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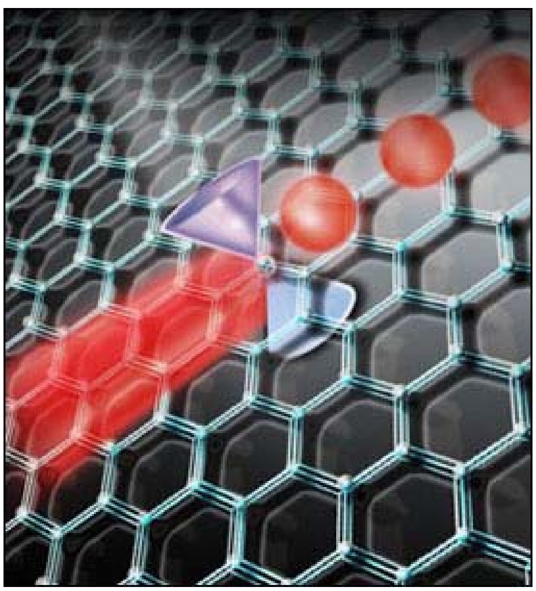
Graphene-Silicon PICs for Low-Power Telecom

NEW YORK, July 16, 2012 — A one-carbon-atom-thick sheet of graphene has transformed a passive device into an active one that generates microwave photonic signals and performs parametric wavelength conversion at telecommunication wavelengths. This optical nonlinear behavior could lead to broad applications in optical interconnects and low-power photonic integrated circuits (PICs).

"Graphene has been considered a wonderful electronic material where electron moves like an effectively massless particle in the atomically thin layer," notes Philip Kim, professor of physics and applied physics at Columbia. He is an early pioneer in graphene research and discovered its low-temperature high electronic conductivity. "And now, the recent excellent work done by … Columbia researchers demonstrates that graphene is also unique electro-optical material for ultrafast nonlinear optical modulation when it is combined with silicon photonic crystal structures."



Ultralow-power optical information processing is based on graphene on silicon photonic crystal nanomembranes. (Image: Nicoletta Barolini)

Led by Chee Wei Wong, the Columbia scientists developed a graphene-silicon device whose optical nonlinearity enables the system parameters to change with the input power level. They discovered that, by optically driving the electronic and thermal response in the silicon chip, they could generate a radio-frequency carrier on top of the transmitted laser beam and control its modulation with the laser intensity and color.

Using different optical frequencies to tune the radio frequency, they found that the graphene-silicon hybrid chip achieved radio-frequency generation with a resonant quality factor more than 50 times lower than that achieved by scientists in silicon.

"We are excited to have observed four-wave mixing in these graphene-silicon photonic crystal nanocavities," said Wong, professor of mechanical engineering, and director of the Center for Integrated Science and Engineering, and Solid-State Science and Engineering. "We generated new optical frequencies through nonlinear mixing of two electromagnetic fields at low operating energies, allowing reduced energy per information bit. This allows the hybrid silicon structure to serve as a platform for all-optical data processing with a compact footprint in dense photonic circuits."

Until now, researchers could isolate graphene only as single crystals with micron-scale dimensions, limiting the material to studies confined within laboratories.

"The ability to synthesize large-area films of graphene has the obvious implication of enabling commercial production of these proven graphene-based technologies," said James Hone, an associate professor of mechanical engineering, and whose team provided the high-quality graphene for this study. "But large-area films of graphene can also enable the development of novel devices and fundamental scientific studies requiring graphene samples with large dimensions. This work is an exciting example of both — large-area films of graphene enable the fabrication of novel optoelectronic devices, which in turn allow for the study of scientific phenomena."

"We have been able to demonstrate and explain the strong nonlinear response from graphene, which is the key component in this new hybrid device," said Tingyi Gu, the study's lead author and a doctoral candidate in electrical engineering. "Showing the power efficiency of this graphene-silicon hybrid photonic chip is an important step forward in building all-optical processing elements that are essential to faster, more efficient modern telecommunications."

The study appeared online July 15 in *Nature Photonics*.

For more information, visit: www.engineering.columbia.edu

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