Nanoscience – Using a Scanning Tunneling Microscope (STM)

An STM is a rare and unique microscope that enables you to see atoms, which are the building blocks of matter. To appreciate the tiny size of an atom, a few facts and figures need to be considered.

You know that a meter is approximately 39-inches, or about three inches longer than a yard.

A **nanometer (nm)** = 10^{-9} meters = 1 billionth of a meter.

An **angstrom (Å)** = 10^{-10} meters = $1/10^{th}$ billionth of a meter.

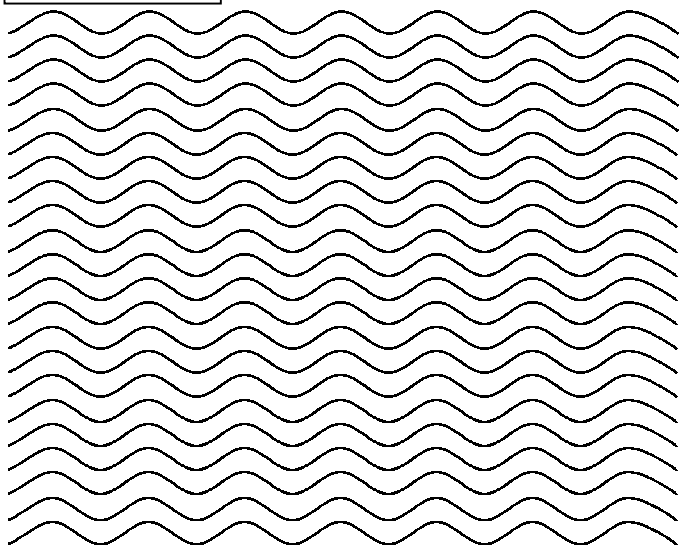
An **atom** is about 2-3 Å in diameter. In solids, the distance between the center of one atom and the center of another atom, is also 2-3 Å.

How does the STM work?

It uses a scanning process by moving a tungsten wire tip, back and forth, just above the surface of a sample material, one line at a time.

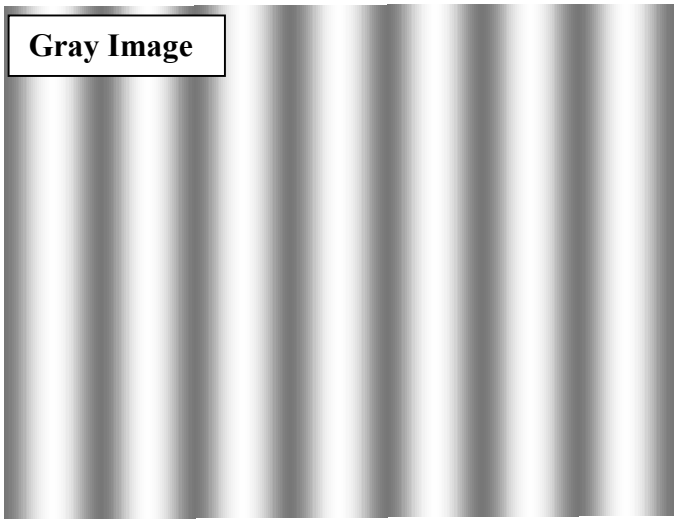
The following pictures illustrate two graphical ways of presenting the STM image data. In the line image, the data is shown as one line of data per horizontal row. The peaks of the curves represent where the STM tip is further from the sample, while the dips of the curves represent where the STM tip is closer to the sample (constant tunneling current mode).

Line Image



In the gray image, the data is shown as gray levels where each pixel has a gray value which depends on the STM tip height (constant current mode). Where the tip is further from the sample, the pixel is more white; where the tip is closer to the sample, the pixel will be more dark.

Gray Image



Tunneling is the term given to the flow of electrons going from the tip to the sample or from the sample to the tip. It requires a voltage (+ or -) between the tip and the sample to initiate the flow. The symbol for a tunneling current is $\mathbf{I_t}$.

- **1 Amperes (Amps) = A**
- **I_t ~ nA (nanoamps) = 10^{-9} A**
- **1 Amp ~ 10^{19} ē/second (s) –** Note: It takes about 2 A to run a light bulb
- **1 nAmp ~ 10^{10} ē/s = 10 billion ē/s**
- **1 Amp = $\frac{1C}{s}$** (C = Coulomb)
- **ē ~ 1.6 x 10^{-19} C**

TUNNELING OF ELECTRONS AT SCANNING TIP

This is the process that produces the image of a surface with atomic resolution to see individual atoms. By getting the scanning tip and the sample within a nm of each other and applying a voltage, the electron clouds, which occupy most of the volume of an atom, around each nucleus of the surface atoms, overlap with the electron clouds of the tip atoms. This allows the electrons from the tip to pass across to become electrons in the sample. This process is called tunneling.