Charge Fractionalization in Molecular Graphene

Franklin Liou (fliou@stanford.edu)

Manoharan Lab, Department of Physics, Stanford University

Abstract

We attempt to produce fractional charge in an arrangement of CO molecules on Cu(111). CO molecules were arranged in a Kekule texture with 3 different domains using a Scanning Tunneling Microscope. Scattering simulation and Tight Binding simulation both show a state at Fermi energy localized near the vortex center, which suggests fractional charge. Experimental results also show an increased Local Density of States near the vortex center at this energy, indicating possible observation of fractional charge.

Introduction

Zero energy electron excitations which possess fractional quantum numbers are predicted to appear near vortex centers and outer edge of a Kekule textured graphene lattice with 3 domains [1]. The Kekule distortion opens a gap between positive energy states and negative energy states. Due to this fact, increased local Density of States near the vortex at mid-gap energy is the signature of fractional charge in graphene.

Fractional Charge in Polyacetylene

The existence of a "kink" in the alternating bond strengths can be thought of as two solitons carrying fractional quantum numbers. These solitons can be separated at an arbitrary distance, creating fractional charge.

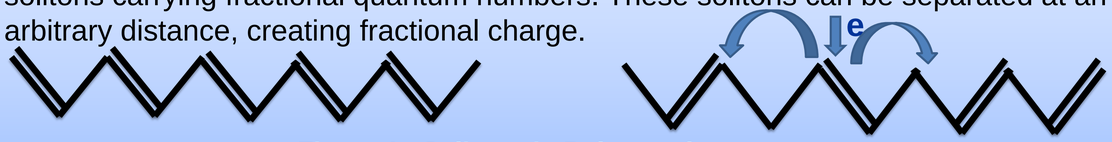

Figure 1. Solitons in Polyacetylene

Creating the Lattice

We designed a lattice using 3 honeycomb units with different arrangements of CO molecules. The distance between the nearest atoms in different honeycombs simulate chemical bonds of different strengths. The 3 honeycombs in the unit cell were then rotated to generate 3 domains.

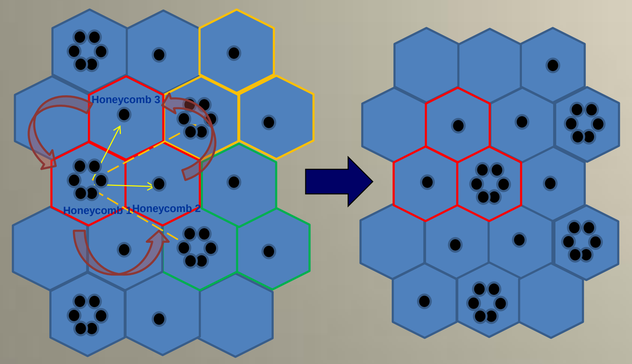

Figure 2. Lattice Design
We build Kekule distorted graphene, in which we rotate unit cells to obtain 3 different lattice domains.

