Epitaxial graphene grown on silicon carbide for fundamental physics and nanoelectronics.

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The invention of graphene based electronics at Georgia Tech (patented in 2003 [1]) was based on carbon nanotube properties of ballistic and coherent transport as well as several other outstanding features of carbon nanotubes, including the possibility of tuning the bandgap in graphene ribbons using the ribbon width. Silicon carbide, with its natural property to produce epitaxial graphene layers after heating in vacuum was considered to be the most promising platform for graphene based electronics.

Considerable advances have since been made in realizing graphene electronics however it is clear that the field is still in its infancy. Graphene devices are not yet competitive with those produced from standard electronic materials. Nevertheless, currently, epitaxial graphene on silicon carbide is still considered to be the most viable platform for high performance graphene based electronics. (In contrast, mechanically transferred CVD graphene is showing potential for low end electronics applications; exfoliated graphene is not scaleable and backgating is not useful for electronics.) There have been demonstrations of extremely high frequency transistors and the possibility of using epitaxial graphene Hall bars as resistance standards. But there remain serious questions whether graphene based nanoelectronics can be realized. The moblities of narrow ribbons produced by standard lithography methods generally show strong localization effects and the apparent band gaps are most likely mobility gaps. Many of these problems can be traced back to edge scattering effects that ultimately result from rough and chemically poorly defined edges.

Recent work at Georgia Tech has demonstrated that many of these problems can be overcome by “growing” graphene on the edges of structures that are directly etched onto the silicon carbide in order to produce interconnected narrow graphene ribbons. These graphene ribbons are demonstrating many of the advantageous properties of carbon nanotubes. Gated ribbons show evidence of single channel ballistic transport, also observed in carbon nanotubes, and PN junctions show evidence of “Klein tunneling” effects. On the other hand, the ribbons produced by this method apparently do not have band gaps. Nevertheless, it is clear that “sidewall” graphene electronics is opening new directions in graphene based electronics, that resembles nanotube based electronics. But this does imply a departure from the standard field effect transistor paradigm of electronics.

This talk will present an overview of these developments as well as providing a survey of the vast fundamental physics that has been accomplished with graphene that it epitaxially grown on silicon carbide.

[1] W.A. de Heer, C. Berger, P.N. First, US Patent No 7015142 (filed 2003, issued 2006)