Platform for Quantum Strain Engineering in Graphene

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Abstract
We report our progress toward using mechanical strain to engineer the quantum transport properties of graphene. Graphene is promising for quantum strain engineering studies due to its enormous elastic mechanical deformation range, high electron mobility, and relativistic charge carriers. We are combining ultra-small and clean suspended graphene transistors [1-3] (see Fig. 1a), with a mechanical breakjunction (MCBJ) instrumentation [4] (Fig. 1b) to create a widely tunable graphene strain engineering platform.

To fabricate our suspended graphene transistors, we deposit gold bow-tie nanowires on exfoliated graphene and suspend them. Using a custom electromigration technique [1-3], we create ultra-short (~10 to 50 nm) suspended sections of graphene (Fig. 1a) which show ballistic transport and can be engineered into quantum dots [3]. The suspended gold contacts can be up to microns in length and act as long cantilever arms when straining the channel. We built a custom mechanical breakjunction (MCBJ) setup (Fig. 1b), where a precision mechanical assembly bends the silicon wafer substrate on which the transistors are fabricated. While the bending range of thin silicon is limited, given the long suspended contacts and short channel length of the devices, this instrumentation should readily allow strains up to ~ 10% [4]. The assembly is hosted in a cryostat operating down to 0.3 K and in magnetic fields up to 9 T.

Using our MCBJ assembly, we studied the tunnel current across gold junctions to quantitatively calibrate the mechanical motion of our suspended gold electrodes (Fig. 1c). Initial tests, show that we can smoothly tune the resistance of these tunnel junctions. Through the application of large uniaxial strain, we aim to create graphene strain transistors [5]. We also plan to explore graphene mechanical oscillators with tunable frequencies approaching the THz range [2] and strong electro-mechanical coupling.

References

[1] J. O. Island, V. Tayari, S. Yigen, A. C. McRae, and A. R. Champagne, *Appl. Phys. Lett.*, **99** (2011).
[2] J. O. Island, V. Tayari, A. C. McRae, and A. R. Champagne, *Nano. Lett.*, **12** 4564 (2012).
[3] V. Tayari, A. C. McRae, S. Yigen, J. O. Island, J. M. Porter, and A. R. Champagne, *Nano. Lett.,* **15** (2015).
[4] A. R. Champagne, A. N. Pasupathy, D. C. Ralph, *Nano Lett*. **5**, 305 (2005)
[5] M. Fogler, F. Guinea, and I. Katsnelson, *Phys. Rev. Lett.* **101** (2008).

Figure

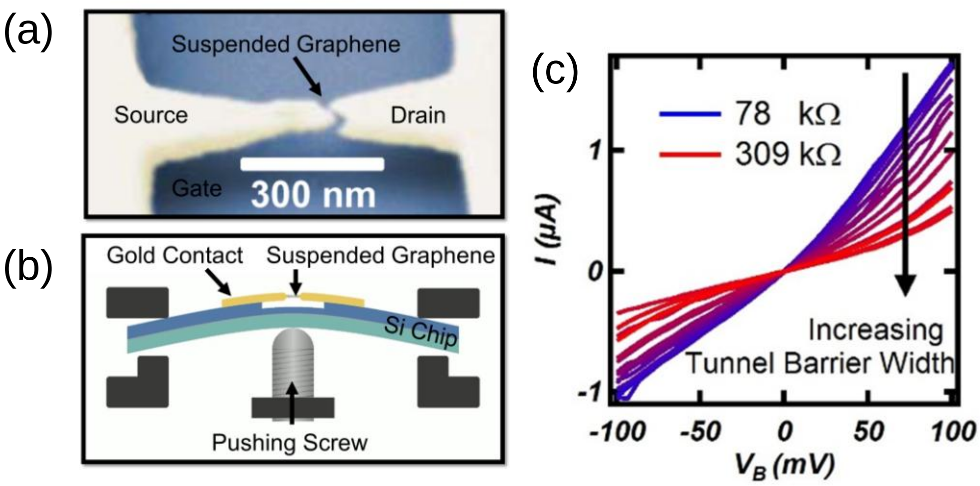

Fig 1. Quantum strain engineering with a MCBJ setup. (a) Ultra-short graphene breakjunctions with gold contacts made using electromigration. The graphene channel is ~ 10 nm long. (b) Schematic of our

MCBJ setup. A pushing screw bends the thin Si substrate, applying strain to the suspended sample. (c) Initial *I*-*V* transport data from gold tunnel junctions, measured with the MCBJ assembly.