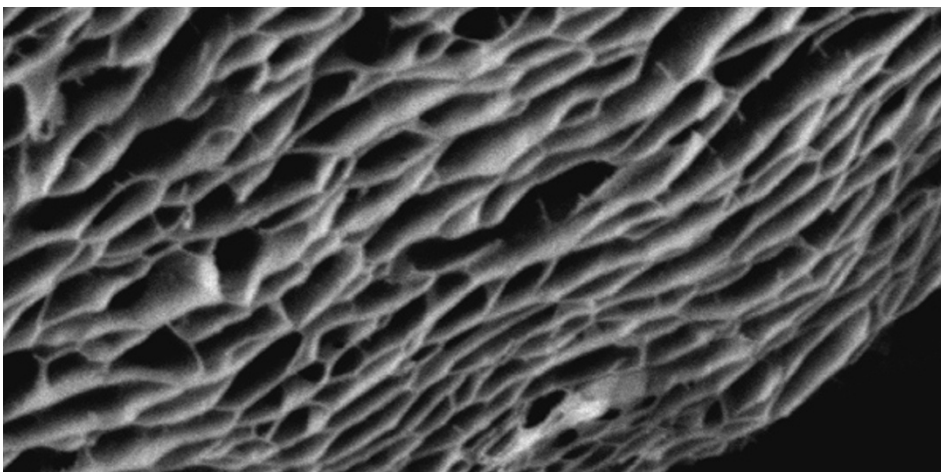


# Graphene spun into metre-long fibres

A liquid crystal starting phase is key to drawing macro-scale threads from these nano-scale flakes.

James Mitchell Crow

06 December 2011



Nano-sized flakes of graphene oxide can be spun into graphene fibres several metres long, researchers in China have shown. The strong, flexible fibres, which can be tied in knots or woven into conductive mats, could be the key to deploying graphene in real-world devices such as flexible batteries and solar cells<sup>1</sup>.

When it comes to physical properties, graphene is remarkably well-rounded. This two-dimensional mesh of carbon atoms has the highest mechanical strength ever recorded, and also breaks records for its thermal and electrical conductivity. But harnessing graphene's properties requires finding a way to turn these tiny 800-nanometre-wide flakes of carbon into macro-scale materials.

Zhen Xu and Chao Gao at Zhejiang University in Hangzhou, China, have achieved just that. They have used an industrial process called wet spinning to turn an aqueous solution of graphene oxide — a modified form of graphene that is easier to dissolve — into fibres that are tens of metres long. A final chemical reduction treatment turns the long strings of graphene oxide back into graphene.

“In the last few years, there has been big progress in the properties of graphene,” says Gao. “But it is hard to imagine how graphene, a single-layered material less than a nanometre thick, could be turned into a macroscopic material before this study.”

Previous efforts in this area have focused on producing sheets of graphene ‘paper’, but that material, Gao says, “is only a few millimetres in scale; it is not a continuous material that you can make as long as you want.”

The team's trick for fibre formation is to start with a solution of graphene oxide so pure and so concentrated that it forms liquid crystals. This half-liquid, half-solid state will flow like a viscous fluid, but the graphene oxide molecules within it are assembled into neat rows. Because of this internal order, liquid crystals are a good starting material for spinning fibres, says Gao, noting that Kevlar is also made from liquid crystals.

Graphene is not the first carbon material to be spun into fibres — long threads of conventional carbon fibre and carbon nanotubes have already been developed. But graphene fibres could offer some advantages: carbon nanotubes are notoriously difficult to make in a pure form, which compromises the performance of the final product, and making carbon fibre is an expensive, high-energy process.

“Carbon fibre is made by a high-temperature treatment. Our fibres are made just by spinning a water-based solution — it is quite green and quite easy,” says Gao.

Improving the graphene fibre's strength is Gao's next goal. His first-generation fibres have some structural imperfections, which compromises mechanical performance. “At the moment, the mechanical strength can't compete with carbon fibres, but we believe that

the mechanical properties can be greatly improved.”

However, strength is not necessarily needed if the fibres are to be used primarily for their electrical properties. Hua Zhang, who studies graphene synthesis at Nanyang Technological University in Singapore, says that the fibres “will definitely have some applications — maybe for touch panels, for sensors or for functional textiles”.

Earlier this year, Xu and Gao were one of two research groups that published the first results showing graphene oxide liquid crystals<sup>2,3</sup>. Sang Ouk Kim of the Korea Advanced Institute of Science and Technology in Daejeon, who led the other study, is optimistic about the latest results.

“This new fibre structure formation is an important step in carbon-based liquid crystal research,” says Kim. “Following our work I have seen many reports showing graphene-based liquid crystal systems. I expect that this new field will grow, and will be an important one for carbon-based high performance material fabrication.”

*Nature* | doi:10.1038/nature.2011.9549

## References

---

1. Xu, Z. & Gao, C. *Nature Communications* **2**, 571 (2011).
2. Kim, J. E. *et al. Angew. Chem. Int. Ed.* **50**, 3043–3047 (2011).
3. Xu, Z. & Gao, C. *ACS Nano* **5**, 2908–2915 (2011).