Graphene applications in electronics and photonics

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Graphene, which is composed of a one-atom-thick layer of carbon atoms in a honeycomb-like lattice (like atomic-scale chicken wire), is the world's thinnest material – and one of the hardest and strongest. Indeed, the past few years have seen an explosion of research into the properties and potential applications of graphene, which has been touted as a superior alternative to silicon.

Because graphene is a two-dimensional material, "all of it is an exposed surface," says physical chemist Phaedon Avouris, manager of the Nanometer Scale Science and Technology division at IBM's T.J. Watson Research Center in Yorktown Heights, N.Y. "While graphene has a number of extremely useful properties, including very fast electron mobility, high mechanical strength, and excellent thermal conductivity, the interactions of graphene with its environment – for example, with the substrate it is placed on, the ambient environment, or other materials in a device structure – can drastically affect and change its intrinsic properties."

"Our interest is to understand the properties of this new material under conditions that are present in actual technology and apply this knowledge to design, fabricate, and test graphene-based electronic and optoelectronic devices and circuits," says Avouris, who will present new experimental results on the use of graphene in fast electronics and photonics at the AVS meeting in Nashville, Tenn., held Oct. 30 – Nov. 4. He will also discuss what still needs to be done to translate these applications into commercial products.

Avouris, an IBM Fellow, has been involved in nanotechnology research for 25 years, and has spent the last 15 years studying the properties and applications of carbon nanotubes, a close relative of graphene. "So it was natural that when graphene was isolated in 2004, I turned my attention to it. With the help of funding from DARPA, we started a focused effort on graphene electronics," he says.

Unlike conventional semiconductors like silicon and gallium arsenide, which are currently used in electronics, graphene does not have a band-gap – the energy difference between a material's non-conductive and conductive state. "This makes it unsuitable for building digital switches, which require the ability to switch the current off completely," Avouris says. "However," he adds, "the excellent electrical properties of graphene, such as its high electron mobility coupled with modest current modulation, make it very appropriate for very fast (high-frequency) analog electronics," which are used in wireless communications, radar, security systems, imaging, and other applications.

"We already have demonstrated high-frequency graphene transistors – greater than 200 gigahertz – and simple electronic circuits such as frequency mixers," says Avouris, "and we have also demonstrated very fast photodetectors and have used them to detect optical data streams."

In the future, graphene researchers need to improve the quality of synthetic graphene and to study its properties under conditions relevant to technology, says Avouris, who is "very optimistic" about the future of graphene in both electronics and photonics and anticipates the development of additional new applications.

More information: The AVS 58th International Symposium & Exhibition will be held Oct. 30 – Nov. 4 at the Nashville Convention Center. Presentation NS-WeM-4, "Graphene-based Electronics and Optoelectronics," is at 9 a.m. on Wednesday, Nov. 2.