Application Note CI30

Differential conductance measurements on Pd break-junctions measured using an attoCPS I

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In this application, we use an attocube 4-point probe station, contained in a ^{4}He cryostat, to perform tunneling spectroscopy measurements in metallic nanogap devices. The samples consist of palladium nanowire constriction patterns atop a Si/SiO_2 substrate fabricated in arrays containing between 60 and 100 devices. A single nanowire is contacted by two probes and a thermally-assisted electromigration process is employed to create a sub-nanometer tunneling gap (Figure 1). Differential conductance across the gap is measured as a function of source-drain bias. A third probe is used to contact the conducting substrate, which is used as a back gate.

Nanopositioners independently move each DC probe along the x, y, and z directions, enabling electrical contact to each device in succession. The contacting process is monitored by an inspection optics that provides good optical resolution to securely make contact to the contact pads of about 50 - 100 µm in size.

The attocube probe station attoCPS I provides a versatile transport characterization tool with an exceptionally high throughput, ideal for experiments in which many devices are required for a thorough analysis. Tunneling gaps formed with a break junction technique may be used to study a variety of complex physical phenomena, but the resulting detailed geometric configuration of the electrodes will be different for each device. Through the analysis of many samples one can extract generic features which may then be anticipated with a certain frequency of occurrence.

Transport measurements in Pd break junctions reveal anomalous features in the spectrum of *dI/dV* vs. V_{SD} at low temperatures (Figure 2). The sharp, bias-symmetric features undergo a rapid decrease in both amplitude and voltage position as temperature is increased, as demonstrated in the colormap of Figure 3. The associated energy of these features evolves with temperature in accord with a mean-field transition. As discussed in [1], the origin of these differential conductance features is attributed to inelastic processes involving a paramagnetic to ferromagnetic phase transition occurring at the site of the break junction tips. The accessibility of this experiment has been greatly increased by the attocube probe station and has demonstrated how nanoscale confinement of seemingly simple materials can lead to phenomena not observable in bulk samples and macroscale thin films.

References

[1] G . D . Scott, J . J . Palacios, and D . Natelson, ACS Nano **4**, 2831-2837 (2010).

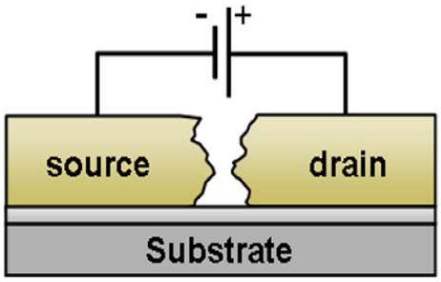

Figure 1: *Schematic of a Pd tunnel junction formed with the electromigration technique. The conducting substrate is used as a back gate isolated from the device with a thermal oxide insulating layer.*

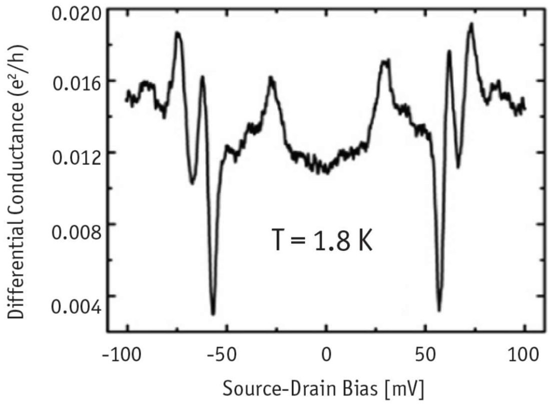

Figure 2: *A single trace of dI/dV vs. source-drain bias acquired near the base temperature of the system.*

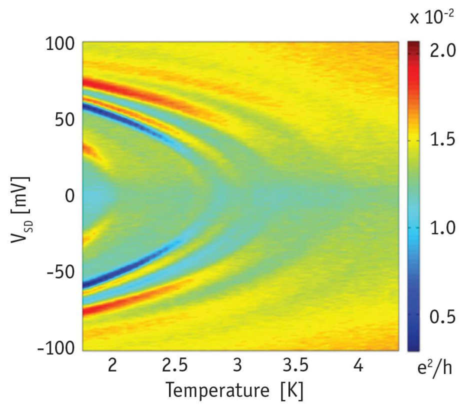

Figure 3: *Colormap depicting the temperature evolution of the sharp differential conductance features. Traces of dI/dV are measured as a function of source-drain bias at temperatures ranging from 1.75 K to 4.5 K in 50 mK increments. The colorbar indicates relative amplitude of dI/dV.*

Fig. 1-3 courtesy of G.D. Scott and D. Natelson, Rice University.