Local Measurement of Graphene Electronics using Gate Mapping Tunneling Spectroscopy

J. Chae1,2, Y. Zhao1,2, S. Jung1,2,3, A. F. Young4, C. R. Dean5,6, L. Wang6, Y. Gao6, K. Watanabe7, T. Taniguchi7, J. Hone6, K. L. Shepard5, P. Kim4, N. B. Zhitenev1 and J. A. Stroscio1


Project Overview
Goal
- Develop new microscopic measurement methods to investigate future electronic materials in real device geometries
- Application – Future Electronic Materials/Nanofabrication
  - Determining the role of the reduced disorder potential by using h-BN spacers
  - Determining how electron interactions change carrier velocities

Graphene on h-BN
- Substrate induced scattering
- Hexagonal – Boron Nitride
- Ripples
- Charge traps
- Acoustic phonon (~59 meV)
- Atomic flatness
- Low charge traps
- High surface phonon energy (>100 meV)

Precision Transfer Schematics
- Graphene exfoliation
- Sacrificial layer removal
- Dr water
- PMMA
- Water soluble layer
- SiO2
- H-BN crystal exfoliation
- Micromanipulator under optical microscope
- Resist Removal + Ar/H2 Annealing @ 300°C

Final Device with Contacts
- After Transfer
- After Metal Contact

Topographic Image
- Comparison of Graphene on SiO2 and BN Substrates

Disorder Potential Map
- Reduced Disorder by h-BN Spacer

Gate Mapping Tunneling Spectroscopy
- Tip Alignment/Gate Map Spectroscopy
- Exchange chamber (~300 K)
- STM module
- Tip alignment at RT in UHV with X Y walker stage
- Tip offset after cooling to 4K ≤ 10μm
- B1 ≤ 10 T, B2 ≤ 1.5 T
- FIM for tip preparation

Fermi Velocity Renormalization
- Determination of Constant Density Axis
- Simulation of gate map shows that local gating by the STM tip voltage results in a tilted angle of Landau level pinning positions, affecting the true energy and density positions.
- Deviation from single particle physics is observed at low carrier density regime.

Electron-electron Driven Fermi Velocity Renormalization
- Landau Level Quantization in Graphene
- Renormalized Fermi Velocity

Conclusions
- Graphene devices on BN substrates were fabricated using precision transfer techniques.
- STM/STS measurements of graphene on BN substrates show an improvement compared to that of graphene on SiO2 substrate.
- A change in the carrier velocity due to electron interactions was determined as a function of carrier density with a preservation of the light-like linear dispersion.