new hot papers - 2010

May 2010

(Late commentary entry for March 2010)

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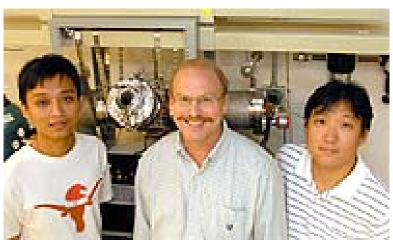
Rodney S. Ruoff & Sungjin Park talk with *ScienceWatch.com* and answer a few questions about this month's New Hot Papers in the field of Materials Science. The authors have also sent along images of their work.



Professor Rodney Ruoff (center) is flanked by post-docs Weiwei Cai (left, a physicist) and Sungjin Park (right, a chemist) in front of the reactor where they are producing carbon-13 labeled graphite, that allows for studies of carbon-13 labeled graphene, a single-atom thick layer of carbon atoms.

[+] enlarge

Article Title: Aqueous Suspension and Characterization of Chemically Modified Graphene Sheets
Authors: **Park, S**;An, JH;Piner, RD;Jung, I;Yang, DX;Velamakanni, A; Nguyen, ST;**Ruoff, RS**
Journal: CHEM MATER
Volume: 20
Issue: 21
Page: 6592-6594
Year: NOV 11 2008
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SW: Why do you think your paper is highly cited?

Colloidal suspensions of graphene platelets and chemically modified graphene platelets are of interest for both fundamental and practical reasons. Colloids have a wide range of uses, such as in electrical energy storage, paints, inks, composites, paper materials, and so on.

Also, there are fascinating fundamental issues about how graphene-based platelets disperse in liquids. One might guess that those citing our work are also expanding the borders of knowledge on graphene-based materials, and are finding this paper relevant to their work.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

We explain how reduced graphene oxide platelets—these are atom-thick platelets with the basic "graphene" skeletal framework and some chemical groups attached to that framework—can be dispersed in water. If such platelets immediately agglomerate, clump together, etc., then certain sorts of studies, as well as final product materials, cannot be made.

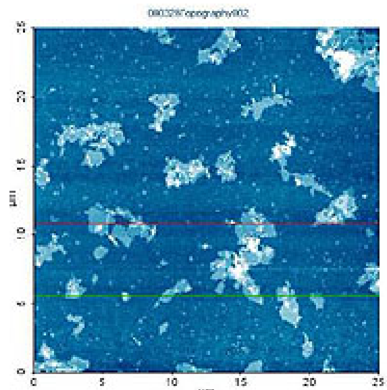
SW: Would you summarize the significance of your paper in layman's terms?

Dispersing chemically modified graphene platelets and graphene platelets in solvents is very important for many potential industrial end uses. There is also the fascinating fundamental science of how atom-thick platelets that are microns in diameter—and thus often have aspect ratios of over 1,000—behave in liquids.

SW: How did you become involved in this research, and were there any problems along the way?

Ruoff: Shortly after the reports on carbon nanotubes that appeared in the early 1990s, I began to think about graphene, a single layer of graphite, and (conceptually) a nanotube "unrolled." In 1998, I led my team to invent and use methods to pattern graphite to create "pillars" that could then be separated into very thin layers of material.

The papers we published in 1999 included one entitled "Tailoring graphite with the goal of achieving single sheets," Lu XK, *et al., Nanotechnology* 10: 269-72, 1999. But such top-down approaches will never yield the thousands of metric tons of very thin platelets needed for many exciting applications.



An atomic force microscopy (AFM) image of dried-down deposits from an aqueous suspension, deposited onto a mica substrate, showing exfoliation of individual hKMG platelets.

View/download three accompanying figures and descriptions.

PDF

Colloidal suspensions of graphene were something I became interested in, and I had the objective of exfoliating graphite itself to achieve individual layers. I hired a postdoctoral fellow, Dr. Sasha Stankovich, and we set about attempting to do that.

