Lecture #2: Electric transport in graphene

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Outline
I) Introduction: length scales
II) Diffusive and incoherent transport
III) Ballistic and coherent transport
IV) Conclusion: experiments

A beehive in my garden (Paris)

Cargèse, October 2008
Preamble

Geim et al., Nature 2005; aussi Kim et al.
II) Diffusive and incoherent transport

FIG. 3. Varying dielectric screening in situ. Mobility as a function of $T$ for two graphene devices in ethanol (symbols). Dielectric constant $\kappa$ of ethanol increases from $\approx 25$ to $55$ with decreasing $T$. The solid curve is the $T$ dependence expected in the case of dominant Coulomb scatterers; the calculations are done using to Eq. (1). The presented measurements were done at $n = 3 \times 10^{12}$ cm$^{-2}$ but are characteristic for other concentrations too.

Geim et al., arXiv:0809.1162
III) Ballistic and coherent transport

De Picciotto et al., Nature 2001
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Tworzydlo et al., PRL 2006
III) Ballistic and coherent transport

Tworzydlo et al., PRL 2006
IV) Experiments: diffusive and incoherent

Geim et al., Nature 2005; aussi Kim et al.
IV) Experiments: diffusive and incoherent

Savchenko et al., PRL 2008
IV) Experiments: diffusive and incoherent

FIG. 4: The minimum conductivity and limiting mobility values at metallic regime for all 19 samples measured at 1.6 K. Filled symbols indicate two devices, K145 and K146 made out of the same graphene flake as shown in the optical microscope image in the inset.

Kim et al., PRL 2007
IV) Experiments: ballistic and coherent

Kim et al., arXiv:0805.1830
IV) Experiments: ballistic and coherent

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Miao et al., Science 2007
IV) Experiments: ballistic and coherent

Morpurgo et al., Nature 2007
Room Temperature Limits:

Currently:
\[ \mu_{RT} \sim 10^4 \text{ cm}^2/\text{Vs} \]
(charged impurities)

Substrate-limited:
SiO\textsubscript{2} surface phonons:
\[ \mu_{RT} \sim 4 \times 10^4 \text{ cm}^2/\text{Vs} \]

Intrinsic:
acoustic phonons:
\[ \mu_{RT} \sim 2 \times 10^5 \text{ cm}^2/\text{Vs} \]
@ \( n = 10^{12} \text{ cm}^{-2} \)

Room temperature mobility of **200,000 cm\textsuperscript{2}/Vs** possible!

Ballistic transport over >2 microns