MAR11-2010-005159

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Scanning Tunneling Microscopy of Dirac Fermions at mK Temperatures

JOSEPH STROSCIO, NIST

Since the beginning of the last century new frontiers in physics have emerged when advances in instrumentation achieved lower experimental operating temperatures. Notable examples include the discovery of superconductivity and the integer and fractional quantum Hall effects. New experimental techniques are continually adapted in order to meet new experimental challenges. A case in point is scanning tunneling microscopy (STM) which has seen a wealth of new measurements emerge as cryogenic STM instruments have been developed in the last two decades. In this talk I describe the design, development and performance of a scanning probe microscopy facility operating at a base temperature of 10 mK in magnetic fields up to 15 T [1]. The microscope is cooled by a custom designed, fully ultra-high vacuum (UHV) compatible dilution refrigerator (DR) and is capable of in-situ tip and sample exchange. Sub-picometer stability at the tip-sample junction is achieved through three independent vibration isolation stages and careful design of the dilution refrigerator. The system can be connected to, or disconnected from, a network of interconnected auxiliary UHV chambers used for sample and probe tip preparation. Current measurements are focusing on Dirac fermions in graphene and in topological insulators. The history of the fractional quantum Hall states in semiconductor heterostructures suggests that studying graphene at lower temperatures and higher magnetic fields may reveal new quantum phases of matter. Scanning tunneling spectroscopy of graphene at mK temperatures reveals the detailed structure of the degenerate Landau levels in graphene, resolving the full quartet of states corresponding to the lifting of the spin and valley dengeneracies [2]. When the Fermi level lies inside the four-fold Landau manifold, significant electron correlation effects result in enhanced valley splitting and spin splitting. New many-body states are observed at fractional filling factors of 7/2, 9/2, and 11/2.

[1] *A 10 mK Scanning Probe Microscopy Facility*, Y. J. Song, A. F. Otte, V. Shvarts, Z. Zhao, Y. Kuk, S. R. Blankenship, A. Band, F. M. Hess, and J. A. Stroscio, Rev. Sci. Instrum. (in press).

[2] *High Resolution Tunneling Spectroscopy of a Graphene Quartet*, Y. Jae Song, A. F. Otte, Y. Kuk, Y. Hu, D. B. Torrance, P. N. First, W. A. de Heer, H. Min, S. Adam, M. D. Stiles, A. H. MacDonald, and J. A. Stroscio, Nature **467**, 185 (2010).