The excitement of two dimensions

Graphene is setting the world of materials science alight, constantly revealing new surprises.

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Graphene is the hottest thing in solid-state science to my mind. And I can't be the only one with that opinion. The excitement was almost palpable at the recent Spring meeting of the European Materials Research Society (EMRS), where two of the symposia held joint sessions on the new material and its remarkable properties.

The discovery of zero-dimensional fullerenes and one-dimensional nanotubes left one form of carbon conspicuous by its absence – the two-dimensional form of graphite called graphene. Graphene was first observed by Andre K. Geim, Kostya S. Novoselov, and colleagues in 2004 [*Science* **306**, 666], and since then the surprises have kept coming. The first was that a truly two-dimensional material – a single atomic layer – could exist at all, confounding long-standing predictions by Peierls and Landau. Then there's the charge carriers, which behave like massless relativistic particles with a chirality, and a new quantum Hall effect that even persists at room temperature. But perhaps the biggest surprise is that graphene can be obtained by extracting single carbon sheets from graphite in an incredibly simple way. "Anyone with Scotch tape can jump on this field," remarked Philip Kim of Columbia University at the EMRS meeting.

All of this – a new material with the promise of novel physics – has quite naturally led to a great deal of interest with many new reports at conferences and in journals. What made the presentations at EMRS different, was that graphene has become a real materials science endeavor. Thoughts turned beyond the interests of fundamental physics to doping, defects, and how to open a bandgap in this semimetal and realize devices.

Nanoscale ripples or undulations have been seen in freely suspended graphene sheets by Jannik C. Meyer of the University of California, Berkeley (UCB) and colleagues. This means graphene isn't a perfectly flat, two-dimensional material after all, perhaps explaining why graphene is stable. What drives ripple formation is another question. Alessandra Lanzara, also of UCB, showed angle-resolved photoelectron spectroscopy of graphene grown epitaxially on SiC substrates. This technique is able to map the electronic structure below the Fermi energy and reveals that the SiC substrate breaks the symmetry of the single graphite layer, leading to a bandgap. Finally, Cinzia Casiraghi of the University of Cambridge, UK, demonstrated how Rayleigh scattering can be used to pinpoint graphite sheets on a surface and reveal how many carbon layers are present. The method shows up graphene better than optical microscopy and is much quicker than atomic force microscopy for finding samples.

I'm certain graphene will offer up many more surprises. How they are exploited will be down to materials science.

materialstoday

Published by
Elsevier Ltd.
The Boulevard, Langford Lane,
Kidlington, OX5 1GB, UK

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Tel: +44 (0)1858 439 601
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Subscription orders & payments
Price: €178 / US$199
Europe/ROW Tel: +31 20 485 3757
USA Tel: +1 212 633 3730

Printed by Headley Brothers Ltd, Kent, UK
ISSN 1369-7021
Journal number: 03069