Transport properties of disordered CVD graphene in the strong localized regime

Fabrice Iacovella[1], Pierre Trinsoutrot[2], Anatoli Mitioglu[1], Véronique Conédéra[3], Matthieu Pierre[1], Bertrand Raquet[1], Michel Goiran[1], Hugues Vergnes[2], Brigitte Caussat[2] and Walter Escoffier[1]

[1] Laboratoire National des Champs Magnétiques Intenses,
University of Toulouse, UPS, INSA, CNRS-UPR 3228,
143 av. De Rangueil, F-31400 Toulouse, France

[2] ENSIACET-INP de Toulouse, Laboratoire de Génie Chimique,
UMR CNRS 5503,
4 allée Emile Monso, F-31432 Toulouse, France

[3] Laboratoire d'Analyse et d'Architecture des Systèmes,
University of Toulouse, UPS, INSA, INP, ISAE, UT1, UTM,
7 avenue du colonel Roche, F-31077 Toulouse Cedex 4, France

fabrice.iacovella@lncmi.cnrs.fr

The Chemical Vapor Deposition (CVD) of graphene is nowadays one of the most promising methods for the production of large scale graphene films [1]. The growth is first initiated onto transition metal substrates (Cu, Pt.) before being transferred onto an insulating wafer. High quality and homogeneous graphene films can be obtained this way, displaying amazing electronic properties such as the anomalous Quantum Hall Effect at low temperature and high magnetic field [2]. On the other hand, achieving high quality graphene films requires states-of-the art techniques and when the ideal set of parameters is not fulfilled, one may end up with a variety of disordered graphene devices with interesting electronic properties. We investigated the extreme limit of a highly disrupted multi-layer graphene film showing high electrical resistance. We demonstrate that electronic conduction occurs through hopping between localized sites, provided the drain-source voltage remains higher than a temperature-dependent threshold value. An exhaustive data analysis concludes that the sample can be assimilated as an array of very tiny graphene dots (~6nm in diameter) weakly interacting each other. The presence of such few-layer graphene islands is confirmed thanks to Raman spectroscopy [3]. In the strongly localized regime, the magneto-conductance (MC) happened to be unusual, being first positive up to 6T and then negative by about 50% up to the maximum experimental magnetic field (55T) (cf fig. 1). While the positive MC is nicely explained through magnetic field delocalization induced processes [4], the negative MC, on the other hand, remains unsettled. The reentrance of the Quantum Hall Effect, at high field and low carrier density, constitutes a stimulating hypothesis. This assumption is further reinforced through investigations of another similar sample with intermediate disorder, where the Hall mobility reads 1000 cm²/(V.s). At low carrier density and very high magnetic field, the MC is strongly negative because of the onset of the n=0 Landau level degeneracy lifting. The galvanometric properties display reproducible oscillations of the magneto-resistance which shifts towards higher/lower magnetic field when the carrier density is changed. These are interpreted as Shubnikov-de Haas oscillations which herald the establishment of the QHE (cf fig. 2). It is worth noticing, though, that precise quantized values of the Hall resistance are not achieved even at the highest magnetic field. Actually, such an observation is puzzling since it challenges the robustness of the quantum state for filling factor v=2 in low mobility graphene samples decorated with multi-layer patches [5]. These antagonist results can be brought back together of one considers the presence of connected multi-layer islands, which set the electronic properties of the sample in between those of graphene and graphite.

