Probing the Microscopic Structure of the Localized State in Quantum Point Contacts

Y. Yoon[1], J. P. Bird[1], L. Mourokh[2], T. Morimoto[3], N. Aoki[3], Y. Ochiai[3] & J. L. Reno[4]

1: Department of Electrical Engineering, University at Buffalo, Buffalo, NY 14216
2: Department of Physics, Queens College of CUNY, Flushing, NY 11367 & Quantum Cat Analytics, 1751 67 St. #E11, Brooklyn, NY 11204
3: Department of Electronics and Mechanical Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan
4: Nanostructure & Semiconductor Physics Department, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185-1415

There has been great interest in the idea that the "0.7 feature" in quantum point contacts (QPCs) is related to a spin-dependent phenomenon, possibly a spontaneous spin polarization of electrons near pinch off. One suggestion is that self-consistent interactions among the electrons lead to the formation of a localized state in the QPC, which can produce a Kondo effect similar to that which has been inferred in experiments. In previous work [1-3], we have provided evidence for the electrical detection of this localized state in a device consisting of coupled QPCs. In this experiment, we detect the formation of the localized state in one QPC by making a measurement of the conductance of the other. The key observation is of a resonance in the "detector" QPC that we have shown theoretically [3] to be consistent with the formation of a localized state in the "swept" QPC. In this presentation, we report on new experiments of this type that we have performed to characterize the microscopic structure of the self-consistently formed localized state in QPCs. Our investigations reveal several characteristics:
1) The conductance resonance persists to remarkably high temperatures, larger than 30 K. This observation allows a quantitative estimate of the magnitude (~several meV) of the self-consistently formed barriers that confine the localized state in the QPC.
2) Although the conductance resonance decreases steadily with increasing temperature, we find that its linewidth remains virtually constant. This demonstrates that the conductance resonance arises from the interaction of the localized state with a specific one-dimensional state in the detector QPC.
3) The resonance consistently occurs for more-negative gate voltage than the 0.7 feature, just after pinch off of the swept QPC. This indicates that the 0.7 feature is observed when the barriers of the self-consistently formed localized state have been lowered so that it is now strongly coupled to the reservoirs, similar to the ideas of the Kondo model.
This demonstrates that the conductance resonance arises from the interaction of a one-dimensional state in the detector QPC with the localized state in the swept QPC.

[1] For a brief overview, see: J. P. Bird and Y. Ochiai, Science **303**, 1621 (2004).
[2] T. Morimoto, Y. Iwase, N. Aoki, T. Sasaki, Y. Ochiai, A. Shailos, J. P. Bird, M. P. Lilly, J. L. Reno, and J. A. Simmons, Appl. Phys. Lett. **82**, 3952 (2003).
[3] V. I. Puller, L. G. Mourokh, A. Shailos, and J. P. Bird, Phys. Rev. Lett. **92**, 96802 (2004).

Work supported by the DoE, ONR and NYSTAR. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.