Keeping electronics cool: Findings on modified form of graphene could have impacts in managing heat dissipation

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A University of California, Riverside engineering professor and a team of researchers have made a breakthrough discovery with graphene, a material that could play a major role in keeping laptops and other electronic devices from overheating.

Alexander Balandin, a professor of electrical engineering at the UC Riverside Bourns College of Engineering, and researchers from The University of Texas at Austin, The University of Texas at Dallas and Xiamen University in China, have shown that the thermal properties of isotopically engineered graphene are far superior to those of graphene in its natural state.

The research efforts were led by the Professor Rodney S. Ruoff of UT Austin and Balandin, a corresponding author for the paper, "Thermal conductivity of isotopically modified graphene." It was published online Jan. 8 by the journal Nature Materials and will later appear in the print publication.

The results bring graphene – a single-atom thick carbon crystal with unique properties, including superior electrical and heat conductivity, mechanical strength and unique optical absorption – one step closer to being used as a thermal conductor for managing heat dissipation in everything from electronics to photovoltaic solar cells to radars.

"The important finding is the possibility of a strong enhancement of thermal conduction properties of isotopically pure graphene without substantial alteration of electrical, optical and other physical properties," Balandin said. "Isotopically pure graphene can become an excellent choice for many practical applications provided that the cost of the material is kept under control."

He added: "The experimental data on heat conduction in isotopically engineered graphene is also crucially important for developing an accurate theory of thermal conductivity in graphene and other two-dimensional crystals."

The research used the optothermal Raman method, a thermal conductivity measuring technique developed by Balandin. In 2008, Balandin and his group members demonstrated experimentally that graphene is an excellent heat conductor. They also developed the first detailed theory of heat conduction in graphene and related two-dimensional crystals.

The work presented in the Nature Materials paper shows that the thermal conductivity of isotopically engineered graphene is strongly enhanced compared to graphene in its natural state.

Naturally occurring carbon materials, including graphene, are made up of two stable isotopes: about 99 percent of 12C (referred to as "carbon 12") and 1 percent of 13C (referred to as "carbon 13"). The difference between isotopes is in the atomic mass of the carbon atoms. The removal of just about 1 percent of carbon 13, also called isotopic purification, modifies the dynamic properties of crystal lattices and affects their thermal conductivity.

The importance of the present research is explained by practical needs for materials with high thermal conductivity. Heat removal has become a crucial issue for continuing progress in the electronics industry, owing to increased levels of dissipated power as the devices become smaller and smaller. The search for materials that conduct heat well has become essential for the design of the next generation of integrated circuits and three-dimensional electronics. Balandin, who is also founding chair of the materials science and engineering (MS&E) program at UC Riverside, believes graphene will gradually be incorporated into different devices.

Intially, it will likely be used in some niche applications such as thermal interface materials for chip packaging or transparent electrodes in photovoltaic solar cells or flexible displays, he said.

In a few years, it could be used with silicon in computer chips, for example as interconnect wiring or heat spreaders. It also has the potential to benefit other electronic applications, including analog high-frequency transistors, which are used in wireless communications, radar, security systems and imaging.

Balandin and the following researchers contributed to the findings in the Nature Materials paper:

The team at UT Austin, which performed the isotopic purification of graphene, included Ruoff, Shanshan Chen, a post-doctoral fellow, Weiwei Cai a former post-doctoral researcher who is now a professor at the Xiamen University and Columbia Mishra, a graduate student.

The team at UT Dallas, who performed molecular dynamics simulations that compared well with the stronger thermal connectivity of the isotopically engineered graphene, included Kyeongjae Cho, a professor, and Hengji Zhang, graduate student.

Provided by University of California - Riverside