Hot new material can keep electronics cool: Few atomic layers of graphene reveal unique thermal properties

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Professor Alexander Balandin and a team of UC Riverside researchers, including Chun Ning Lau, an associate professor of physics, have taken another step toward new technology that could keep laptops and other electronic devices from overheating.

Balandin, a professor of electrical engineering in the Bourns College of Engineering, experimentally showed in 2008 that graphene, a recently discovered single-atom-thick carbon crystal, is a strong heat conductor. The problem for practical applications was that it is difficult to produce large, high quality single atomic layers of the material.

Now, in a paper published in *Nature Materials*, Balandin and co-workers found that multiple layers of graphene, which are easier to make, retain the strong heat conducting properties.

That's also a significant discovery in fundamental physics. Balandin's group, in addition to measurements, explained theoretically how the materials' ability to conduct heat evolves when one goes from conventional three-dimensional bulk materials to two-dimensional atomically-thin films, such as graphene.

The results published in *Nature Materials* may have important practical applications in removal of dissipated hear from electronic devices.

Heat is an unavoidable by-product when operating electronic devices. Electronic circuits contain many sources of heat, including millions of transistors and interconnecting wiring. In the past, bigger and bigger fans have been used to keep computer chips cool, which improved performance and extended their life span. However, as computers have become faster and gadgets have gotten smaller and more portable the big-fan solution no longer works.

New approaches to managing heat in electronics include incorporating materials with superior thermal properties, such as graphene, into silicon computer chips. In addition, proposed three-dimension electronics, which use vertical integration of computer chips, would depend on heat removal even more, Balandin said.

Silicon, the most common electronic material, has good electronic properties but not so good thermal properties, particularly when structured at the nanometer scale, Balandin said. As Balandin's research shows, graphene has excellent thermal properties in addition to unique electronic characteristics.

"Graphene is one of the hottest materials right now," said Balandin, who is also chair of the Material Sciences and Engineering program. "Everyone is talking about it."

Graphene is not a replacement for silicon, but, instead could be used in conjunction with silicon, Balandin said. At this point, there is no reliable way to synthesize large quantities of graphene. However, progress is being made and it could be possible in a year or two, Balandin said.

Initially, graphene would likely be used in some niche applications such as thermal interface materials for chip packaging or transparent electrodes in photovoltaic solar cells, Balandin said. But, in five years, he said, it could be used with silicon in computer chips, for example as interconnect wiring or heat spreaders. It may also find applications in ultra-fast transistors for radio frequency communications. Low-noise graphene transistors have already been demonstrated in Balandin's lab.

Balandin published the Nature Materials paper with two of his graduate students Suchismita Ghosh, who is now at Intel Corporation, and Samia Subrina, Lau. one of her graduate students, Wenzhong Bao, and Denis L. Nika and Evghenii P. Pokatilov, visting researchers in Balandin's lab who are based at the State University of Moldova.

Provided by University of California - Riverside

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