ACCOUNTS
of chemical research

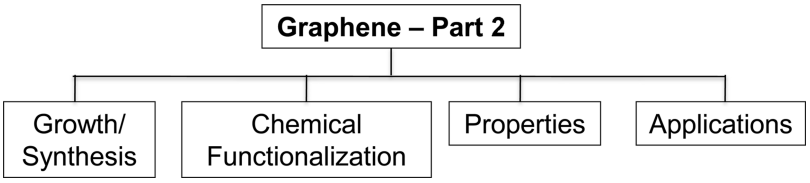
GUEST EDITORIAL

Graphene – The Mother of Two-Dimensional (2-D) Materials

Graphene has traditionally been regarded as the Mother of conjugated carbon materials; it is after all, the only one of the conjugated carbon allotropes in which carbon is rigorously sp^2 hybridized. Both the fullerenes and carbon nanotubes admit varying degrees of rehybridization in order to accommodate the curvature implied by their structures. However graphene has now spawned another brood, a vast vista of 2-D materials that might be derived from other elemental compositions whose properties could eclipse that of graphene itself. However the contents of this issue and its antecedent, call this viewpoint into question. While some would argue that graphene research is now mature, the focus on this material began in earnest only in 2004. The modern era of graphene research is only 10 years old, yet these two issues of *Accounts of Chemical Research* lay out a fascinating collection of Accounts on the chemistry of graphene, the material that was the subject of a Nobel Prize in Physics. Certainly other 2-D materials should be revisited and may be of great interest when isolated in monolayer form, but conjugated carbon is special in all of its incarnations.

Conjugated carbon has been very good to chemists, physicists, and mixtures thereof, particularly if we admit a little hydrogen. It is easy to think of Nobel Prizes, mainly in chemistry, given for advances in this area including the Diels–Alder reaction, pericyclic reaction theories, polyacetylene (1-D), fullerenes (0-D), and now graphene (2-D), all of which are concerned with some aspect of conjugated (hydro) carbons.

The themes of the Accounts in this issue follow the pattern of Graphene, Part 1, but there is a definite shift in emphasis toward properties and applications. While there are contributions that primarily fall in the categories detailed in the graphic, virtually all articles touch on properties and emphasize (potential) applications.



Graphene, Part 2, is focused on aspects of graphene synthesis, chemical modification and processing, the structural, electronic, magnetic, optical, and mechanical properties of graphene, and a wide-range of applications that are anticipated for 2-D graphene-based materials:

- **Johann Coraux and co-workers** discuss hybrid systems in which graphene is associated with molecules or metals, the electronic and magnetic consequences of epitaxial graphene hybrids, and the optical properties of graphene decorated with optically active molecules.
- **Shintaro Fujii and Toshiaki Enoki** discuss the fabrication of nanographene with zigzag and armchair edges and the use of scanning probe microscopy to characterize the electronic structure and properties of the two forms of nanographene.
- **Byung Hee Hong, Dal-Hee Min, and co-workers** discuss recent attempts to use graphene and graphene oxide for biomedical research, the techniques that are available to prepare graphene materials for biomedical applications, and the use of graphene in biosensing and cell differentiation and growth.
- **Jiaxing Huang and co-workers** discuss material processing issues associated with graphene oxide, its use as a precursor to chemically modified graphene, and the application of fluorescence quenching microscopy to observe graphene-based sheets on substrates and in solution.
- **Prashant Kamat and Ian Lightcap** discuss the assembly of graphene composite materials with a focus on the electronic structure and excited state properties of graphene hybrids with semiconductors and metals,

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the use of such materials to effect electron capture and transport through the 2D carbon network, and the application of graphene composites as sensing, energy storage, and energy conversion devices.

- **Richard Kaner and Jonathan Wassei** discuss a range of synthetic routes to graphene including intercalation/exfoliation, chemical reduction of graphene oxide with hydrazine, chemical vapor deposition, and laser scribed graphene, together with the application of these graphene materials to chemical sensors, flash memory storage devices, transparent conductors, distributed ignition, and supercapacitors.
- **Liang-Shi Li and co-workers** discuss their synthesis of stable, atomically precise colloidal graphene quantum dots (QDs), together with quantum confinement phenomena such as the energy relaxation dynamics and the potential applications of these new QDs in solar cells.
- **Zhongfan Liu and co-workers** discuss their CVD growth of high-quality graphene via the application of process engineering to the controlled surface growth of graphene on Cu/Ni substrates.
- **Kian Ping Loh and Chenliang Su** discuss the catalytic applications of the carbon allotropes, graphene oxide (GO), GO hybrids, and derivatives in a variety of synthetic transformations and the correlation of GO reactivity with its chemical constitution.
- **Jiwoong Park and co-workers** discuss the occurrence of grain boundaries in graphene grown by chemical vapor deposition (CVD) and their effect on the electrical and mechanical properties, together with an analysis of the various structures of multilayer CVD graphene.
- **Wendelin Stark and Fabian Koehler** discuss the relationship of graphene chemistry to that of other carbon allotropes, the modification of the electrical properties of graphene by covalent attachment of aryl radicals generated from diazonium chemistry, the synthesis of graphene-coated nanoparticles, and the introduction of a variety of functional groups on graphene surfaces.
- **James Tour and Dustin James** discuss methods to produce graphene powder, flakes, ribbons, and sheets, an improved synthesis of graphene oxide, the use of multiwall carbon nanotubes to produce nanoribbons, and the use of solid carbon sources as precursors to graphene sheets.
- **Oleg Yazyev** provides a theoretical overview of the various electronic structures and interactions that are important in understanding the properties of graphene nanoribbons, including the presence of metallic, semiconducting, and half-metallic magnetic phases.
- **Chongwu Zhou and co-workers** discuss the growth, transfer, and applications of graphene grown by chemical vapor deposition (CVD) on Ni and Cu substrates, with a focus on the application of CVD graphene in transparent electronics, organic photovoltaics, and transistors.

The present issue and its predecessor collectively offer a series of compelling Accounts on the synthesis, chemical functionalization, properties, and potential applications of graphene, which serves as a vivid snapshot of the progress and promise of this fast moving area of chemical research.

Views expressed in this editorial are those of the authors and not necessarily the views of the ACS.

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