Graphene for quantum electrical metrology and the revised International System of units SI

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The quantum Hall effect and the Josephson effect have revolutionized the electrical measurements by providing universal and highly reproducible realizations of the units ohm and volt related to the elementary charge *e* and Planck's constant *h*, only. In 2018, these quantum electrical standards will culminate in the revision of the International System of units SI based on fixing several fundamental physical constants (Fig. a). The next challenges concern the extension of their applications, the simplification of their use for broadened dissemination towards industrial end-users and their integration in more complex systems. Graphene can play a critical role towards these objectives. At LNE, with graphene grown by CVD on SiC, we have recently demonstrated robust Hall resistance quantization with state-of-the-art accuracy ($<10^{-10}$) in relaxed experimental conditions (magnetic field down to 3.5 T (Fig. b), temperature up to 10 K or current up to 0.5 mA), much easier than those required by GaAs/AlGaAs devices [1]. These conditions are compatible with integration of the standard in a compact, simple-to-operate and lower-cost cryogen-free system. In addition, the reduction of the operation magnetic field (expected down to 1 T) renders possible the integration of the graphene-based quantum Hall resistance standard with metrology superconducting devices. This is a big advantage to miniaturize a recent experiment that we have performed at LNE. Actually, by the combination of a quantum Hall resistance standard, a Josephson voltage standard and a SQUID-based cryogenic transformer arranged in an original circuit, we have demonstrated a programmable quantum current standard related to *e* and realizing the ampere with unprecedented accuracy (10^{-8}) [2]. Beyond, we are currently assessing the integration on a graphene chip of various quantum electrical metrology devices. Based on graphene, we can now consider the perspective of a universal and highly accurate quantum electrical multimeter. Such a device will contribute to realize and disseminate the advantages of the revised SI and will considerably improve electrical measurements.

References

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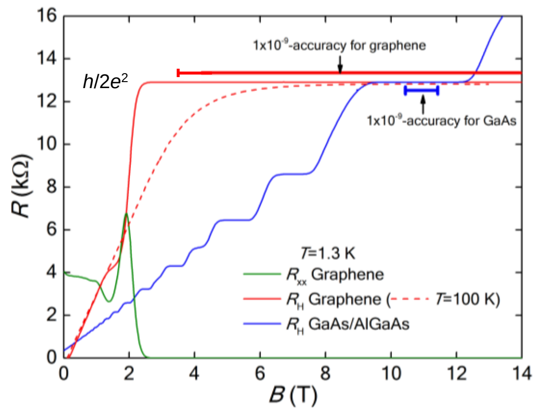
[2] J. Brun-Picard, S. Djordjevic, D. Leprat, F. Schopfer, and W. Poirier, Phys. Rev. X, 6, 041051 (2016)

Figures



b)

a)

Figures : a) The revised SI based on fundamental constants. b) Hall resistance (R_H) and longitudinal resistivity (R_{xx}) as a function of the magnetic flux density in a Hall device based on CVD graphene on SiC (GaAs/AlGaAs device for comparison)