Strong Fermi level pinning in graphene in extraordinary magnetoresistance devices with high magnetic field sensitivity and how it changes magnetoresistance

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While extraordinary magnetoresistance (EMR) has drawn a lot of attention to applications such as hard drive read heads and magnetic sensors, EMR devices based on graphene encapsulated in hexagonal boron nitride demonstrate many interesting physics phenomena. At first, encapsulated graphene EMR devices show an extremely large magnetoresistance, $MR=(R(B)-R_0)/R_0 \sim 10^7\%$ [1], and a very high room-temperature sensitivity dR/dB 104 kΩ/T [2]. Both are the highest records for EMR devices to date and exceed the previous records by multiple times [1, 3, 4]. Secondly, we report a strong asymmetry in the zero-field resistance as a function of gate voltage due to Fermi level pinning (FLP) and the resultant band re-alignment and pn-junctions at the graphene-metal shunt interface [1]. The large density of states in the metal pins the Fermi level in graphene, so it is highly doped and conductive near the metal. The asymmetry is stronger in 1D edge-contacted graphene than 2D surface-contacted graphene because the former has a better overlap of the metal and carbon orbitals, while in the latter case the metal atoms do not form covalent bonds with graphene p orbitals [5]. While metal-induced FLP is not reported in graphene Hall device, in EMR geometry the current performs circular motions around graphene channels and could experience FLP. Many resistance traces in response to magnetic field show additional features and each seem to be a combination of two different traces. We also ascribe to FLP that changes the conductivity of graphene near the metal shunt [1,6–8]. Here we use finite element simulation in COMSOL to show how metal contact-induced FLP influences graphene properties and magnetoresistance.

References

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Figures

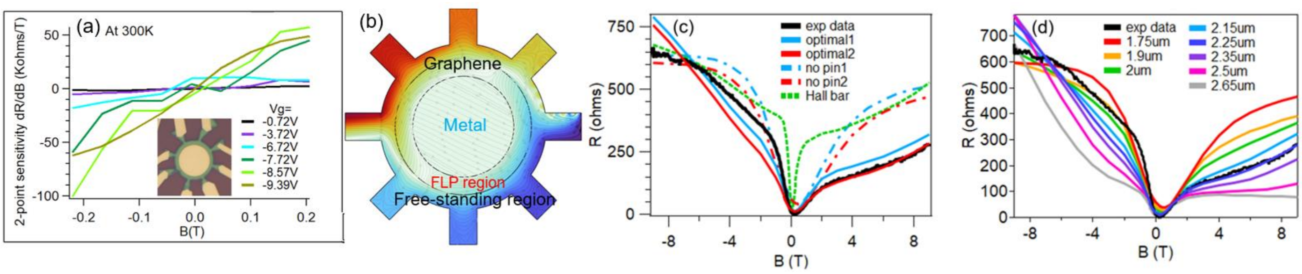

Figure 1: (a) Room-temperature sensitivity dR/dB reached in encapsulated graphene EMR devices. (b) Geometry of EMR device with metal shunt, FLP region and free-standing region of graphene. (c) Experiment (black solid line) and simulations of resistance as a function of B. Blue and red solid lines are from two sets of optimal values. (d) Simulations of resistance as a function of B with varying radius of FLP region.