UB engineers prove that carbon nanotubes are superior to metals for electronics

BUFFALO, N.Y. -- In the quest to pack ever-smaller electronic devices more densely with integrated circuits, nanotechnology researchers keep running up against some unpleasant truths: higher current density induces electromigration and thermomigration, phenomena that damage metal conductors and produce heat, which leads to premature failure of devices.

But University at Buffalo researchers who study electronics packaging recently made a pleasant discovery: that's not the case with Single-Walled Carbon Nanotubes (SWCNTs).

"Years ago, everyone thought that the problem of cooling for electronics could be solved," said Cemal Basaran, Ph.D., professor in the UB Department of Civil, Structural and Environmental Engineering and director of the Electronics Packaging Lab in UB's School of Engineering and Applied Sciences. "Now we know that's not true. Electronics based on metals have hit a wall. We are done with metals."

Single Walled Carbon Nanotubes are extremely thin, hollow cylinders, measuring no thicker than a single atom. Thousands of times stronger than metals, they are expected to one day replace metals in millions of electronic applications.

Basaran and his doctoral student Tarek Ragab have spent the past four years performing quantum mechanics calculations, which prove that in carbon nanotubes, higher current density does not lead to electromigration and thermomigration; it also produces just one percent of the heat produced by traditional metals, such as copper.

Basaran will present the findings in November when he delivers a keynote lecture at the American Society of Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition in Orlando.

The findings demonstrate yet another tantalizing property of CNTs, he said.

"It has been assumed that for carbon nanotubes, the electrical heating process would be governed by Joules law, where resistance in a circuit converts electric energy into heat," said Basaran. "We are the first to show mathematically, from a quantum mechanics point of view, that carbon nanotubes do not follow Joules law."

According to Basaran, this essential difference between metals and carbon nanotubes lies in the way they conduct electricity.

"Even though carbon nanotubes are conductive, they do not have metallic bonds," he said. "As a result,
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Joule law define the heat as $I^2R$. So it takes the collective resistance of the material, regardless of the mechanisms of scatterings, but in CNT's due to there unique energy dispersion relations, a large portion of the resistance is due to scatterings involving momentum exchange rather than energy exchange that cause the joule heating. That's why joule law doesn't apply to nanostructures like CNTs.

Joules Law

March 23, 2009 by Anonymous, 8 weeks 3 days ago
Comment id: 35529

Joule law is for metallic bond materials, where atoms are bonded to each other with a sea of electron. CNT is a covelent bond material. So it is natural that Joule law does not apply, because concept of resistance is based on metallic bond. Both quantum mechanics calculations and experimental data show that in ballistic conduction Joule Law does not work. It is like trying to use solid mechanics equations to fluid mechanics. They are different animals.

reply

What????

March 20, 2009 by Anonymous, 8 weeks 5 days ago
Comment id: 35482

Quote from article.
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This statement appears to be meaningless.

Joules law #1,
States that the heat produced is proportional to the current squared * resistance.
Just because the resistance to current flow is lower in a carbon nanotube than a metal such as copper doesn't mean that Joules law isn't followed.

Joules law #2, which doesn't seem to apply here, says that the internal energy of an ideal gas is independent of its pressure and volume.

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