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# In-situ TEM-STM Investigation of Conductance in Bimetallic Atomic Wires

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Much of the promise of nanotechnology arises from the exploitation of inherently nanoscale phenomena. For example, metallic wires exhibit an anomalous rise in resistivity as the wire diameter approaches the electronic mean free path of the metal (~39 nm for copper at room temperature), due to both fundamental quantum mechanical effects and the increased contribution from surface scattering effects [1]. In its extreme manifestation, nanowires drawn up from the metallic sample by an STM tip even exhibit quantized conductance [2-5]. In order to correlate this behavior with structural and physical characteristics of the nanowire, an STM can be incorporated into a TEM holder to enable atomic resolution imaging of the wire being electrically probed. Such a system has been used, for example, to correlate quantized conductance measurements with atom-sized wires of Au [6-8], but very little work has been done with other metal systems.

Using a TEM-STM holder, we have investigated the combined physical, structural and electrical measurements of a bimetal system, using a gold wire as the STM "tip" and a copper wire as the stationary sample. Figure 1 shows a low magnification TEM image of the two wires being brought into close proximity, with an enlargement of the circled promontory of the Cu wire showing an intact crystalline lattice. This protrusion was imaged in STM mode (Fig. 2) before the two wires were brought into contact for electrical measurements (Fig. 3). Initially nonlinear results suggested the presence of an oxide layer on the surface of the copper, which was overcome by application of a brief voltage pulse. Although the response curve was more linear after flashing, the remaining deviation from Ohmic behavior suggests the presence of residual oxygen still contaminating the surface of the wire. The use of energy filtered imaging in conjunction with EELS will be discussed in the context of this residual oxygenation and "quasi-real-time" monitoring of the oxidation state of the metal.

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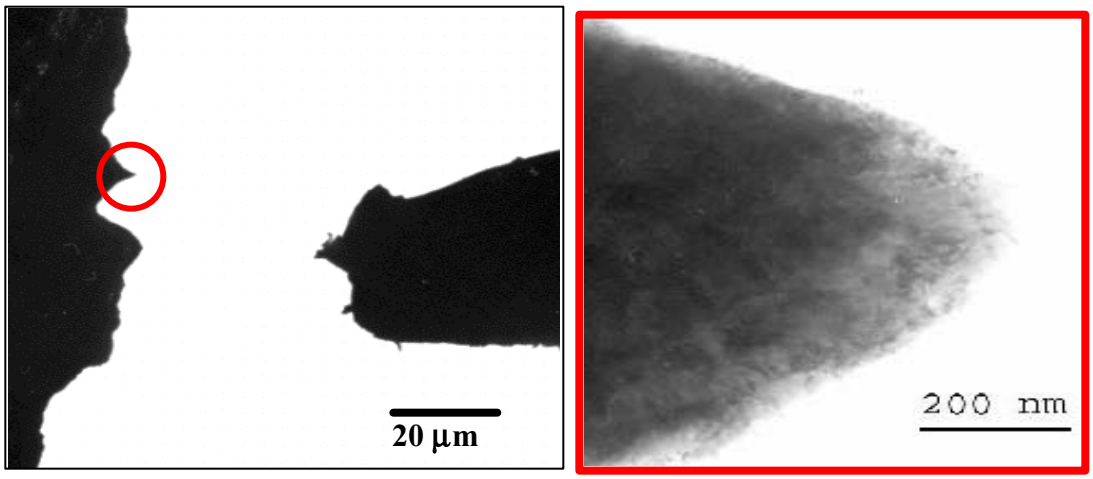


Figure 1. (Left) Low magnification TEM image of a copper (left) and a gold (right) wire being brought into contact. (Right) Enlarged image of the tip of the Cu wire.

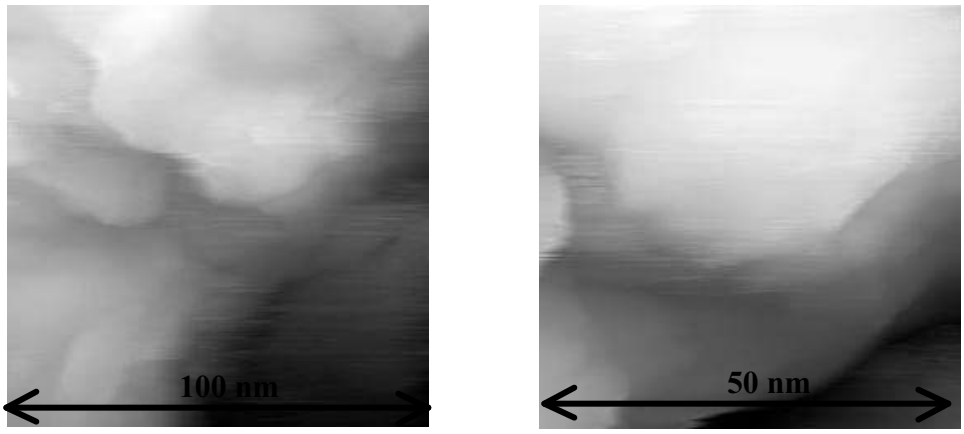


Figure 1. STM images of the tip of a copper wire, obtained using a Nanofactory TEM-STM holder in a JEOL 2010F transmission electron microscope.

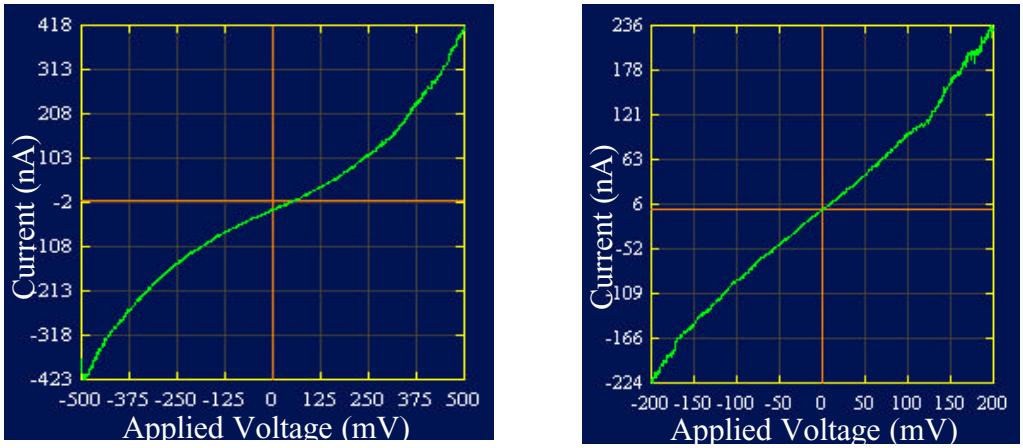


Figure 2. Voltage-Current measurements for a copper nanowire in contact with the STM tip. The nonlinear behavior evident in the left image suggests the possible presence of an oxide at the interface. A brief voltage pulse was applied to improve the contact, resulting in a more linear response curve.

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