Scientists demonstrate potential of graphene films as next-generation transistors

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Physicists at the University of Pennsylvania have characterized an aspect of graphene film behavior by measuring the way it conducts electricity on a substrate. This milestone advances the potential application of graphene, the ultra-thin, single-atom thick carbon sheets that conduct electricity faster and more efficiently than silicon, the current material of choice for transistor fabrication.

The research team, led by A.T. Charlie Johnson, professor in the Department of Physics and Astronomy at Penn, demonstrated that the surface potential above a graphene film varies with the thickness of the film, in quantitative agreement with the predictions of a nonlinear Thomas-Fermi theory of the interlayer screening by relativistic low energy charge carriers. The study appears online in the journal *Nano Letters* and will appear in print in the August edition.

Johnson's study, "Surface Potentials and Layer Charge Distributions in Few-Layer Graphene Films," clarifies experimentally the electronic interaction between an insulating substrate and few-layer graphene films, or FLGs, the standard model for next-generation transistors.

It is more practical to develop devices from FLGs, rather than single-layer materials. To make use of these films, graphene must be placed on a substrate to be functionalized as a transistor. Placing the film on a substrate causes an electronic interaction between the two materials that transfers carriers to or from, or "dopes," the FLG.

The focus of the Penn study was aimed at understanding how these doped charges distribute themselves among the different layers of graphene. The distribution of these charges determines the behavior of graphene transistors and other circuits, making it a critical component for device engineering. The team measured the surface potential of the material to determine how these doped charges were distributed along the transistor, as well as how the surface potential of the transistor varied with the number of layers of graphene employed.

Using electrostatic force microscopy measurements, the team characterized the surface potential of the graphene film and found it to be dependent on the thickness of the graphene layers. The thicker the carbon strips, the higher the electronic surface potential, with the surface potential approaching its limit for films that were five or more sheets thick. This behavior is unlike that found for conventional metals or semiconductors which would have, respectively, much shorter or longer screening lengths.

The surface potential measurements were in agreement with a theory developed by Penn professor and physicist Eugene Mele. The theory makes an important approximation, by treating electrostatic interactions in the film but neglecting quantum mechanical tunneling between neighboring layers. This allows the model to be solved analytically for the charge distribution and surface potential.

While prior theoretical work considered the effect of a substrate on the electronic structure of FLG, few experiments have directly probed the graphene-substrate interaction. Quantitative understanding of charge exchange at the interface and the spatial distribution of the resulting charge carriers is a critical input to device design.

Graphene-derived nanomaterials are a promising family of structures for application as atomically thin transistors, sensors and other

nanoelectronic devices. These honeycomb sheets of sp2 -bonded carbon atoms and graphene sheets rolled into molecular cylinders share a set of electronic properties making them ideal for use in nanoelectronics: tunable carrier type and density, exceptionally high carrier mobility and structural control of their electronic band structures. A significant advantage of graphene is its two-dimensionality, making it compatible with existing planar device architectures. The challenge is realizing the potential of these materials by fabricating and insulating them on substrates.

Source: University of Pennsylvania