Small Business Evaluation and Entrepreneur's (SBEE) Program

A collaboration between the NU Nanoscale Science and Engineering Center NSEC and Kellogg Graduate School of Management

Directors: Professors Barry Merkin and Chad A. Mirkin

PROPOSAL

The purpose of the new Small Business Evaluation and Entrepreneurs (SBEE) Program is to facilitate the commercialization of new technological developments, by providing scientists with the tools to successfully launch new businesses. Through this program scientists propose ideas for starting businesses to a team of Kellogg students. Students select proposals and provide research and write business plans for presentation to investors. Your completed proposal will be forwarded for review to Kellogg students for inclusion in the SBEE Program. Please be advised that limited time and resources make acceptance of all projects submitted impossible. However, projects will be solicited throughout the year.

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Name Professor Rod Ruoff

Collaborators S. Stankovich, D. A. Dikin, G. Dommett, K. Kohlhaas, E. Zimney, E. Stach, R. Piner, S. T. Nguyen. (Karen Greig, MBA regarding business opportunity)

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Title of Project: Cost-Effective Graphene Composite Materials

Summary:

(Describe the underlying technological development that you feel has potential for commercialization, suggested length 1 page)

A general approach has been developed for the preparation of graphene-polymer composites via complete exfoliation of graphite and molecular dispersion of individual, chemically modified graphene sheets within polymer hosts.

Electrically conductive graphene-polymer nanocomposites can be prepared by solution-phasing mixing of exfoliated phenyl isocyanate-treated graphite oxide sheets with polystyrene, followed by their chemical reduction. These composites feature individual graphene sheets well dispersed throughout the polymer matrix. Similar dispersions have been achieved with other styrenic polymers such as acrylonitrile-butadiene-styrene and styrene-butadiene rubbers.

The electrical properties of the composites compare well with the best values reported in the literature for nanotube-polymer composites. Absolute conductivities of the graphene-polystyrene composites are also essentially the same as the values reported for SWNT-filled polystyrene composites. Samples made by a quasi-industrial method (hot pressing, a few samples made with injection molding).

Graphene sheets have a higher surface-to-volume ratio than SWNTs – making graphene potentially more favorable for altering all matrix properties. SWNTs are still much more expensive than graphite. The highest commodity pricing of graphite as been $0.4325/pound compared to the best price for SWNTs which is $25/gram or $11,340/pound (260kX that of graphite!)

The authors of the study expect that this method of preparation and incorporation of individual graphene sheets into polymer matrices will lead to further development of a brand new class of materials with enhanced properties and even introduce new functionalities to polymer composites. This bottom-up chemical approach of tuning the graphene sheet properties provides a path to a broad new class of graphene-based materials and their use in a variety of applications.

Potential Applications:
(Describe the potential applications for this new technology and target markets, suggested length ½ -1 page)

The technology developed by Ruoff, et al has two main advantages. The first is its ease of use for large-scale industrial applications where the conductivity of carbon fibres is insufficient, but where carbon nanotubes would be too expensive. The second is its applicability to a variety of polymers. The modification of graphite oxide by phenyl isocyanate should be considered as a proof-of-concept demonstration. The phenyl group could be replaced by other groups compatible with different polymers. This opens up a wide area of research that could lead to a large family of composites with differing properties.

Graphene composites could be very useful: for example, in the manufacture of fuselages for aircraft, which must combine low weight, high strength and electrical conductivity. This last property is necessary for protection against lightning strikes while in flight. It is unknown yet whether the conductivities of composites in polymers other than polystyrene are of the same magnitude as those of the best examples of nanotube mats (made entirely of nanotubes) they are comparable to nanotube-polymer composites. Even if conductivities are several orders of magnitude lower (speculated by N. Kotov in a companion analysis article in *Nature*, but which Ruoff, et al take issues with since it is yet to be determined) as well as lower than the conductivity of graphite itself, there are positive trade-offs for graphene-sheet composites (low cost and the plentiful supply of graphite) even more favorable relative to CNTs.

Those expressing interest, among others, in the development of this process are:
Honeywell, Tyco, Ciba Speciality Chemicals, DuPont, Ford, Boeing.

Sources:

S. Stankovich, D. A. Dikin, G. Dommett, K. Kohlhaas, E. Zimney, E. Stach, R. Piner, S. T. Nguyen, & R. S. Ruoff. *Nature* Magazine: “Graphene-based composite materials”, July, 2006

Nicolas A. Kotov, Dept. of Chemical Engineering, University of Michigan. *Nature* Magazine: “Carbon Sheet Solutions”, July, 2006