Electrochemistry of Atomically Thin Metallic Wires

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As materials shrink to the nanometer scales, various quantum phenomena become important, which may lead to novel applications. One interesting example is conductance quantization in metallic nanowires, which occurs when the nanowires are atomically thin. We have studied double layer charging and electrochemically induced molecular adsorption effects on the conductance of the metallic wires.

In order to study the double layer charging effect, we measured the change in the conductance quantized at various quantum steps by modulating the electrochemical potential. The change is as high as ~5% per 100 mV at the lowest quantum step, but it decreases at higher steps as the wires become thicker. We attribute the observed changes to the double layer charging effect.

In the presence of molecular adsorption, the conductance drops to fractional values. The conductance changes correlate with the binding strength of the molecules to the metal wires. This observation suggests the possibility of chemical sensor applications based on the adsorbate-induced changes in the quantized conductance of the nanowires, but the mechanism of the conductance change is not understood. One possible mechanism is the scattering of conduction electrons by adsorbates, which reduces the conductance. This theory explains naturally the decreases in the conductance but fails to explain other experimental facts. For example, the mechanical stability of the nanowires is strongly dependent on molecular adsorption. We have studied the mechanical stability by pulling a nanowire with a STM and found that the length over which the nanowire can be pulled before breaking is much longer in the presence of molecular adsorption. So it is clear that the binding of a molecule onto an atomically thin metal wire affects the mechanical properties of the wire.