

## APPENDIX D

### More about the STM Tip

An electrochemical process is used to make the tips. For tungsten, a fine wire is held vertically and partially immersed in an aqueous solution of base. The tungsten surface is oxidized to a dense, soluble oxide when a 5-V potential is applied to the wire. The tungsten oxide flows down past the tip and prevents further electrolysis except where the wire enters the solution. A different method, an alternating current etching procedure, is used with Pt and Pt-Ir alloys. In both cases localized etching creates a “neck” in the wire, and the wire will be etched through at this thin part, as the bottom part falls off. The tip usually terminates in a small cluster of atoms or the desired single atom.

Piezoelectric materials that expand or contract when a voltage is applied to them are used to make a scanner that controls the tip's position. The most common way of using piezoelectric materials for the tip positioning is to take a single tube of piezoelectric material, typically a ceramic, and to place four metal electrodes on the outside of the tube and a single electrode inside. The tube will extend or contract along its length and/or bend in any direction, if appropriate combinations of voltages are applied to the electrodes. The tip is mounted along the axis of the tube, at its end. The surface-to-tube separation increases or decreases with changes in the level of expansion or contraction. The tip moves mainly sideways, because it has been made so that the amount that it bends is small compared to its length. A typical piezoelectric scanner requires voltages that are around 100V, and the tip can move inside a square scan area with 0.004 mm sides. Levers, gears, and other piezoelectric translators allow the tip to come within a few micrometers of the sample without crashing into it. It needs to be less than 10 angstroms from the surface to detect the tunneling current between the sample and the tip. At this distance the electron orbitals of the sample and the tip nearly overlap. Hence, a small voltage can be applied, and current is produced from the quantum mechanical tunneling that occurs.