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Magnetoresistance of high mobility graphene in parallel magnetic fields

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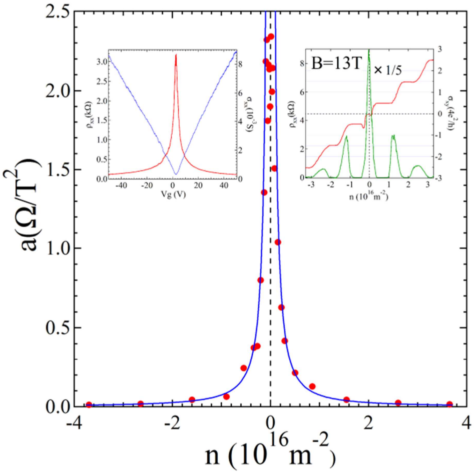
It is well known that there are ripples in graphene suspended in space or placed on a substrate. Due to the presence of ripples, a magnetic field applied parallel to the two dimensional plane of graphene creates locally the magnetic field component normal to the surface of ripples according to the gradient of the local surface against the magnetic field. Because ripples vary in size and in curvature from place to place, a random magnetic field with zero mean is produced and, hence, a system of Dirac fermions in random magnetic fields is formed. Investigations of electrical transport properties of Dirac fermions in random magnetic fields coupling with ripples are interesting.

Recently, the magnetoresistance of graphene in parallel magnetic fields has been investigated.[1, 2, 3] However, the samples used have low mobility approximately $2.0\text{x}10^3$ cm^2/Vs to $3.5\text{x}10^3$ cm^2/Vs and it was not clear whether the transport properties observed is intrinsic to Dirac fermions or not. In the present paper we report the experimental results obtained using graphene with high mobility about $2\text{x}10^4$ cm^2/Vs exfoliated onto a Si/SiO_2 substrate at a temperature of 1.9 K. The upper left inset of the figure shows the gate voltage dependence of resistivity ρ_{xx} and $\sigma_{xx} = \rho_{xx}^{-1}$ in zero magnetic field and the upper right inset shows QHE results at B = 13 T. These results confirm the present graphene has high quality enough to investigate the intrinsic properties of Dirac fermions in random magnetic fields.

We have measured magnetoresistance applying the parallel magnetic field $B_{//}$ between -15 T and +15 T along the source-drain direction at several gate voltages. The negative magnetoresistance due to the weak localization and the normal component of the random magnetic field was small in contrast to the previous experiments. [1, 2] The magnetoresistance $\Delta\rho = \rho(B_{//}) - \rho(0)$ was approximately parabolic against $B_{//}$ and we have determined the coefficient a by fitting the equation $\Delta\rho = aB_{//}^2 + b$ to the data. The main panel of the figure shows the carrier density dependence of the coefficient a. The blue lines represent $|n|^{-3/2}$ dependence predicted by the semiclassical calculation. [1] The experimental results in the carrier density $|n|>1\text{x}10^{11}$ cm^{-2} have shown good agreement with the result of semiclassical calculation. However, the coefficient a shows saturation in the range of $|n|<1\text{x}10^{11}$ cm^{-2}. We discuss these results combining with the results of AFM measurements of the ripples.



References:

[1] M. B. Lundeberg and J. A. Folk, *Phys. Rev. Lett.* **105**, 146804 (2010).

[2] J. Wakabayashi and T. Sano, *J. Phys.: Conf. Ser.* **334,** 012039 (2011).

[3] J. Wakabayashi and K. Sano, *J. Phys. Soc. Jpn.* **81,** 013702 (2012).