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Science news

Standing graphene film scores over flat cousin

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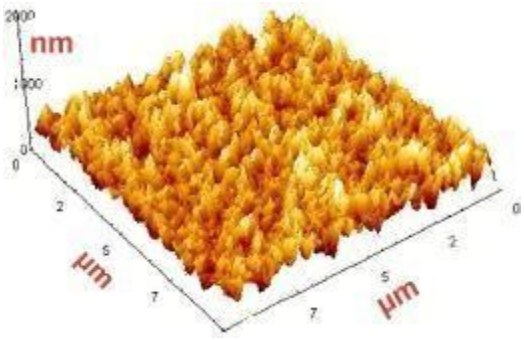
Wonder material graphene is bracing to get up and go, quite literally, with an innovative twist that makes it even more powerful. Researchers have synthesised 'standing graphene' in vertical sheets as opposed to its 'laid-back' cousin, the flat graphene sheets.[1] Vertical graphene sheets could help develop powerful beams of electrons as well as devices such as high resolution electron microscopes.



Atomic Force Microscope image of standing graphene films on a silicon substrate. © *Behura, S. K. et al.*

Graphene, the remarkable two-dimensional material, is just a one-atom thick layer of carbon atoms arranged in a hexagonal pattern like a honeycomb. Due to its amazing physical properties — extremely light, stronger than steel, a good conductor of heat and electricity and almost transparent to light — graphene has several potential uses, from ultra-thin displays and touch screens, to transistors and solar arrays.

To this list, one can add field-electron emission (FEE) — a phenomenon of 'tunneling' of electrons from a solid surface to the vacuum when subjected to a strong electric field. The open surfaces and sharp edges of the graphene film are good for field emission due to local field enhancement at the edges, allowing electrons to tunnel into vacuum at low electric fields. In graphene, the FEE takes place at room temperature unlike most electron emitters such as an X-ray machine source that utilises thermionic emission to generate high-current electron beams. Such devices are bulky and cause heating of the surrounding device housing.

Being a 'cold' emitter with unique geometry and electrical properties makes graphene an ideal material for FEE applications. But conventional methods to prepare graphene lead to growth of graphene sheets that lie flat on the substrate surface. "Flat graphene sheets have fewer (electron) emission sites," Sanjay Behura from the Gujarat Energy Research & Management Institute in Gandhinagar and the first author of the report told *Nature India*.

To increase the number of emission sites, Behura and co-workers decided to fabricate graphene films that stand vertically on the substrate instead of lying flat on it.

They used a 300 nanometre (nm, billionth of a metre) thick Silicon-oxide film on p-type Silicon wafer as the substrate. "Free-standing vertically oriented graphene films were synthesized directly on the substrate by hot-filament chemical vapour deposition without any catalyst or special substrate treatment," the researchers said. The graphene sheets, thus fabricated were about 600 to 800 nm tall, "standing roughly vertical to the substrate and having a smooth surface topography and corrugated nature."

Though other uses of vertical graphene synthesised on metallic substrates have been reported earlier, none has been used for field electron emission earlier. Also, Behura and his team have directly deposited graphene on a dielectric substrate which is necessary for electronic applications.

The vertical films were found to be better electron emitters than the flat ones due to the high density of sharp edges on substrate that locally enhance the electric field, dramatically increasing field emission.

Behura said they have demonstrated that "vertically oriented graphene films can be grown directly on dielectric substrates avoiding metal catalyst contamination and other damages to the graphene film." The work, he said, has also shown the feasibility of large-area preparation and large field enhancement factor with good emission stability suggesting that the vertical films could be used as a potential source of high performance field electron emitter.

The researchers in this work are from: *Gujarat Energy Research & Management Institute and Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India; and the University of Saskatchewan, Canada*.

References

1. Behura, S. K. *et al*. Vertically-oriented few-layer graphene as an electron field-emitter. *Phys. Status Solidi A.* (2013) doi: **10.1002/pssa.201329172**

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