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Graphene gives a tremendous boost to future terahertz cameras

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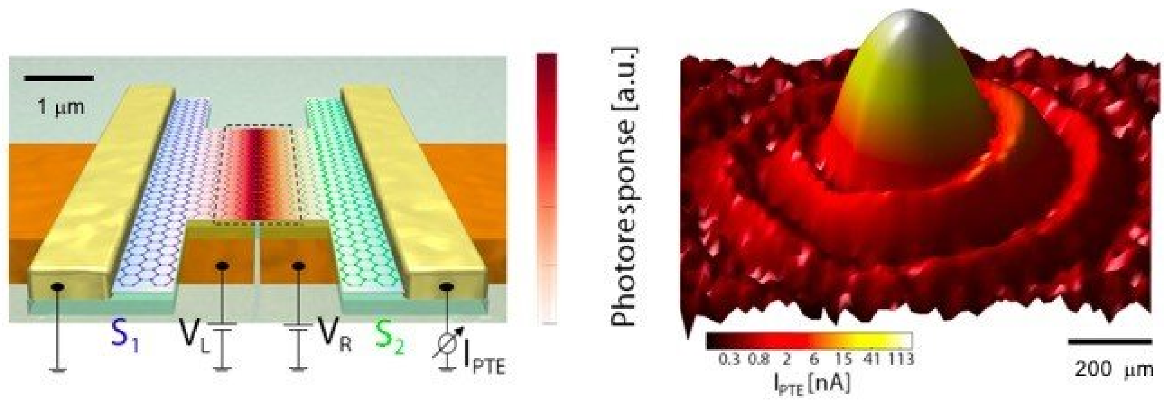

Left) Schematic representation of the central part of the graphene-based THz photodetector device, containing the hBN-encapsulated graphene channel, on top of the narrow-gap antenna structure. By applying distinct voltages to the left and right antenna branches, a pn-junction is created in the graphene channel with unequal Seebeck coefficients on the left and right of the junction. Incident light is focused by the antenna above the gap, which is where the photoresponse is generated. (Right) Measurement of a THz focus, obtained by scanning the THz detector in the plane of the focus. The observation of several rings of the Airy pattern indicate the high sensitivity of the detector. Credit: ICFO

In a recent study, researchers developed a novel graphene-enabled photodetector that operates at room temperature, is highly sensitive, fast, has a wide dynamic range, and covers a broad range of THz frequencies. The researchers have achieved a solid understanding of how the PTE effect gives rise to a THz-induced photoresponse, which is valuable for further detector optimization.

Detecting terahertz (THz) light is extremely useful for two main reasons: First, THz technology is becoming a key element in applications regarding security (such as airport scanners), wireless data communication and quality control, to mention just a few. However, current THz detectors have limitations, including simultaneously meeting the requirements for sensitivity, speed, spectral range, and operating at room temperature. Second, terahertz light is a very safe type of radiation due to its low-energy photons, with more than 100 times lower energy than that of photons in the visible light range.

Graphene-based materials are useful for detecting light. Graphene does not have a bandgap, as compared to standard materials used for photodetection, such as silicon. The bandgap in silicon prevents absorption, and thus detection, of incident light with wavelengths longer than one micron. In contrast, for graphene, even terahertz light with a wavelength of hundreds of microns can be absorbed and detected. Hz detectors based on graphene have shown promising results, but none are yet as effective as commercially available detectors in terms of speed and sensitivity.

In a recent study, ICFO researchers Sebastián Castilla and Dr. Bernat Terres, led by ICREA Prof. at ICFO Frank Koppens and former ICFO scientist Dr. Klaas-Jan Tielrooij, and an international collaborative of researchers, have been able to overcome these challenges. They have developed a novel graphene-enabled photodetector that operates at room temperature, and is highly sensitive, fast, has a wide dynamic range, and covers a broad range of THz frequencies.

In their experiment, the scientists optimized the photoresponse mechanism of a THz photodetector. They integrated a dipole antenna into the detector to concentrate the incident THz light around the antenna gap region. By fabricating a 100-nanometer antenna gap, they were able to obtain a great intensity concentration of THz incident light in the photoactive region of the graphene channel. They observed that the light absorbed by the graphene creates hot carriers at a pn-junction in graphene; subsequently, the unequal Seebeck coefficients in the p- and n-regions produce a local voltage and a current through the device generating a very large photoresponse, thus leading to a highly sensitive, high-speed response detector with a wide dynamic range and a broad spectral coverage.

The results of this study could contribute to the development a fully digital low-cost camera system as cheap as the camera inside the smartphone, since such a detector has very low power consumption and is fully compatible with CMOS technology.

More information: Sebastián Castilla et al, Fast and Sensitive Terahertz Detection Using an Antenna-Integrated Graphene pn Junction, *Nano Letters* (2019). DOI: 10.1021/acs.nanolett.8b04171

Provided by ICFO

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