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New test reveals purity of graphene: Terahertz waves used to spot contaminants

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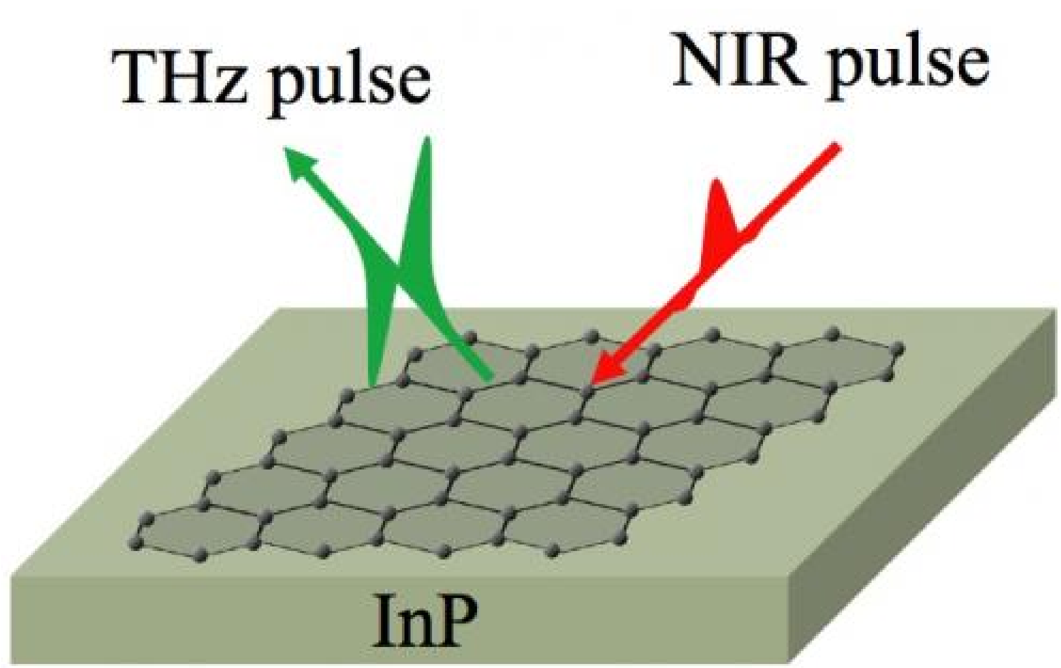


Rice and Osaka researchers have come up with a simple method to find contaminants on atom-thick graphene. By putting graphene on a layer of indium phosphide, which emits terahertz waves when excited by a laser pulse, they can measure and map changes in its electrical conductivity. Credit: Rice and Osaka universities

Graphene may be tough, but those who handle it had better be tender. The environment surrounding the atom-thick carbon material can influence its electronic performance, according to researchers at Rice and Osaka universities who have come up with a simple way to spot contaminants.

