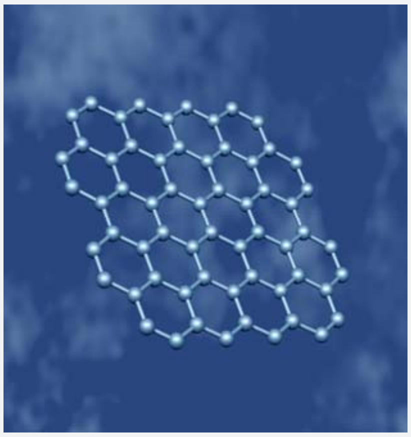
Graphene Research at the University of Maryland



The pencil hasn't been innovative technology since the 19th century. But graphene, the one-atom thick sheet of carbon that, when stacked, forms graphite, the "lead" in pencils, may be the key to future electronic applications. Research results from Maryland's Center for Nanophysics and Advanced Materials (CNAM) show that graphene's unusual electronic spectrum makes the material poised to replace and surpass silicon, which is reaching its limitations in terms of making chips smaller and faster. For years, physicists were unable to isolate graphene, but the recently discovered ability to "exfoliate" graphene from graphite using sticky tape has opened the door to exciting new applications.

Graphene's two-dimensional chicken-wire structure, low resistivity and extreme thinness make it promising in applications that require thin, tough, electrically conducting films such as touch screens and photovoltaic cells. But the simplicity of its structure also poses unique challenges for physicists and materials scientists looking for applications. The semiconductors in modern electronic circuits—those found in computers and cell phones, for instance—demand stability. So research at CNAM focuses on understanding the limits of graphene's conductivity, what causes the scattering of its electrons, and how to make graphene more stable and reliable.
Research on graphene at the University of Maryland is an interdisciplinary effort, involving investigative teams in nanotechnology, materials science and condensed matter physics. While research in nanotechnology focuses on graphene's electronic properties, research in material science investigates the control of the material fabrication of graphene, and research in condensed matter physics examines the behavior of electrons in graphene for its potential use as a semiconductor.

Michael Fuhrer leads the team that investigates the possibilities of graphene for electronic application, particularly exploring the potential of graphene's high level of mobility and the promise that suggests for the material's use in electrically conducting, transparent film.

Ellen Williams leads a team in research on surface science. Current experimentation focuses on determining the effects of the impurities in graphene, leading to an understanding of the material's potential in a cleaner state.

Shankar Das Sarma leads a team of post-doctoral researchers interested in understanding the theory behind the material science of graphene and the research currently being done on its applications.

Center for Nanophysics and Applied Materials — **http://www.cnam.umd.edu/**
Joint Quantum Institute — **http://www.jqi.umd.edu/**

Michael Fuhrer, Center for Nanophysics and Advanced Materials

According to Michael Fuhrer, principal investigator of the University of Maryland's CNAM and the Maryland NanoCenter, the electrical current in graphene is carried by only a few electrons moving much faster than the electrons in a metal such as silver, the material with the lowest known resistivity at room temperature. Current research in his group focuses on getting cleaner samples of graphene, with the expectation that, once the dirt is removed, graphene at room temperature should have about 35% less resistivity than silver. Low resistivity is important because it determines mobility rates, or the speed at which electronic devices can turn on and off. Fuhrer's team has demonstrated that graphene has an extremely high potential mobility rate, many times higher than silicon or any other conventional semiconductor. Because of graphene's extreme thinness, however, it must sit on a substrate, and that coupling reduces graphene's mobility. Ongoing research by the team seeks to find better substrates for graphene, which will be key to applications of inexpensive, plentiful graphene.

Michael Fuhrer **mfuhrer@physics.umd.edu** **http://www.physics.umd.edu/mfuhrer/**
Maryland Nanocenter **http://www.nanocenter.umd.edu/**

Ellen Williams, Surface Physics Group

Over the course of her career, Distinguished University Professor Ellen D. Williams (elected to the National Academy of Sciences in 2005) has investigated the atomic-scale interactions on the surfaces of materials. Practical applications in the field of nanotechnology, and currently on graphene, are a focus of her research group in experimental surface science. Their experiments to understand the atomic structure of graphene-based electronic devices (for example, graphene sheets supported by a silicon substrate) have been enabled by the novel cleaning process the team devised to produce atomically clean graphene sheets. In conjunction with the work by the Fuhrer group, work in the Williams group to find a suitable substrate for graphene will allow manufacturing of semiconductor devices at low cost.

Ellen Williams **edw@physics.umd.edu**
Surface Physics/The Williams Lab **http://www.physics.umd.edu/spg/**

Shankar Das Sarma, Condensed Matter Theory Center

Shankar Das Sarma's work on the research council of the Joint Quantum Institute emphasizes research in condensed matter physics, the physics that produced the transistor and superconducting materials. Sarma, a Distinguished University Professor, received the 2008 Kirwan Faculty Research Prize in recognition of his internationally groundbreaking work in quantum computing. Sarma leads a team of postdoctoral students collaborating to understand the theory behind the experiments being done on graphene. Their research examines the physics of graphene's "exotic" superconductivity, investigating why and how graphene may effectively operate as a switching device. Their research demonstrates that graphene's mobility may be improved by eliminating charged impurities or by applying it to a different substrate. Such findings substantiate graphene's potential as a superconductor.

Shankar Das Sarma **dassarma@umd.edu,**
Condensed Matter Theory Center **http://www.physics.umd.edu/cmtc/**