Electrons, when scattered by static defects, form standing waves that can be seen on many metal and semiconductor surfaces. Such an interference pattern, often denoted as a Friedel oscillation, is not expected to impact how electrons conduct in the material because the large electron density can easily dwarf the Friedel oscillation so that the latter has little effect on the electronic structure and transport. The situation can be different in materials such as graphene and topological insulators, where the electron density is often low and the electronic interaction can become important. In this paper, we demonstrate that the Friedel oscillation can open an energy gap for electron transport which can in turn lead to asymmetric transport behavior across a monolayer/bilayer graphene boundary.

The Friedel gap is opened because the charge oscillation couples the right- and left-going waves near the Fermi energy, representing an extra energy cost for electron transmission across the interface. Due to the dependence of the Friedel oscillation on the bias voltage, these gaps can manifest themselves as asymmetric electrical transport across the interface if the gaps on both sides are different. Such a transport asymmetry is experimentally demonstrated in our multi-probe scanning tunneling potentiometry measurements across a monolayer-bilayer boundary in epitaxial graphene formed on SiC (0001).

The sensitivity of the transport asymmetry to the scattering boundary conditions makes scanning tunneling potentiometry a suitable tool to probe the phase of electron wave functions in particular with respect to chirality, Berry’s phase, and pseudospin polarization.

Reference
“Energy Gap Induced by Friedel Oscillations Manifested as Transport Asymmetry at Monolayer-Bilayer Graphene Boundaries”
Kendal W. Clark¹, X.-G. Zhang¹, Gong Gu², Jewook Park¹, Guowei He³, R. M. Feenstra³, and
An-Ping Li¹*
¹ Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA
² Department of Electrical Engineering & Computer Science, University of Tennessee, Knoxville, TN 37996, USA
³ Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA
* Email: apli@ornl.gov


Acknowledgment of Support
This research was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Office of Basic Energy Sciences, U.S. Department of Energy. The work (GG) was partially supported by the ORNL-UTK Joint Institute of Advanced