A convenient quantum Hall resistance standard in graphene devices: performance and physics

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An ongoing goal of metrologists is to exploit the robustness of the quantum Hall effect in graphene to develop quantum Hall resistance standards (QHRS) operating in more convenient experimental conditions than the usual standards made of GaAs/AlGaAs heterostructures, which require high magnetic inductions (B~10T), low temperatures (T~1.3 K) and currents (I~40 µA) to be accurate to within 10^{-9}, in relative value. Indeed, making QHRS compatible with simple cryogen-free experimental setups would improve the dissemination of an accurate realization of the ohm. Although the 10^{-9} accuracy of the quantized Hall resistance R_H on the ν=2 plateau (ν is the Landau level filling factor) was demonstrated in a few graphene devices [1], this was obtained at still high and not competitive operating magnetic fields up to now.

We will present measurements performed in Hall bar devices, made of graphene grown by chemical vapor deposition (CVD) of propane/hydrogen on SiC, that can demonstrate quantization of R_H within $1\text{x}10^{-9}$ under relaxed and extended experimental conditions. Figure 1a reports the Hall R_H and longitudinal R_{xx} resistances as a function of B measured in a graphene device with electron density of $1.8\text{x}10^{11}$ cm^{-2} and mobility of 9400 cm^{2}V^{-1}s^{-1}. It shows a R_H plateau extending from 2.5 T to 14 T, much wider that the one of a GaAs/AlGaAs reference device. By comparison with a GaAs/AlGaAs QHRS, R_H in this graphene device was found accurately quantized within $1\text{x}10^{-9}$ (or below) over a 10-T wide range of B with a remarkable lower bound at 3.5 T (fig.1b), T as high as 10 K, or I as high as 0.5 mA. The quantization accuracy was even tested within the ultimate measurement uncertainty of $8.2\text{x}10^{-11}$. The (B, T, I) parameter space ensuring a $1\text{x}10^{-9}$ quantization accuracy of R_H is found much extended in this graphene device than in the GaAs-based device. This makes this graphene QHRS versatile since it can be used in various combinations of experimental conditions [2]. This performance is explained by a strong localization of the electronic states in the bulk which maintains over a wide range of parameters, as revealed by the measurement of R_{xx} values as low as a few µΩ (fig.1c). Variable range hopping mechanism with soft Coulomb gap can explain the evolution of R_{xx} as a function of T and I, over a wide range of B, in the samples of intermediate electron density (≈ $3.2\text{x}10^{11}$ cm^{-2}) [3]. Besides, in the lowest carrier density sample, this dissipation mechanism model is questioned. All these features, as well as the coupling between R_H and R_{xx}, will be discussed considering the device structural properties.

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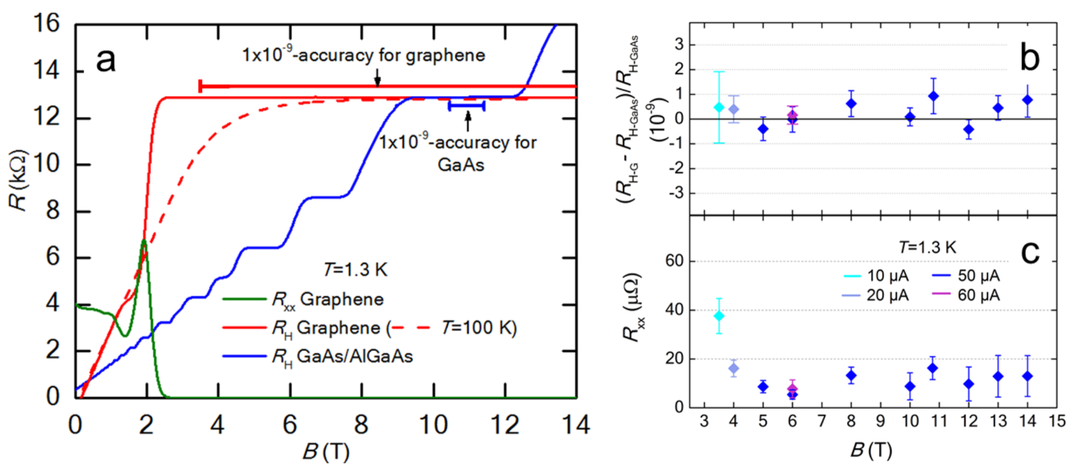

Fig.1: a) R_H and R_{xx} *versus B; b)* Relative deviation of R_H measured in graphene from R_H measured in GaAs/AlGaAs *versus B; c)* R_{xx} in graphene *versus* B, for several I values.