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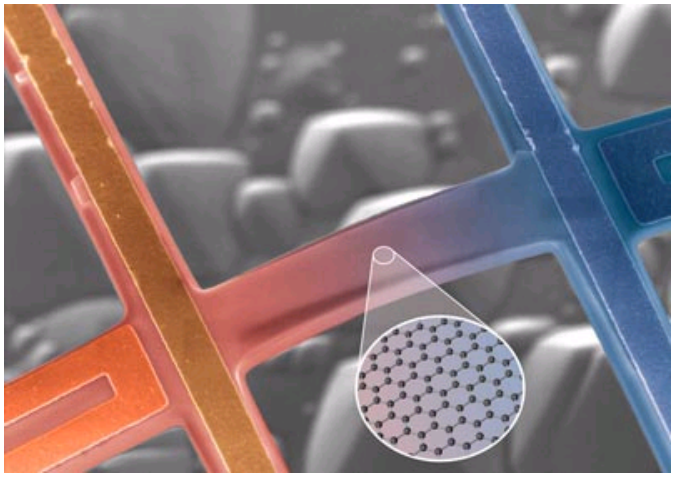
Carbon sheets offer cool solution for computers

Apr 8, 2010



Cool stuff

Two-dimensional sheets of carbon atoms could be used to cool computer chips faster than any other material used in electronics today. That is the view of researchers in the US and France, who have measured graphene's thermal conductivity when placed on silica – a commonly employed substrate in electronic devices. They found that graphene conducts heat more than twice as well as copper wires, which are routinely used in electrical interconnects, and 50 times better than silicon thin films.

Graphene consists of a single, flat sheet of carbon arranged in a honeycombed lattice. Since the material was first created in 2004, its unique electronic and mechanical properties have amazed researchers, who have been eyeing up graphene for a host of device applications. In particular, it could be used to make ultrafast transistors because the electrons in graphene behave like relativistic particles with no rest mass, which means that they whizz through the material at extremely high speeds.

Even though all-graphene electronics might still be a distant dream, the material could be used to dissipate the unwanted heat generated by conventional silicon circuits, which can otherwise slow electronic devices and make them unreliable. Previous measurements had shown that free-standing graphene boasts a thermal conductivity of up to 5000 $Wm^{-1}K^{-1}$ at room temperature – higher even than diamond, which is nature's best heat conductor. However, in practical applications, graphene needs to be interfaced with composites or other substrates, such as silica (SiO_2).

Measurements by Li Shi at the University of Texas at Austin, along with colleagues at Boston College and the French atomic-energy commission (CEA), now show that graphene in contact with SiO_2 has a thermal conductivity of 600 $Wm^{-1}K^{-1}$. Although this figure is not as high as freestanding graphene, it still outdoes that of bulk copper, which has a thermal conductivity of around 400 $Wm^{-1}K^{-1}$ and is widely used to cool computer chips, and that of copper thin films (typically below 250 $Wm^{-1}K^{-1}$). The conductivity is reduced because phonons – quantized vibrations of the crystal lattice – "leak" across the graphene-substrate interface.

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Novel approach

Shi and colleagues obtained their results using a novel method to measure the thermal conductivity of graphene supported on a SiO_2 beam. The researchers began by first attaching a single graphene layer to the SiO_2 by mechanically shaving off (or "exfoliating") layers. They then measured the thermal conductance of the combined structure before etching away the graphene layer and re-measuring the conductance of just the SiO_2.

The difference between the two values gave the thermal conductance (in Watts per Kelvin) of the graphene alone, which was then used to determine the thermal conductivity (in Watts per metre per Kelvin) by taking into account its length, width and thickness.

The team also developed a theoretical model to understand the measurement results, which showed that out-of-plane "flexural" vibration modes in the graphene are important for the material's high thermal conductivity. These vibrations are suppressed when graphene is interfaced to another material.

The researchers are now looking at how the support layer affects graphene that has more than one layer of carbon atoms (so-called "few-layer" graphene). "We expect that the interface interaction effect will become weaker for the top layers in supported few-layer graphene," Shi told *physicsworld.com*. "This means that the effective thermal conductivity of supported few-layer graphene could be even higher than that of supported, monolayer graphene."

Ravi Prasher of chip manufacturer Intel in Chandler, Arizona, who was not involved in the work, says that the new study is "remarkable" because it combines thermal, structural and mechanical phenomena into one theoretical framework. "[It] is a crucial first step towards explaining the thermal conductivity of supported graphene," he says.

The work was published in *Science*.

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