Graphene - Another New Kid on the (Carbon) Block

by Dirk M. Guldi

Carbon is fashionable—not only in chemistry! In 2010, the Nobel Prize in physics went to A. Geim and K. Novoselov for the discovery of a new form of the element carbon, graphene. The Nobel Prize in chemistry was awarded to R. H. Heck, E. Negishi, and A. Suzuki for the discovery of the palladium-catalyzed cross-coupling reactions that generate carbon–carbon bonds. These recent Nobel awards on top of that awarded in 1996 to H. Kroto, R. Smalley, and R. Curl for the discovery of fullerenes, underline the significance of the discovery of new forms and chemistry involving carbon. Thus it is not surprising that graphene is presently the hottest material in condensed matter physics and is making a rapid foray into chemistry and materials science.

Of all the elements in the periodic table, only carbon provides the basis for life on earth. Carbon is also the key for many technological applications ranging from drugs to synthetic materials that have become indispensable in our daily life and have influenced the world's civilization for centuries. Importantly, the structural diversity of organic compounds and molecules results in sheer endless chemical and physical properties. Altering the periodic binding motifs in networks of sp^3-, sp^2-, and sp-hybridized C-atoms represents the conceptual starting point for constructing a wide palette of carbon allotropes. To this end, the past two decades have served as a test-bed for measuring the physico-chemical properties of carbon in reduced dimensions starting with the advent of fullerenes (0D) and followed in chronological order by carbon nanotubes (1D) and other nanoarchitectures (*e.g.*, nanohorns).

The youngest 2D representative of these synthetic carbon allotropes is the material featured in this special issue of the magazine, namely, graphene. Its extraordinary properties render it a promising material for electronics and for other applications in material sciences energy conversion systems. A flat monolayer of graphene, for example, as a zero-gap semiconductor, is nearly transparent and exhibits the lowest resistivity known for any material at room temperature. Additionally, the high electron mobility of graphene at room temperature enables its implementation in transparent conducting electrodes.

Such visionary features became a reality when Andre Geim, and his former grad student, Konstantin Novoselov, developed in 2004 a simple technique that allowed the isolation of graphene, a sheet of carbon a single atom thick. Other fabrication strategies, in particular epitaxial growth and solubilization from

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TOP 10

Ten Most Cited Papers on Graphene-related Carbon Nanostructures in the *Journal of The Electrochemical Society*

1. J. S. Xue and J. R. Dahn, "Dramatic Effect of Oxidation on Lithium Insertion in Carbons Made from Epoxy Resins," *J. Electrochem. Soc.*, **142**, 3668 (1995). Times Cited: 112

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10. I. Mukhopadhyay, N. Hoshino, S. Kawasaki, F. Okino, W. K. Hsu, and H. Touharaa, "Electrochemical Li Insertion in B-doped Multiwall Carbon Nanotubes," *J. Electrochem. Soc.*, **149**, A39 (2002). Times Cited: 30

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bulk graphite, have been demonstrated and are paving the way to systematic experiments and technological applications. Although the graphene revolution isn't quite here yet, there is lots of exciting work going on, in laboratories around the globe.

In this issue of *Interface*, we review the status of graphene from scientific aspects to real-world applications. The Nobel laureate, Novoselov, reviews the magic of flat carbon covering aspects such as electronic properties and application/mass production in an article reprinted from the *ECS Transactions*. Obeng and P. Srinivasan then lead off the feature articles with a review of how graphene may shape up the future of semiconductors by overviewing materials, devices, and applications. Malig, Englert, Hirsch, and Guldi then provide a brief overview on the wet chemistry of graphene with detailed insights into covalent and non-covalent approaches. In the next feature article, Shi, Bhalla, Chen, Gunaratne, Jiang, and Meletis describe atomistic computations of hydrogen absorption on graphene with implications on the hydrogen storage capability of this material. Finally Radich, McGinn and Kamat discuss graphene-based composites for electrochemical energy storage.

About the Author

Dirk M. Guldi is one of the world-leading scientists in the field of charge transfer/nanocarbons. In particular, he is well-known for his outstanding contributions to the areas of charge-separation in donor-acceptor materials and construction of nanostructured thin films for solar energy conversion. His scientific career began at the University of Köln, from where he graduated in chemistry (1988) and from where he received his PhD (1990). After a postdoctoral stay at the National Institute of Standards and Technology in Gaithersburg/USA (1991/1992), he took a position at the Hahn-Meitner-Institute Berlin (1992-1994). Following a brief stay as a Feodor-Lynen Fellow at Syracuse University/USA he joined the faculty of the Notre Dame Radiation Laboratory/USA (1995). Then, after nearly a decade in the USA, the University of Erlangen-Nürnberg succeeded in attracting Dirk M. Guldi back to Germany. He is the recipient of numerous honors and awards: VCI Abschlussstipendium (VCI, 1990), Heisenberg Preis (DFG, 1999), Grammaticakis-Neumann Prize (Swiss Society of Photochemistry, 2000), JSPS Award (Japan Society for the Promotion of Science, 2003), JPP Award (Society of Porphyrins & Phthalocyanines, 2004), and Elhuyar-Goldschmidt Award (Spanish Chemical Society, 2009). He was elected Chair of the ECS Fullerenes, Nanotubes, and Carbon Nanostructures Division in 2008. He may be reached at dirk.guldi@chemie.uni-erlangen.de.