Transparent electronics from graphene-based electrodes (w/ Video)

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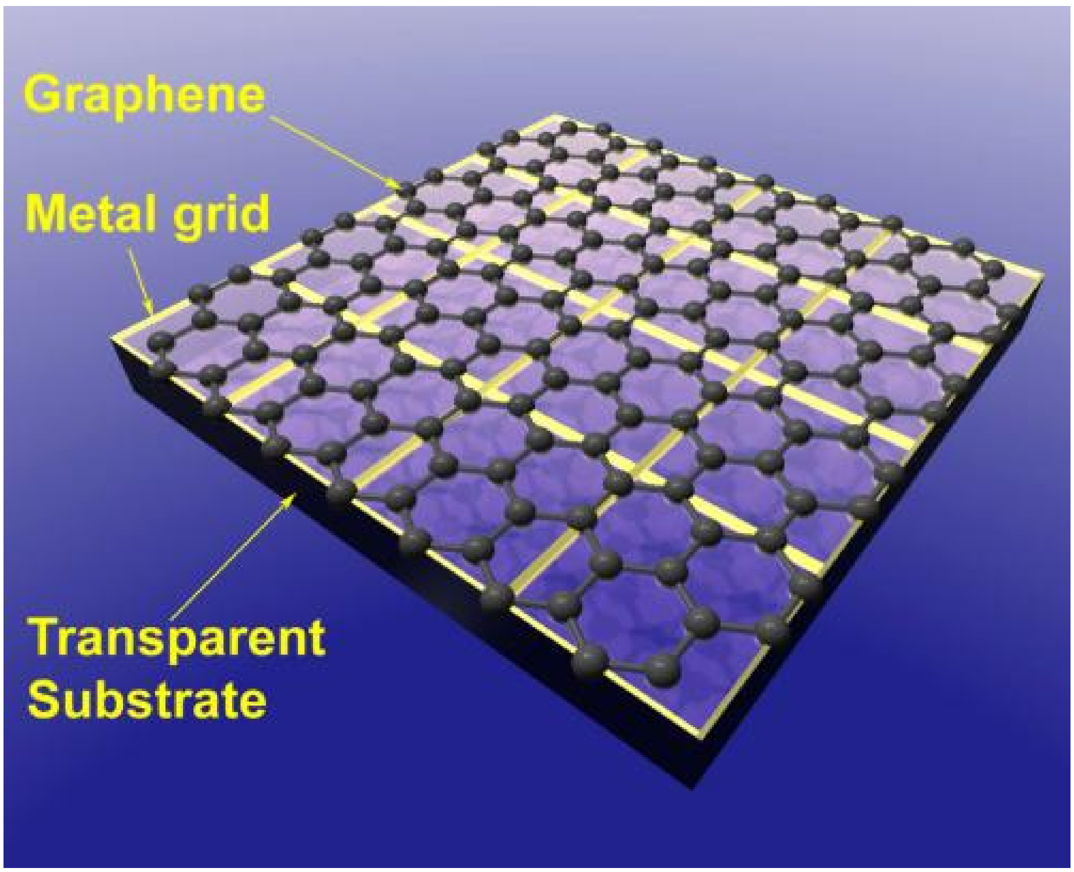

A hybrid material that combines a fine aluminum mesh with a single-atom-thick layer of graphene outperforms materials common to current touch screens and solar cells. The transparent, flexible electrodes were developed in the lab of Rice University chemist James Tour. (Credit: Yu Zhu/Rice University)

Flexible, transparent electronics are closer to reality with the creation of graphene-based electrodes at Rice University.

The lab of Rice chemist James Tour lab has created thin films that could revolutionize touch-screen displays, solar panels and LED lighting. The research was reported in the online edition of *ACS Nano*.

Flexible, see-through video screens may be the "killer app" that finally puts graphene -- the highly touted single-atom-thick form of carbon -- into the commercial spotlight once and for all, Tour said. Combined with other flexible, transparent electronic components being developed at Rice and elsewhere, the breakthrough could lead to computers that wrap around the wrist and solar cells that wrap around just about anything.

The lab's hybrid graphene film is a strong candidate to replace indium tin oxide (ITO), a commercial product widely used as a transparent, conductive coating. It's the essential element in virtually all flat-panel displays, including touch screens on smart phones and iPads, and is part of organic light-emitting diodes (OLEDs) and solar cells.

ITO works well in all of these applications, but has several disadvantages. The element indium is increasingly rare and expensive. It's also brittle, which heightens the risk of a screen cracking when a smart phone is dropped and further rules ITO out as the basis for flexible displays.

The Tour Lab's thin film combines a single-layer sheet of highly conductive graphene with a fine grid of metal nanowire. The researchers claim the material easily outperforms ITO and other competing materials, with better transparency and lower resistance to electric current.

"Many people are working on ITO replacements, especially as it relates to flexible substrates," said Tour, Rice's T.T. and W.F. Chao Chair in

Chemistry as well as a professor of mechanical engineering and materials science and of computer science. "Other labs have looked at using pure graphene. It might work theoretically, but when you put it on a substrate, it doesn't have high enough conductivity at a high enough transparency. It has to be assisted in some way."

Conversely, said postdoctoral researcher Yu Zhu, lead author of the new paper, fine metal meshes show good conductivity, but gaps in the nanowires to keep them transparent make them unsuitable as stand-alone components in conductive electrodes.

But combining the materials works superbly, Zhu said. The metal grid strengthens the graphene, and the graphene fills all the empty spaces between the grid. The researchers found a grid of five-micron nanowires made of inexpensive, lightweight aluminum did not detract from the material's transparency.

"Five-micron grid lines are about a 10th the size of a human hair, and a human hair is hard to see," Tour said.

Tour said metal grids could be easily produced on a flexible substrate via standard techniques, including roll-to-roll and ink-jet printing. Techniques for making large sheets of graphene are also improving rapidly, he said; commercial labs have already developed a roll-to-roll graphene production technique.

"This material is ready to scale right now," he said.

The flexibility is almost a bonus, Zhu said, due to the potential savings of using carbon and aluminum instead of expensive ITO. "Right now, ITO is the only commercial electrode we have, but it's brittle," he said. "Our transparent electrode has better conductivity than ITO and it's flexible. I think flexible electronics will benefit a lot."

In tests, he found the hybrid film's conductivity decreases by 20 to 30 percent with the initial 50 bends, but after that, the material stabilizes. "There were no significant variations up to 500 bending cycles," Zhu said. More rigorous bending test will be left to commercial users, he said.

"I don't know how many times a person would roll up a computer," Tour added. "Maybe 1,000 times? Ten thousand times? It's hard to see how it would wear out in the lifetime you would normally keep a device."

The film also proved environmentally stable. When the research paper was submitted in late 2010, test films had been exposed to the environment in the lab for six months without deterioration. After a year, they remain so.

"Now that we know it works fine on flexible substrates, this brings the efficacy of graphene a step up to its potential utility," Tour said.

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