Quantum Hall effect in graphene: Breakdown, disorder and energy loss rates

R.J. Nicholas[1], J. Huang[1], J. A. Alexander-Webber[1], D.K. Maude[2], T. J. B. M. Janssen[3], A. Tzalenchuk[3,4], V. Antonov[4], T. Yager[5], S. Lara-Avila[5], S. Kubatkin[5] and R. Yakimova[6]

[1]*Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, U.K.*
[2]*Laboratoire National des Champs Magnetiques Intenses, Ave de Rangueil,Toulouse, France*
[3]*National Physical Laboratory, Hampton Road, Teddington TW11 0LW, United Kingdom*
[4]*Department of Physics, Royal Holloway, University of London, Egham TW20 0EX, United Kingdom*
[5]*Department of Microtechnology and Nanoscience, Chalmers University of Technology, S-412 96 Göteborg, Sweden*
[6] *Department of Physics, Chemistry and Biology (IFM), Linköping University, S-581 83 Linköping, Sweden*

The quantum Hall effect in epitaxial graphene can show remarkable behavior, with a quantum Hall plateau which extends from 1 to 20 T and even up to 50T in extreme cases (Fig. 1), [1], as well as showing remarkably high breakdown current densities of up to 40A/m[1]. We will report how the breakdown currents depend on temperature and magnetic field and show behavior suggestive of a phase transiton between the quantum Hall and dissipative states of the 2D electron gas. The behaviour becomes progressively more dramatic as the system approaches the Dirac point and we have analysed both the quantum and classical Hall effect from 1.5 up to 300K. The carrier density derived from the low-field Hall coefficients for a two-carrier system shows a quadratic increase as a function of temperature (Fig. 1c), which can be well modelled by intrinsic excitation combined with disorder-induced electron-hole puddles [2] where the potential variation is found to be about 12 meV. In the quantum Hall state we observe a resistivity which shows both variable range hopping [3] (VRH), and thermally activated conduction. By fitting the longitudinal conductivity at low temperatures we directly probe the density of states at the Fermi energy and at higher temperatures, the thermal activation regime probes the position of the Fermi energy and the overall behavior gives the total width of the Landau levels which is in remarkable agreement with the zero field result.

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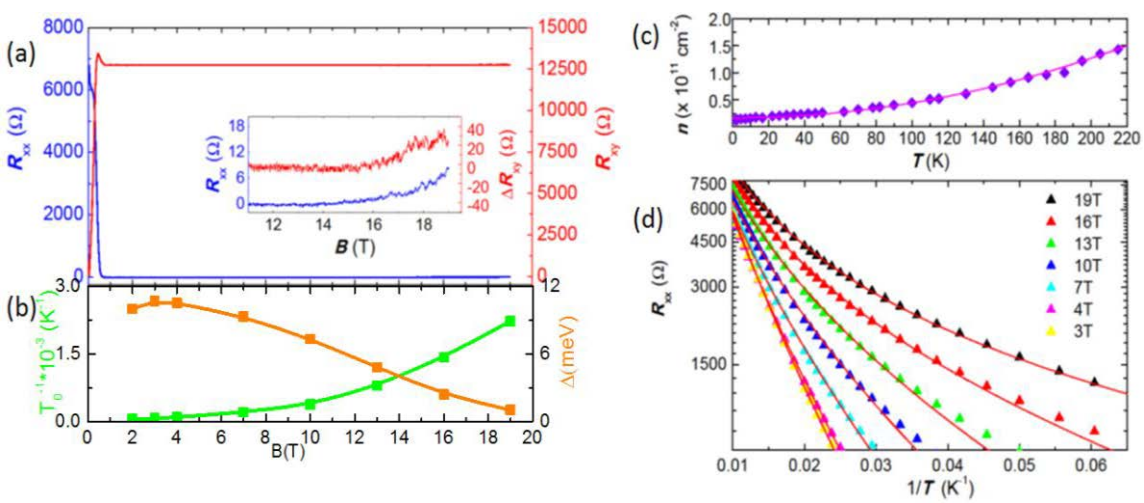

Fig. 1: (a) Quantum Hall effect and resistivity for a sample with a Fermi level close to the dirac point. (b) The hopping parameter Te and the density of states at the Fermi level as a function of magnetic field, (c) The temperature dependence of the carrier density. (d) The resistivity fitted to a combination of VRH and activated conduction.