FAST MOVING FRONTS - 2008

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Sankar Das Sarma talks with *ScienceWatch.com* and answers a few questions about this month's Fast Moving Front in the field of Physics.

Article: Dielectric function, screening, and plasmons in two-dimensional graphene
Authors: Hwang, EH;Das Sarma, S
Journal: PHYS REV B, 75 (20): art. no.-205418 MAY 2007
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SW: Why do you think your paper is highly cited?

This paper is highly cited because it solves the outstanding quantum mechanical problem of theoretically and quantitatively understanding the dielectric screening properties of graphene. Graphene has two-dimensional electrons and holes. These electrons and holes respond to an external electric field by screening the external field, i.e., modifying or changing the external field in a complex manner.

It is extremely important to know how this screening behavior manifests itself in the actual two-dimensional graphene system since all graphene properties will, in the end, depend on how these two-dimensional carriers respond to external perturbations. Our work solves this important problem.

Since this screening behavior manifests itself in many graphene properties, other researchers need to use our theoretical results in their work, leading to a high rate of citations for this paper.

"...our screening paper which we are discussing right now will continue to be cited in the literature for a while since the prospective use of graphene in

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

It describes a new theoretical discovery, i.e., the screening properties of graphene were simply unknown before our work, and became quite well-known afterwards.

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

I touch upon this issue in my response to the first question. But let me elaborate. An important reason for the high level of interest in two-dimensional (2D) graphene is the possibility of its eventual use in micro- or nano-electronic applications such as

transistors or other electronic components.

microelectronics remains an active area of research all around the world."

Our work in this paper and the closely related work, (EH Hwang, S Adam, and S Das Sarma, "Carrier Transport in Two-Dimensional Graphene Layers," *Phys. Rev. Lett.* 98[18]: 186806, 2007), establish theoretically how the movement of electrons carrying electrical current in 2D graphene will be affected by unintentional charged impurities and defects invariably present in the graphene environment—these impurities cause electrical circuits to have finite resistivity. Since the response of the electrons in 2D graphene to the impurities and defects must include the effect of screening, i.e., how the graphene electrons themselves respond to external electric fields, our paper on screening takes on a special significance.

In summary, our paper is significant (and highly cited) because it enables researchers to estimate the electrical resistance of a graphene-based electronic device. Our work has been fully verified by subsequent experiments carried out all around the world, and therefore, future graphene-based electronic devices will use our theory in figuring out the device's performance.

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

I became involved in this work because the United States Office of Naval Research (USONR) approached me, asking if I would be interested in looking into the prospects for 2D graphene-based electronic applications. Since I have extensive experience and background in theoretical research on semiconductor-based 2D transistors (e.g., Si MOSFETs and GaAs HEMTs and HIGFETs), it was quite natural for me and my long-term collaborator Dr. Euyheon Hwang (who did his Ph.D. under my supervision 10 years ago and has continued a very fruitful research collaboration with me for the last 15 years) to become involved in this graphene research.

The surprising thing is that we had very great difficulties publishing this highly cited paper. It took eight months for the paper to be published—submission in October of 2006 and publication in May of 2007—and in fact, the first journal (which shall remain un-named) that we submitted our paper to decided not to publish it! This is perhaps not as strange as it sounds. First, the field of 2D graphene is highly competitive, and second, original theoretical discoveries are often not appreciated when they are put forward for the first time.

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

I continue to remain very active in the 2D graphene field, and have several other highly cited publications. I believe that our screening paper which we are discussing right now will continue to be cited in the literature for a while since the prospective use of graphene in microelectronics remains an active area of research all around the world. I believe that our screening work will remain an important theoretical ingredient in graphene research for the reasons I've discussed above.

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

Our work is mathematical and theoretical physics research. It can at best have some technological implications, and I believe that it does. Physics research typically does not have any direct social or political significance.

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Keywords: dielectric screening, graphene properties, electrons in two-dimensional graphene, micro- or nano-electronic applications, graphene-based electronic device, graphene environment, 2D graphene-based electronic applications, semiconductor-based 2D transistors.

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back to top

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