Graphene-Based Transmission Lines for Electrical Power Distribution

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The DoE Office of Electricity Delivery and Energy Reliability has identified Advanced Components & Operating Concepts for *interconnection* as one of four key technologies to be sought under the Smart Grid Activity [1]. Interconnection in this context describes the physical wires, insulators and towers used in transferring electrical power. Component and concept are intimately related, as the components must be able to withstand or efficiently transmit high power (low loss, safely and without breakdown) at a competitive monetary cost.

Some present limitations include sag (unsafe) in copper and aluminum transmission lines when the current is too high (Joule heating), high cost of liquid nitrogen for dewar jacketed high-temperature superconductors and high cost of insulators for ultrahigh voltage transmission. Identified and field-tested solutions to conventional Cu and Al transmission lines include Al composites that can double the current carrying capacity without sag [2]. However, this is only an incremental improvement over the previous technology. The intention of this white paper is to seek basic funding for a next-generation idea that could revolutionize both voltage and current limitations to transmission lines for more efficient and greater power distribution in the US.

Graphene, or a single layer of graphite, has been shown to transmit carriers relativistically [3] under an externally applied voltage. The transmission of massless fermions in graphene, rather than electrons with a finite mass as in conventional solids such as Cu, would open a new direction for electrical power transmission due to low phonon interaction and inelastic loss. Unfortunately, it is not practical to fabricate single-layer graphene such that it may be stretched over a roadway, let alone many hundreds of miles between substations. However, few layer graphene, before it starts to show properties of becoming graphite, still exhibits a relativisitic transport character and can be made by the ton into graphite nanoplatelets at ~ 4 graphene layers thick, with ~ 1 um diameter [4]. The nanoplatelets could then, with sufficient engineering, be made into a polycrystalline or composite wire. However, before the application reaches this phase, many basic properties of the electronic structure of the graphite nanoplatelets system need to be studied, including: (1) the voltage- and frequency-dependent transmission efficiency; (2) the relationship between resistivity and the electronic density-of-states; (3) losses due to scattering at crystal boundaries; and (4) the total thickness and area dependence of 1–3.

The investigators possess the equipment and hold the expertise in electron spectroscopies (angle-resolved photoemission spectroscopy) and microscopies (scanning tunneling microscopy) to analyze and evaluate the density of states, fabricate and deposit hundreds of milligrams to gram scale quantities of material, and determine the carrier transport character through both spectroscopic and hardwire magnetic measurements (Hall and photo absorption) of graphite nanoplatelets thin films and bulk wires.

More information is immediately available on request through the contacts above.

[1] http://www.oe.energy.gov/smartgrid_02.htm
[2] http://www.netl.doe.gov/moderngrid/docs/Advanced%20Components_Final_v2_0.pdf
[3] K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva, A. A. Firsov, *Science* **306** (2004) 666
[4] Aiping Yu, Palanisamy Ramesh, Mikhail E. Itkis, Elena Bekyarova and Robert C. Haddon, *J. Phys. Chem. C Lett.*, **111** (2007) 7565