Real-world graphene devices may have a bumpy ride

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(PhysOrg.com) -- Electronics researchers love graphene. A two-dimensional sheet of carbon one atom thick, graphene is like a superhighway for electrons, which rocket through the material with 100 times the mobility they have in silicon. But creating graphene-based devices will be challenging, say researchers at the National Institute of Standards and Technology, because new measurements show that layering graphene on a substrate transforms its bustling speedway into steep hills and valleys that make it harder for electrons to get around.

In a new article in Nature Physics, NIST scientists also say that graphene may be an ideal medium for probing interactions between electric conductors and insulators using a scanning tunneling microscope (STM).

According to NIST Fellow Joseph Stroscio, graphene's ideal properties are only available when it is isolated from the environment.

"To get the most benefit from graphene, we have to understand fully how graphene's properties change when put in real-world conditions, such as part of a device where it is in contact with other kinds of materials," Stroscio says.

Typical semiconductor chips are a complicated "sandwich" of alternating conducting, semiconducting and insulating layers and structures. To perform their experiment, the NIST group made their own sandwich with a single atomic sheet of graphene and another conductor separated by an insulating layer. When the bottom conductor is charged, it induces an equal and opposite charge in the graphene.

Examined under an STM, which is sensitive to the charged state of the graphene, the high electron mobility should make the graphene look like a featureless plane. But, says NIST researcher Nikolai Zhitenev, "What we found is that variations in the electrical potential of the insulating substrate are interrupting the orbits of the electrons in the graphene, creating wells where the electrons pool and reducing their mobility."

This effect is especially pronounced when the group exposes the substrate-mounted graphene to high magnetic fields. Then the electrons, already made sluggish by the substrate interactions, lack the energy to scale the mountains of resistance and settle into isolated pockets of "quantum dots," nanometer-scale regions that confine electrical charges in all directions.

It's not all bad news. Direct access to the graphene with a scanned probe also makes it possible to investigate the physics of other substrate interactions on a nanoscopic scale, something which is less possible in conventional semiconductor devices where the important transport layers are buried below the surface.

"Usually, we cannot study insulators at atomic scale," says Stroscio. "The STM works with a closed loop system that keeps a constant tunneling current by adjusting the tip-sample distance. On an insulator there is no current available, so the system will keep pushing the tip closer to the substrate until it eventually crashes into the surface. The graphene lets us get close enough to these substrate materials to study their electrical properties, but not so close that we damage the substrate and instrument."

More information: S. Jung, G. Rutter, N. Klimov, D. Newell, I. Calizo, A. Hight-Walker, N. Zhitenev and J. Stroscio. Evolution of

microscopic localization in graphene in a magnetic field from scattering resonances to quantum dots. *Nature Physics*. Published online Jan. 9, 2010, DOI:10.1038/nphys1866

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