claims to have solved a problem hindering the development of highly sensitive optical devices made of graphene, which could enable applications ranging from imaging and displays to sensors and high-speed communications (Biddut K. Sarker et al, 'Position dependent and millimeter-range photodetection in phototransistors with micron-scale graphene on SiC', Nature Nanotechnology; published online 10 April 2017, DOI: 10.1038/nnano.2017.46).



Graphene field-effect transistor (GFET) developed at Purdue University. (Purdue University image/Erin Easterling.)

As an extremely thin layer of carbon with extraordinary optical and electronic properties, graphene is a promising material for high-performance optoelectronics. However, typical graphene-based photodetectors have only a small area that is sensitive to light, limiting their performance.

The problem has now been solved by combining graphene with a comparatively much larger silicon carbide (SiC) substrate, creating graphene field-effect transistors (GFETs), which can be activated by light, says Yong Chen, a Purdue University professor of physics & astronomy and electrical & computer engineering, and director of the Purdue Quantum Center.

High-performance photodetectors might be useful for applications including high-speed communications and ultra-sensitive cameras for astrophysics, as well as sensing applications and wearable electronics. Arrays of the graphene-based transistors might enable high-resolution imaging and displays.

"In most cameras you need lots of pixels," says Igor Jovanovic, a professor of nuclear engineering and radiological sciences at the University of Michigan. "However, our approach could make possible a very sensitive camera where you have relatively few pixels but still have high resolution," he adds.

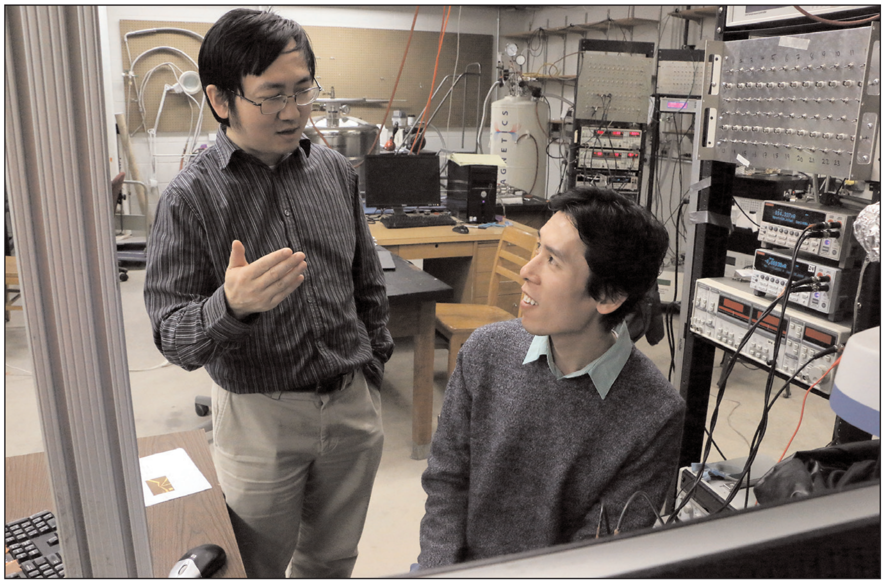
"In typical graphene-based photodetectors demonstrated so far, the photoresponse only comes from specific locations near graphene over an area much smaller than the device size," says Jovanovic. "However, for many optoelectronic device applications, it is desirable to obtain photoresponse and positional sensitivity over a much larger area."

The new findings show that the device is responsive to light on a non-local scale, even when the SiC substrate is illuminated at distances greater than 500μm from the graphene. The photoresponsivity and photocurrent can be increased by as much as 10 times, depending on which part of the material is illuminated. The new photo-transistor is also position-sensitive, so it can determine the location from which the light is coming (important for imaging applications and for detectors).

"This is the first time anyone has demonstrated the use of a small piece of graphene on a large wafer of silicon carbide to achieve non-local photodetection, so the light doesn't have to hit the graphene itself," Chen says. "The light can be incident on a much larger area, almost a millimeter, which has not been done before."

A voltage is applied between the back side of the silicon carbide and the graphene, setting up an electric field in the silicon carbide. Incoming light generates photo-carriers in the SiC.

The research is related to work to develop new graphene-based sensors designed to detect radiation, and was funded with a joint grant from the US National Science Foundation (NSF) and the US Department of Homeland Security plus another grant from the Defense Threat Reduction Agency.



Yong Chen (left) a Purdue University professor of physics and astronomy and electrical and computer engineering, and graduate student Ting-Fung Chung. (Purdue University image/Erin Easterling).

"This particular paper is about a sensor to detect photons, but the principles are the same for other types of radiation," Chen notes. "We are using the sensitive graphene transistor to detect the changed electric field caused by photons — light in this case — interacting with a silicon carbide substrate."

Light detectors can be used in scintillators, which are used to detect radiation. Ionizing radiation creates brief flashes of light, which in scintillators are detected by photo-multiplier tubes (a roughly century-old technology). "So there is a lot of interest in developing advanced semiconductor-based devices that can achieve the same function," Jovanovic says.

The team also explains their findings with a computational model. The transistors were fabricated at the Birck Nanotechnology Center in Purdue's Discovery Park.

Future research will include work to explore applications such as scintillators, imaging technologies for astrophysics, and sensors for high-energy radiation. ■

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