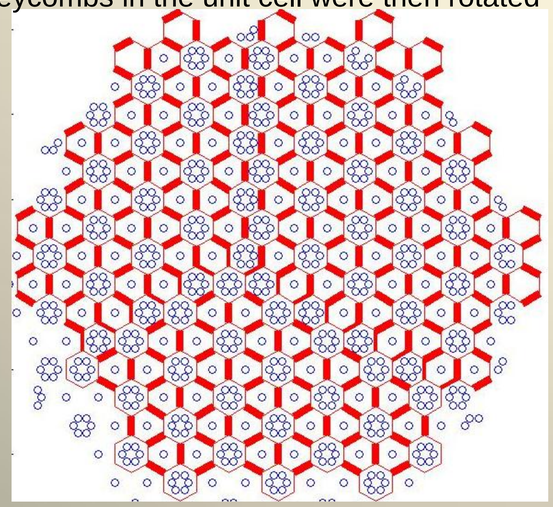

Figure 3. Bonds in the Molecular Graphene lattice we built

Simulations

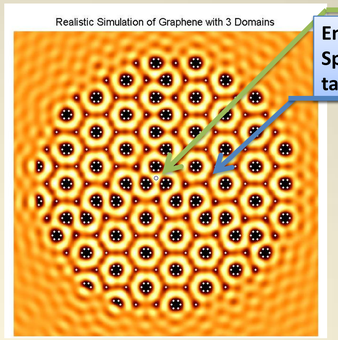

Figure 4. Scattering Simulation at Fermi Energy

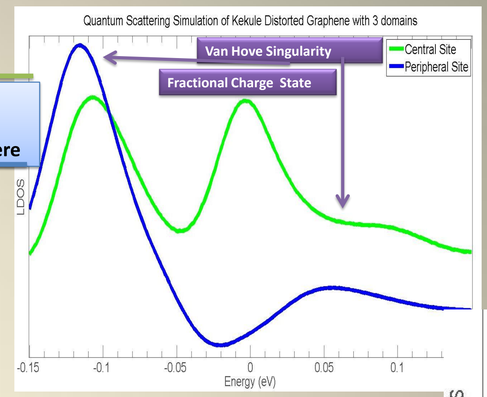

Figure 5. Energy Spectrum from Scattering Simulation

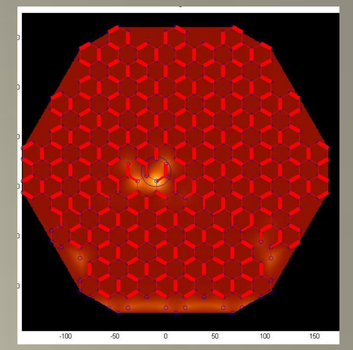

Figure 5. Tight Binding Simulation at Fermi Energy

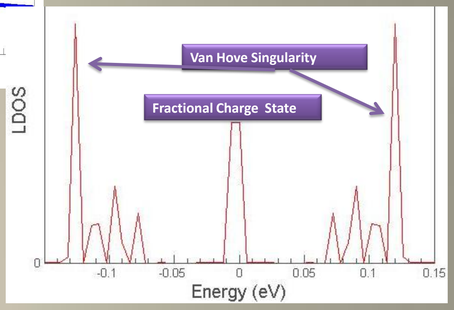

Figure 6. Energy Spectrum from Tight Binding Simulation

Experimental Results

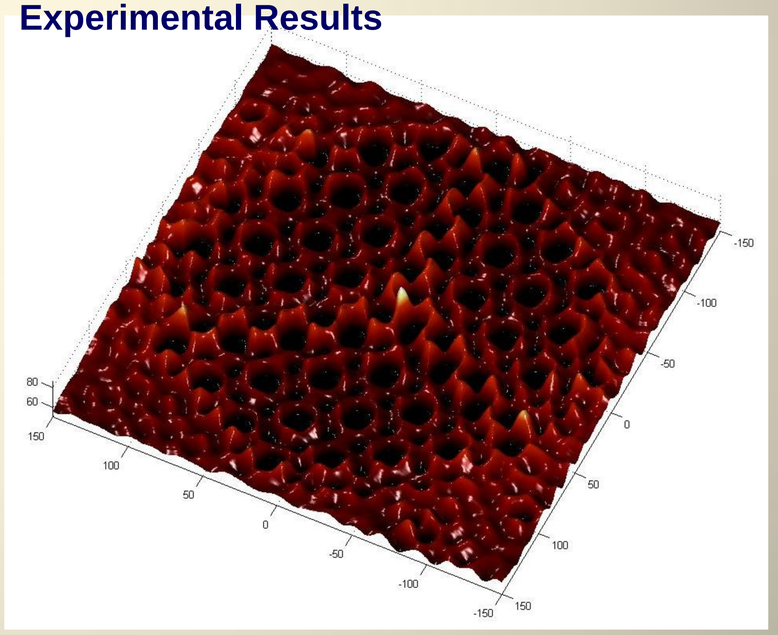

Figure 7. Density of States in our lattice imaged by STM at Fermi Energy. Evidence for Fractional charge can be seen in the center.

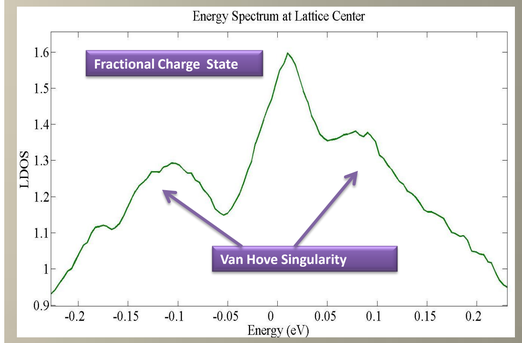

Figure 8. Energy Spectrum at Center of Vortex.

Next Steps

We can further investigate the dependence of the fractional charge state on boundary type and number of domains.

Acknowledgments

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References

[1] Bergman, Doron L., "Realization of a vortex in the Kekule texture of molecular Graphene, at a Y junction where 3 domains meet". *1Physics Department, California Institute of Technology, MC 114-36, 1200 E. California Blvd., Pasadena, CA 91125* (Dated: June 24, 2012)