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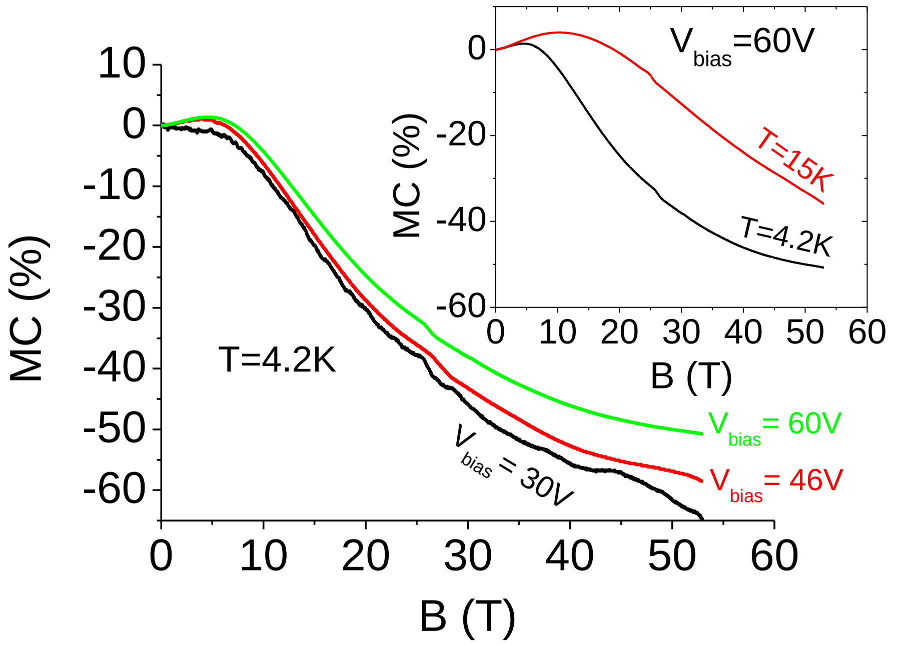

Figure 1: Magneto-conductance in ultra-disordered graphene sample for different bias voltage. The magneto-conductance is positive up to ~6T before turning negative. This effect is amplified at higher temperature (see insert) and higher bias voltage.

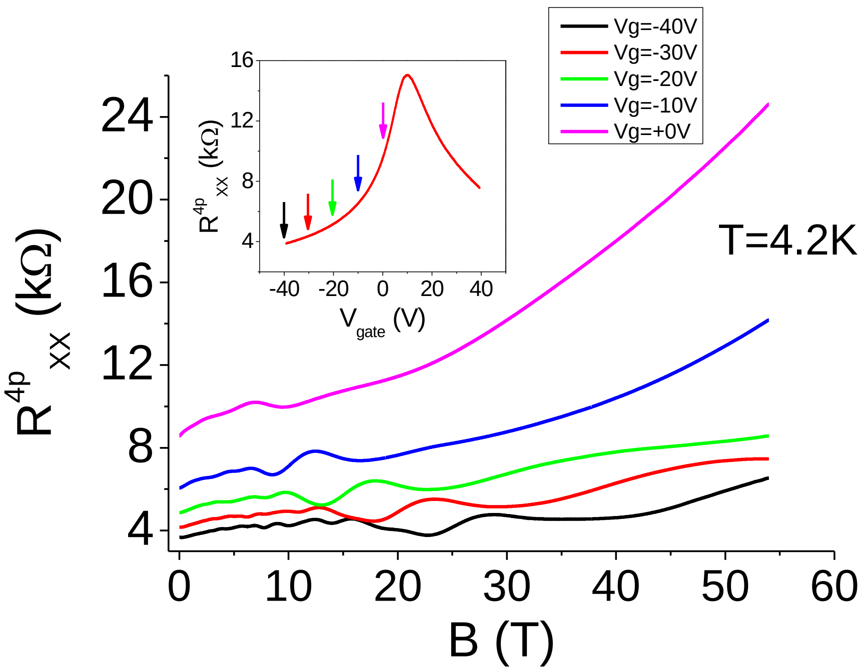

Figure 2: Longitudinal resistance in intermediate disorder few-layer graphene. Measurements are performed at 4.2K for various carrier densities (V_{gate}). Insert: resistance as a function of the back-gate voltage at zero magnetic field. The colored arrows correspond to the different back gate voltage in the main frame.