Fabrication, Properties, and Applications of Ultrahigh Performance Graphene

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Abstract

Two-dimensional materials such as graphene can achieve spectacular performance but are highly sensitive to disorder from the environment. We have developed techniques to controllably 'stack' graphene on insulating hexagonal boron nitride, which dramatically reduces disorder and increases electronic mobility,[1] which in turn leads to superior performance in graphene FETs and emergence of new low-T physics.[2] In addition, these heterostructures can display novel behavior due to the presence of 'superlattice' potentials arising from the graphene-BN stacking.[3] In recent work, we have extended these techniques to create fully encapsulated devices whose performance approaches the ideal behavior of graphene.[4] At room temperature, the electrical transport behavior is near the limit set by acoustic phonon scattering: mean free path is near one µm, correspoinding to mobility of 30,000-100,000 cm^2/Vs, across a wide range in carrier density. At low temperature, fully ballistic transport is seen in devices as large as 15 µm in size, and phenomena such as magnetic focusing can be observed. BN-encapsulated bilayer graphene shows a well-developed fractional quantum Hall spectrum that can be tuned by an applied displacement field. These devices show high performance in a range of practical applications such as photonic devices and sensors. These techniques can be used to create heterostructures of other 2D materials such as MoS_2 and WSe_2, which also show improved performance.

References

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Figures

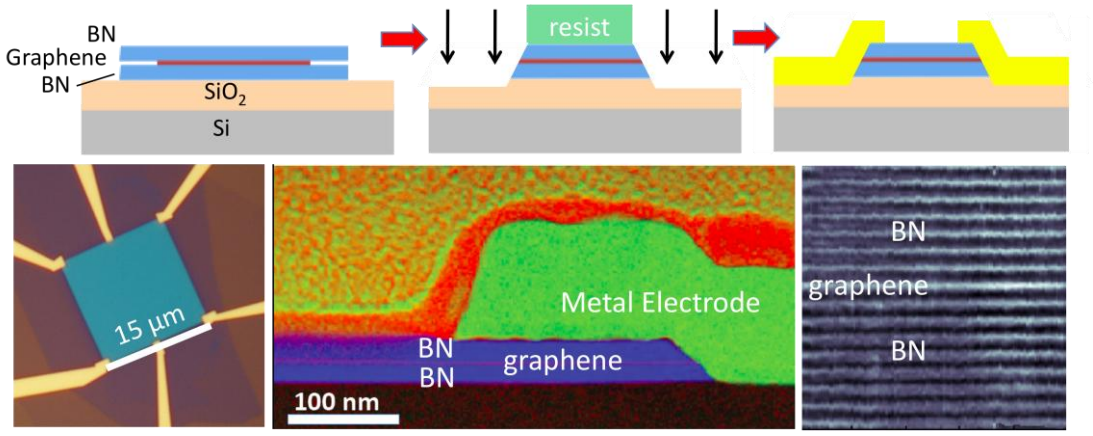

Figure 1. BN-encapsulated graphene. Top, fabrication process flow. Bottom left, optical micrograph of large device. Bottom center, TEM cross-section showing edge contact. Bottom right, HRTEM cross-section showing clean interface between atomic planes of BN and graphene.

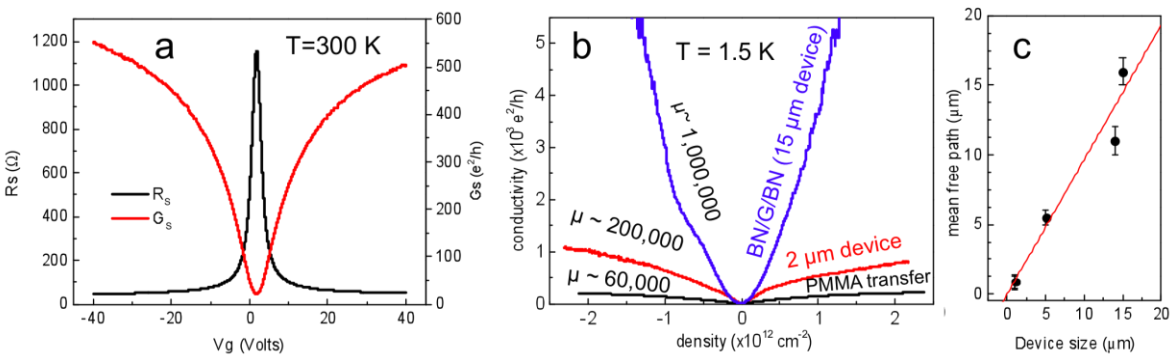

Figure 2. Transport properties of BN-encapsulated graphene. (a) Room-T resistivity and conductivity of 15-µm device. (b) Low-T conductivity vs. carrier density for 15 µm and 2 µm encapsulated devices, and device made by PMMA transfer.[1] (c) Measured low-T mean free path as a function of device size.