Epitaxial graphene homogeneity and quantum Hall effect in millimeter-scale devices

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Fully quantized magnetotransport is observed in two 5.6 mm × 5.6 mm epitaxial graphene (EG) devices, grown on the Si-face of hexagonal SiC(0001) by constrained Si sublimation at 1900 °C[1]. In our sample A, the quantized Hall resistance ($R_{xy} = h/2e^2$) is maintained to five parts in 10^9 up to $I_{xx} \approx 0.72$ mA at $T = 3.1$ K and 9 T. This result exceeds the highest QHE critical currents reported in graphene (0.5 mA) or GaAs heterostructures (0.6 mA) and is ascribed to remarkable uniformity of the EG layer. In our samples, adsorbed polar molecules act as a gate, and it is possible to vary the carrier concentration through this effect[2]. AC transport measurements were made on sample B at seven levels of carrier density, as shown in Fig. 1. Despite the presence of inhomogeneous layer number in some small areas of sample B, the measured mobility is $\mu \approx$ 43 700 $cm^2V^{-1}s^{-1}$ for $n_0 \approx 0.5 \times 10^{10}$ cm^{-2}, which is the highest reported mobility for any graphene sample of millimeter-scale dimensions. For comparison, similar characteristics of μ and n have been reported in gated, high-quality EG devices of < 5 μm width[3], but in those devices the mobility was seen to decrease for values of n below ≈ 10^{11} cm^{-2}. This decrease is absent in the sample B, allowing transport with high mobility at very low carrier densities. Pristine exfoliated graphene on h-BN exhibits mobility about twice what we measure, and typically the maximum mobility occurs at low carrier density[4]. We explain the high level of transport mobility and critical current using various microscopy measurements of the graphene layer and substrate, including Raman mapping that reveals low and uniform strain over much of the surface of both devices. Our results show that disorder in EG produced by the SiC substrate does not result in reduced mobility at low carrier density if the density of scattering sources is relatively low, and that more homogeneous strain in monolayer EG may reduce the level of carrier density fluctuations.

References

[1] Y. Yang, G. Cheng, *et al.*, arXiv:1606.07720 (2016).
[2] Y. Yang, L.-I. Huang, *et al.*, Small 11, **1** (2015) 90 – 95.
[3] D. B. Farmer, V. Perebeinos *et al.*, Phys. Rev. B 84, (2011) 205417
[4] N. J. G. Couto, D. Costanzo, *et al.* Phys. Rev. X 4, (2014) 041019.

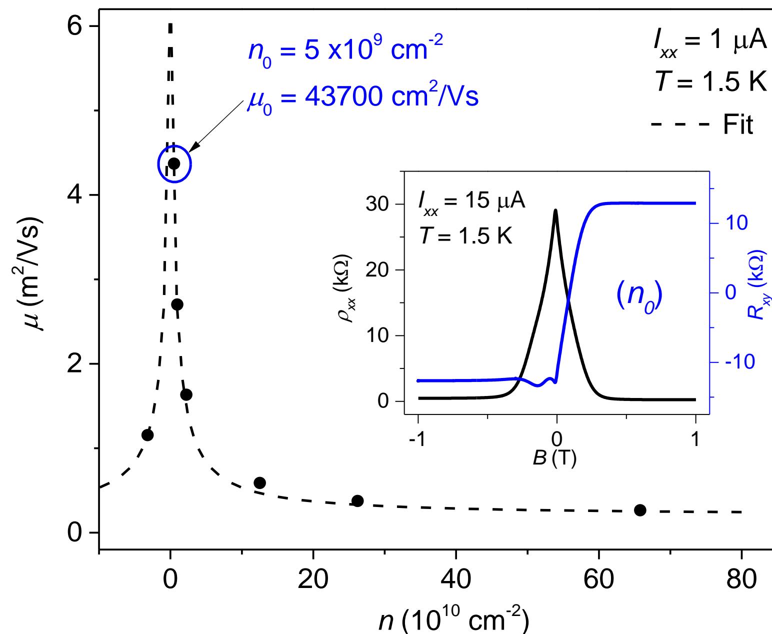

Figure 1