Ultrahigh sensitivity graphene infrared detectors for imaging and spectroscopy

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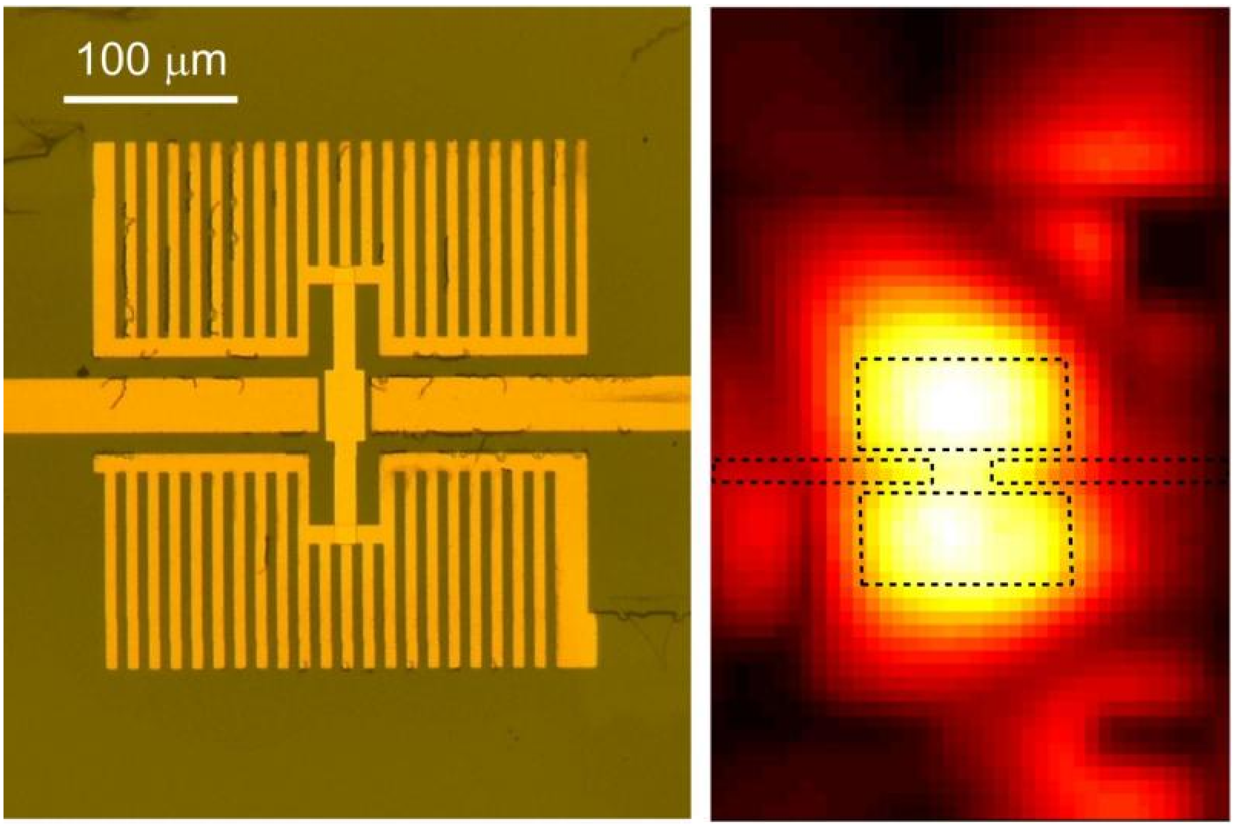

Credit: Graphene Flagship

Researchers from the Graphene Flagship have developed a novel graphene-based infrared (IR) detector demonstrating record high sensitivity for thermal detection. Graphene's unique attributes pave the way for high-performance IR imaging and spectroscopy.

Graphene's benefits are opening possibilities in high-performance IR imaging and spectroscopy. Researchers from the Graphene Flagship, working at the University of Cambridge (UK), Emberion Ltd. (UK), the Institute of Photonic Sciences (ICFO; Spain), Nokia UK, and the University of Ioannina (Greece) have developed a graphene-based pyroelectric bolometer that detects infrared (IR) radiation by measuring tiny temperature changes with an ultra-high level of accuracy. The work, published in *Nature Communications*, demonstrates the highest reported temperature sensitivity for graphene-based uncooled thermal detectors, capable of resolving temperature changes down to a few tens of μK. Only a few nano-Watts of IR radiation power are required to produce such a small temperature variation in isolated devices, about 1000 times smaller than the IR power delivered to the detector by a human hand in close proximity.

The high sensitivity of the detector is of great use for spectroscopic applications beyond thermal imaging. With a high-performance graphene-based IR detector that gives a strong signal with less incident radiation, it is possible to isolate different parts of the IR spectrum. This is of key importance in security applications, where different materials – such as explosives – can be distinguished by their characteristic IR absorption or transmission spectra.

Dr Alan Colli, Principal Engineer at Emberion and co-leader of the research, said: "With a higher sensitivity detector, one can restrict the large thermal band and still form an image using photons in a very narrow spectral range and do multi-spectral IR imaging. For security screening, there are specific signatures that materials emit or absorb in narrow bands. So, you want a detector that is trained in that narrow band. This can be useful while looking for explosives, hazardous substances, or anything of the sort."

Typical IR photodetectors operate either via the pyroelectric effect, or as bolometers, which measure changes in resistance due to heating. The graphene-based pyroelectric bolometer combines both approaches with the excellent electrical properties of graphene, for maximum performance. Graphene acts as a built-in amplifier for the signal, removing the need for external transistors – meaning no losses from parasitic capacitance, and remarkably low noise. The high conductivity of graphene also offers a convenient impedance matching with the external readout integrated circuit (ROIC) used to interface with the detector pixels and the recording device. With the continuous improvement in the quality of graphene (e.g., higher mobility), robust devices with an extended dynamic range (temperature range over which the device will operate reliably) can be fabricated while maintaining the same excellent temperature responsivity.

Prof. Andrea Ferrari, Director of the Cambridge Graphene Centre and co-author of the work said "This work is another example of the steady march of graphene on the roadmap towards applications. Emberion is a new company created to produce graphene photonics and electronics for infrared photodetectors and thermal sensors, and this work exemplifies how basic science and technology can lead to swift commercialisation." Ferrari is the Science and Technology Officer of the Graphene Flagship, and Chair of the Flagship Management Panel.

Prof. Frank Koppens, co-author of the work, is leader of the Quantum Nano-Optoelectronics at ICFO, and leads the Photonics and Optoelectronics work package of the Graphene Flagship. "One of the most promising applications of graphene is broadband photodetection and imaging. Combining visible and infrared detection in one material system is not possible with any other existing technology. The Graphene Flagship program will further build on this work to develop hyperspectral imaging systems, and exploiting the directions where graphene is unique," he said.

Dr Daniel Neumaier (AMO, Germany) is the leader of the Graphene Flagship Electronics and Photonics Integration Division and was not directly involved in the work. He said "The market size of IR detectors has increased dramatically in the last couple of years and these devices are entering more and more application areas. In particular, spectroscopic security screening is becoming more important. This requires high sensitivity under room temperature operation. The present work is a huge step forward in meeting these requirements in graphene-based IR detectors."

More information: U. Sassi et al. Graphene-based mid-infrared room-temperature pyroelectric bolometers with ultrahigh temperature coefficient of resistance, *Nature Communications* (2017). DOI: 10.1038/ncomms14311

Provided by Graphene Flagship