It turns out to be non-trivial, and is still not solved for significant scale-up, although progress on the fundamental science of exfoliation of graphite to yield "pristine" graphene is progressing.

Sasha and I, along with Professor SonBinh T. Nguyen of Northwestern University, faced with the lack of any significant success with graphite itself, turned to making and exfoliating graphite oxide, which readily disperses in water to yield individual "graphene oxide" platelets.

Einstein is quoted as having said, "I have little respect for that type of scientist who is always drilling through the thinnest piece of the wood." So—if one is doing significant work, it is going to be "hard going" most of the time.

There are always problems to overcome. We greatly value the hard work of students and postdocs who try to achieve something significant every day they go into the laboratory! There are challenges, constantly, and of course sometimes our expectations are not met simply because our hypotheses were wrong.

This is actually one of the great joys of science: to be confronted with how nature really is, versus how we guessed it might be, and to find out how nature really is through good experiments, data acquisition, and open-minded analysis.

Park: When I joined Prof. Ruoff's group and I was co-advised by Prof. Nguyen at Northwestern University, I had a background in the area of synthetic chemistry.

Although graphene is a fantastic material, production of homogeneous colloidal suspensions of graphene platelets was a great challenge. I think that chemical modification of graphene platelets is a highly promising route for this goal, based on the variety of possible chemical interactions between chemically modified graphene platelets and solvent molecules.

When we pursued this goal, the most difficult problem was a lack of information about chemical structures of chemically modified graphenes, especially graphite oxide and thus graphene oxide, which is one precursor for making a variety of chemically modified graphenes. Helping to pioneer this new area as well as developing new methods using chemistry was of great interest.

SW: Where do you see your research leading in the future?

My team and I are engrossed in studies of graphene-based and carbon nanotube-based materials. In graphene-based materials, our thrusts are essentially twofold.

One area is in large-area synthesis and properties of pristine mono- and n-layer graphene, for both fundamental science and technology transition in transparent conductive electrodes, nanoelectronics, and other areas.

The other thrust is in colloids with chemically modified or pristine graphene platelets. These are two rather distinct thrust areas, but there is a process of learning from within each area that helps with the other.

In the more distant future, and on a personal level, I am interested in topics related to human and universal consciousness, at the intersection of reductionist science with holistic approaches, acknowledging the existence of psi phenomena, and so on. (Psi topics have been of interest to physical scientists such as Lord Kelvin, Einstein, and many others.)

The interested reader might consider books such as *Entangled Minds: Extrasensory Experiences in a Quantum Reality* and *The Conscious Universe: The Scientific Truth of Psychic Phenomena*, both by Dean Radin, Stanislav Grof's *When the Impossible Happens: Adventures in Non-Ordinary Reality*, Upton Sinclair's *Mental Radio* (the preface is written by Albert Einstein), and so on.

SW: Do you foresee any social or political implications for your research?

I expect that graphene-based materials will find use in a wide variety of applications useful to society. There are significant social implications for this material, as it will engage society in a variety of ways.

As to politics...scientists ideally should be truth seekers, although truth seems to be at odds with politics a significant fraction of the time—at least in my opinion. I believe in freedom, and of science without borders.

Graphene is a material of interest to scientists, engineers, and technologists, in all parts of this world. Perhaps its use in transparent conductive electrodes and nanoelectronics will mean even greater proliferation of the internet and thus of independent sources of information and news that are not entirely tainted by monied interests.

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KEYWORDS: EXFOLIATED GRAPHITE OXIDE; FILMS; DISPERSIONS; NANOSHEETS; REDUCTION.

Additional information:

- Luigi Colombo & Rodney S. Ruoff Discuss Graphene Films, Fast Breaking Paper comment, April 2010.

2010 : May - New Hot Papers : Rodney S. Ruoff & Sungjin Park on Chemically Modified Graphene Sheets