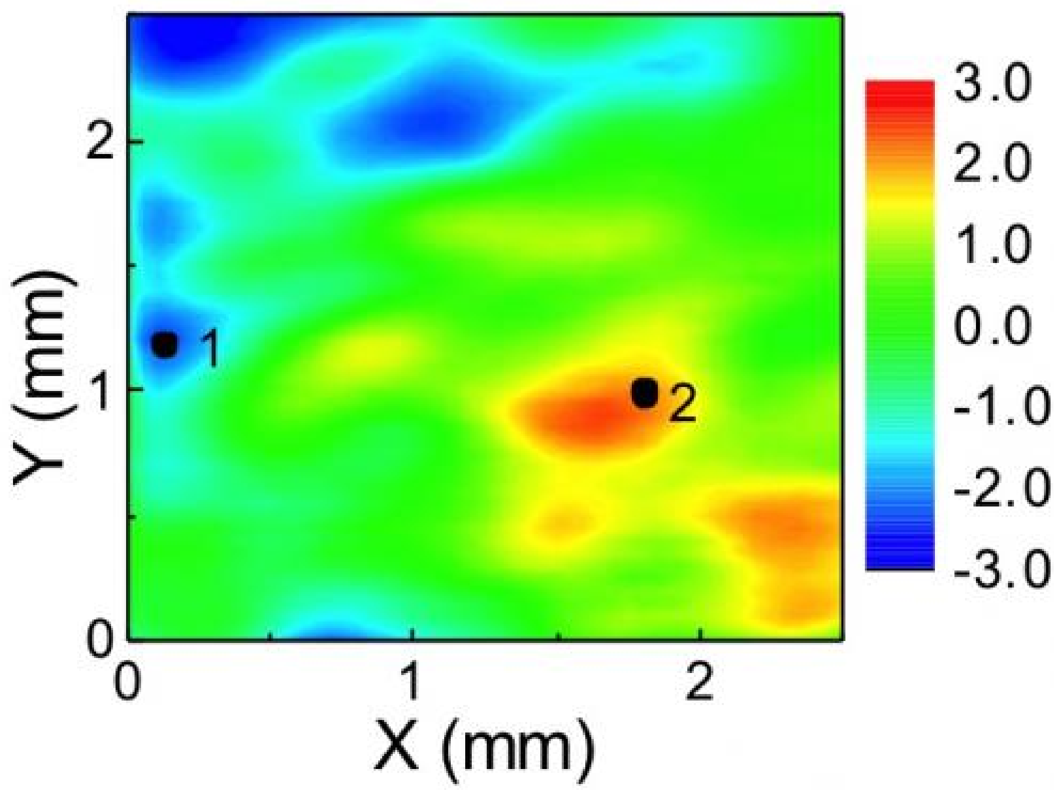
Because it's so easy to accidently introduce impurities into graphene, labs led by physicists Junichiro Kono of Rice and Masayoshi Tonouchi of Osaka's Institute of Laser Engineering discovered a way to detect and identify out-of-place molecules on its surface through terahertz spectroscopy.

They expect the finding to be important to manufacturers considering the use of graphene in electronic devices.

The research was published this week by Nature's open-access online journal *Scientific Reports*. It was made possible by the Rice-based NanoJapan program, through which American undergraduates conduct summer research internships in Japanese labs.

Even a single molecule of a foreign substance can contaminate graphene enough to affect its electrical and optical properties, Kono said. Unfortunately (and perhaps ironically), that includes electrical contacts.

"Traditionally, in order to measure conductivity in a material, one has to attach contacts and then do electrical measurements," said Kono, whose lab specializes in terahertz research. "But our method is contact-less."



An amplitude map of terahertz radiation emitted from graphene-coated indium phosphide shows where oxygen molecules have settled on the surface after exposure to air for a few weeks. The blue at point 1 indicates high polarization due to the adsorption of oxygen molecules, while the orange at point 2 is electronically equivalent to bare indium phosphide. The research by Rice and Osaka universities makes possible a simple way to spot contaminants on graphene. Credit: Rice and Osaka universities

That's possible because the compound indium phosphide emits terahertz waves when excited. The researchers used it as a substrate for graphene. Hitting the combined material with femtosecond pulses from a near-infrared laser prompted the indium phosphide to emit terahertz back through the graphene. Imperfections as small as a stray oxygen molecule on the graphene were picked up by a spectrometer.

"The change in the terahertz signal due to adsorption of molecules is remarkable," Kono said. "Not just the intensity but also the waveform of emitted terahertz radiation totally and dynamically changes in response to molecular adsorption and desorption. The next step is to explore the ultimate sensitivity of this unique technique for gas sensing."

The technique can measure both the locations of contaminating molecules and changes over time. "The laser gradually removes oxygen molecules from the graphene, changing its density, and we can see that," Kono said.

The experiment involved growing pristine graphene via chemical vapor deposition and transferring it to an indium phosphide substrate. Laser pulses generated coherent bursts of terahertz radiation through a built-in surface electric field of the indium phosphide substrate that changed due to charge transfer between the graphene and the contaminating molecules. The terahertz wave, when visualized, reflected the change.

The experimental results are a warning for electronics manufacturers. "For any future device designs using graphene, we have to take into account the influence of the surroundings," said Kono. Graphene in a vacuum or sandwiched between noncontaminating layers would probably be stable, but exposure to air would contaminate it, he said.

The Rice and Osaka labs are continuing to collaborate on a project to measure the terahertz conductivity of graphene on various substrates, he said.

More information: *Scientific Reports*, www.nature.com/srep/2014/14081 … /full/srep06046.html

Provided by Rice University