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News

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Dr. E. H. Yang's Team Awarded AFOSR Grant to Develop Advanced Infrared Detection Technology

Any object with a temperature above absolute zero emits infrared (IR) radiation, and the ability to detect IR light has profoundly expanded visual capabilities, allowing people to see at night and machines to sense motion. Just as visible light is picked up by the silicon-based sensor pixels of a common digital camera, IR radiation is detected by the sensor pixels of an IR camera using a special material. The **Stevens Institute of Technology** team led by Dr. Eui-Hyeok Yang, professor of Mechanical Engineering, with Co-PI Dr. Stefan Strauf, professor of Physics and Engineering Physics**,** has been researching the potential of graphene-based sensor materials for improving IR detection. The team has been awarded a grant from the Air Force Office of Scientific Research (AFOSR) to make IR detection technology more versatile based on bilayer graphene micro-ribbons (BGMRs) that can be tuned to respond to different IR wavelengths.

Dr. Eui-Hyeok Yang

"The overall IR detector market is expected to reach $286 million by 2016. The information and intelligence they provide for scientific research and military uses, respectively, magnifies the value of the technology," says Dr. Michael Bruno (http://research.stevens.edu/Michael-Bruno/rid/54), Dean of the Charles V. Schaefer, Jr. School of Engineering and Science (/ses). "Dr. Yang and Dr. Strauf are formulating a sophisticated and flexible innovation that could set new standards for IR detection in high-grade applications."

Dr. Stefan Strauf

Infrared vision has numerous civilian, military, and scientific uses. When visible light is scarce, objects very often continue to emit IR radiation. Portions of the IR spectrum can pass through haze, air pollution, and even thin solid materials with minimal scattering. IR detection can therefore be used to secure buildings by sensing the presence of a person in a restricted area, provide a tactical advantage in warfare by allowing detailed surveillance of an area in the absence of visible light, and offer powerful investigative tools for space exploration that allow researchers to see the universe in greater detail. For instance, NASA's Wide-field Infrared Survey Explorer (http://www.nasa.gov/home/hqnews/2012/aug/HQ_12-295_WISE_Black_Holes.html) (WISE) mission completed infrared scans of the entire sky in 2011 (pictured above), capturing millions of images and providing a wealth of information on newfound supermassive black holes and extreme dust-obscured galaxies.

The ability to adjust the sensitivity to different wavelengths, or tunability, within a device would represent a tremendous refinement of semiconductor technology for IR detection. The semiconductor materials used in existing IR detectors can only react to a narrow spectrum of IR radiation, and the materials have to be replaced before the detector can sense other wavelengths. The proposed use of BGMRs is novel in this aspect. They can be tuned to react to different parts of the IR spectrum, making it possible to develop IR detectors with extremely broad, ultra-fast photonic response. In high-level IR detection applications like space exploration or military reconnaissance, the wide spectrum and quick response capabilities provide great advantages in power and convenience. A device using BGMRs promises detection speeds higher than existing bolometers (used in many space observatories) while providing comparable sensitivity.

"This novel graphene-based approach promises to establish lower-cost detection of a broader spectrum of infrared radiation than has ever been possible in a single compact instrument, without sacrificing the sensitivity necessary in advanced applications," says Dr. Constantin Chassapis, Deputy Dean of the School of Engineering and Science, and Director of the Department of Mechanical Engineering (/ses/me).

The electromagnetic spectrum. A very narrow portion is visible to the human eye. IR has a longer wavelength than visible light.

The IR spectrum is divided into several bands: Near IR/Short Wave IR (NIR/SWIR), Mid Wave IR (MWIR), Long Wave IR (LWIR), and Very Long Wave IR (VLWIR). Existing sensor materials generally detect IR wavelengths within one of these bands. This innovation based on BGMRs will detect IR radiation across all of these divisions thanks to its tunability, thus allowing researchers to use one device where they might previously have used several. The technology also eliminates the need for bulky dispersive optical elements used in conventional IR sensors, reducing an IR detector's cost as well as making it more convenient and portable. Furthermore, photonic detectors usually have to be kept very cool using cryogenics in order to operate correctly. For certain wavelengths, graphene-based detectors may function accurately without cryogenics.

This innovation represents a refinement of existing attempts at graphene-based IR detection. Semiconductor materials used to detect IR have an energy property called bandgap that determines the range of IR wavelength they can detect. Graphene has zero bandgap and behaves like a metal rather than a semiconductor, but researchers can induce bandgap into graphene by patterning it at very small scales or by applying strain. Current attempts to implement this technology at the nanoscale depend on the width of the nanoribbon and the termination of its edges. The latter parameter can be unruly at such a small scale, making hard to define and control resultant bandgaps.

Dr. Yang's team avoids these limitations by working with *microscale* ribbons, in which the edges do not considerably affect the bandgap. Moreover, the bandgap of the resultant ribbons can then be adjusted in situ, thus allowing the material to scan and respond to different wavelengths of IR.

"This research is an outstanding representation of the success of synergistic efforts between departments," says Dr. Rainer Martini, Director of the Department of Physics and Engineering Physics. "These cross-disciplinary collaborations very often generate the solutions to today's greatest technology challenges."

Dr. Yang is an expert on the fundamentals and applications of graphene, carbon nanotubes, and smart polymers. He is currently PI on a number of active grants in the area of research, education and equipment, from **AFOSR** and **NSF**. He directs the **Micro Device Laboratory** (MDL), a Stevens shared facility, as well as the **Nanoelectronics and Nanomechatronics Laboratory**, his own lab, at Stevens. He is also an Associate Editor of several journals including *IEEE Sensors , and Vice-Chair of ASME MEMS Division*.

Dr. Strauf is Director of the NanoPhotonics Laboratory (NPL) at Stevens, where he oversees cutting-edge research in the fields of solid-state nanophotonics and quantum information science. He has received project funding from AFOSR and NSF as a Co-PI and he is also the recipient of the prestigious **NSF CAREER Award**.

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1 Castle Point Terrace

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