The scanning tunneling microscope

In 1981, Gerd Binnig and Heinrich Rohrer, at IBM Zurich, discovered a practical application of tunneling current: a powerful microscope called the *scanning tunneling microscope,* or *STM.* The STM can produce highly detailed images with resolution comparable to the size of a single atom. The image of the surface of graphite shown in **Figure 3** demonstrates the power of the STM. Note that individual carbon atoms are recognizable. The smallest detail that can be discerned is about 0.2 nm, or approximately the size of an atom's radius. A typical optical microscope has a resolution no better than 200 nm, or about half the wavelength of visible light, so it could never show the detail seen in **Figure 3.**

In the STM, a conducting probe with a very sharp tip (about the width of an atom) is brought near the surface to be studied. According to classical physics, electrons cannot move between the surface and the tip because they lack the energy to escape either material. But according to quantum theory, electrons can tunnel across the barrier, provided the distance is small enough (about 1 nm). Scientists can apply a potential difference between the surface and the tip to make electrons tunnel preferentially from surface to tip. In this way, the tip samples the distribution of electrons just above the surface.

The STM works because the probability of tunneling decreases exponentially with distance. By monitoring changes in the tunneling current as the tip is scanned over the surface, scientists obtain a sensitive measure of the topography of the electron distribution on the surface. The result is used to make images such as the one in **Figure 3.** The STM can measure the height of surface features to within 0.001 nm, approximately 1/100 of an atomic diameter.

Although the STM was originally designed for imaging atoms, other practical applications are being developed. Engineers have greatly reduced the size of the STM and hope to someday develop a computer in which every piece of data is held by a single atom or by small groups of atoms and then read by an STM.

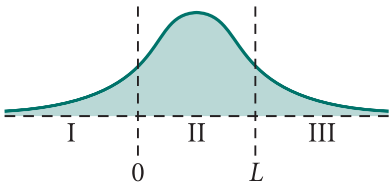

Figure 2
The probability curve for an electron in its lowest energy state shows that there is a certain probability of finding the electron outside the potential well.

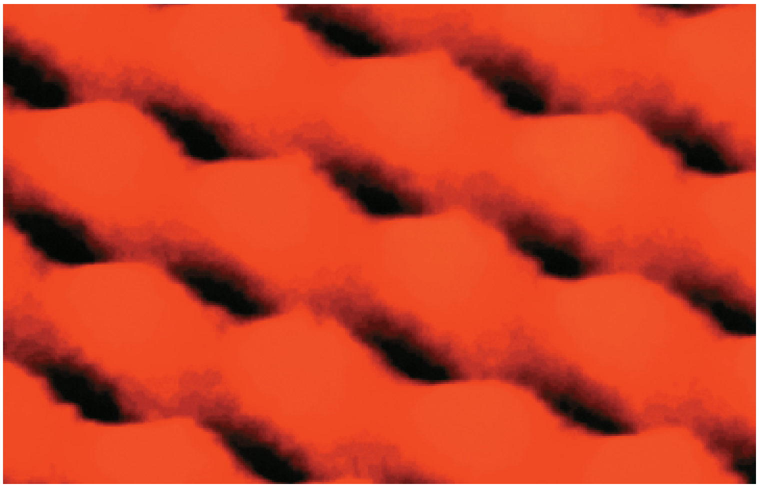

Figure 3
A scanning tunneling microscope (STM) was used to produce this image of the surface of graphite, a form of carbon. The contours represent the arrangement of individual carbon atoms on the surface. An STM enables scientists to see small details on surfaces with a lateral resolution of 0.2 nm and a vertical resolution of 0.001 nm.