STM Imaging

Question: What is the STM really "seeing" when we acquire a picture of the surface?

One idea:

the image is purely geometrical in origin

in this case a picture from the STM is just a spatial map of the topography of the surface. However, we already know that the tunnel current can vary with the work function

i.e.

$$\boxed{I_t \propto e^{-2\sqrt{\frac{2m}{\hbar^2}\bar{\Phi}}\; S}}$$

so even if the distance <u>S</u> was constant, variations in work function can lead to changes in I_t and thus the apparent height of the STM tip.

In fact, Lüth (p. 130-131) explains how the STM can be used to measure the work function $\bar{\Phi}$

But first, let's get a more complete understanding of the tunnel current

The following discussion will follow the book of C. Julian Chen, Intro. to STM, pp. 3-9

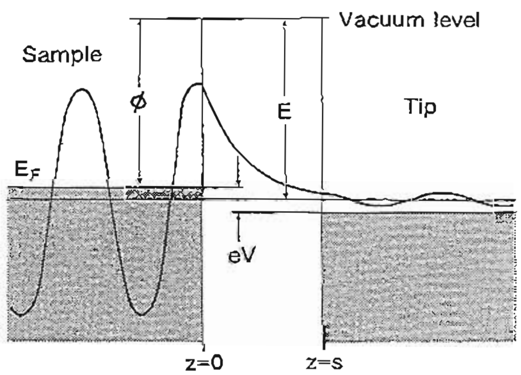

Fig. 1.4. A one-dimensional metal–vacuum–metal tunneling junction. The sample, left, and the tip, right, are modeled as semi-infinite pieces of free-electron metal.

Chen, p. 5

the probability for an electron in the n^{th} sample state to be present at the tip surface is:

$$w \propto |\psi_n(0)|^2 e^{-2\kappa s}$$

Chen, p. 5

$$\kappa = \sqrt{\frac{2m\bar{\phi}}{\hbar^2}}$$

To obtain the total tunnel current, we need to sum over all energies which fall within the tunneling "window"

$$\text{window} = E_F - eV \longrightarrow E_F$$

$$\Delta E = \text{window width} = eV$$

$$\Rightarrow \quad \boxed{I \propto \sum_{E_n = E_F - eV}^{E_F} |\psi_n(0)|^2 e^{-2KS}}$$

Chen, p. 6

Next, define something called the local density of states of the sample

$$\boxed{\rho_s(z, E) \equiv \frac{1}{\epsilon} \sum_{E_n = E - \epsilon}^{E} |\psi_n(z)|^2}$$

Chen, p. 6

ϵ sufficiently small so that the density of electronic states does not vary significantly

$$\Rightarrow \quad \rho_s(0, E) = \frac{1}{eV} \sum_{E_F - eV}^{E_F} |\psi_n(0)|^2$$

This allows one to rewrite the tunneling current in terms of the local density of states at the Fermi level

$$\Rightarrow \quad \sum_{E_F - eV}^{E_F} |\psi_n(0)|^2 = eV \rho_S(0, E)$$

$$\Rightarrow \quad \boxed{I \propto eV \rho_S(0, E_F)\, \underbrace{e^{-2KS}}}$$

this part was taken outside the summation to get this result

Chen, p. 6

Thus, the tunnel current is proportional to the tunneling voltage x the local density of states of the sample x the exponential factor involving the work function Φ

But, if we write the following

$$\frac{1}{eV} \sum_{E_F - eV}^{E_F} |\psi(0)|^2 e^{-2KS} \equiv \rho_S(S, E_F)$$

since $\psi(S) = \psi(0) e^{-KS}$

Chen, p. 7

we can get an even simpler expression:

$$\Rightarrow \quad \boxed{I \propto V \rho_s(S, E_f)}$$