Electron tunneling for ultrafine detail

Scanning tunneling microscopes were developed a few years ago by scientists at IBM Zurich in Switzerland (SN: 4/2/83, p. 213). At the time they were introduced, these instruments' claim to fame was that they were a practical use of the phenomenon of electron tunneling through a vacuum and that they could "see" individual atoms in a solid surface. Now, in what one of the developers, Gerd Binnig of IBM Zurich, calls a new breakthrough, they have developed to the point where they can not only see the atoms but also identify their chemical species. The microscopes now work not only in vacuum but at atmospheric pressure, in water, oil, even solid naphthalene. They work at room temperature and under the refrigeration of liquid nitrogen and liquid helium down to a temperature of about 6 kelvins. "Whatever you do, it seems to work," says Heinz Rohrer of IBM Zurich, another of the instrument's developers. "We don't understand it."

Work has also spread to other centers. A symposium on the subject at last week's meeting in Baltimore of the American Physical Society detailed research with tunneling microscopes from AT&T Bell Laboratories, Stanford University, the University of California at Santa Barbara and the Universidad Autonoma (Autonomous University) of Madrid. In response to one of these contributions Rohrer remarked that it shows that "atomic resolution doesn't happen only in Switzerland."

Tunneling is one of those seemingly contradictory predictions of quantum mechanics that nevertheless work. According to classical physics, if two electrodes are separated by a gap, which may be either vacuum or an insulating material, no current will flow between them until the driving voltage is strong enough to cause a spark or burn out the insulation. According to quantum mechanics, long before this state is reached, if the gap is narrow enough (several atomic diameters), a current will flow consisting of electrons that "tunnel" through the energy barrier represented by the gap, even though the electrons do not have enough energy to go *over* the barrier.

To make a microscope, researchers fashion one electrode as a sharply tapered tip. The other is the surface to be investigated. The tip scans back and forth over the surface. Since the current depends on the distance between tip and surface, any surface roughness will be reflected by changes in the current. The apparatus uses these differences to draw a picture of the surface. With a resolution of a few angstroms, the device can map out individual atoms on the surface.

Now, says Binnig, the instrument not only sees atoms but can see into their electronic structure. Nicolas García of the Universidad Autonoma, who is working out a detailed theory of how the scanning tunneling microscope works, notes that different chemical species have different electronic structures and that should affect the current and voltage characteristics. And indeed a kind of spectroscopy can be done, identifying different chemical species by what Binnig calls their "color." For example, he says, you can put oxygen on a clean surface and see where oxide forms.

García's experimentalist colleagues in Madrid and Barcelona, Arturo Baro, Rodolfo Miranda and José L. Carascosa, have been using the microscope for biological studies. Among other things, Baró and Miranda, operating at normal pressure and with wet specimens (not dried or otherwise prepared), have worked out the structure of a virus called ϕ 29. It is 300 angstroms long and has a "head" attached to its body by a thin connector. The connector seems to be important for the process of infection. This is an example, García says, of something that light microscopes cannot resolve. In Barcelona, in another application of the microscope, Carascosa has been working on prostheses in teeth and bone structure.

At Stanford University, Calvin F. Quate and his students A.L. deLozanne and S.A. Elrod have developed a low-temperature scanning tunneling microscope. They have used it to chart the electronic structure of the surfaces of conductors. They have also studied the onset of superconductivity as an appropriate conductor is chilled below the critical temperature at which its electrical resistance disappears. They can chart the configuration and growth of regions of superconductivity of the surface as this process goes on.

Paul K. Hansma of U.C. Santa Barbara decided to forsake scanning ability for stability and developed squeezable tunnel junctions. He makes the two electrodes by laying down strips on glass microscope slides. The slides are arranged so that the strips cross each other, the crossing being the junction. Tiny spacers are inserted between the slides. Hansma uses a magnetic field to squeeze these junctions. The squeeze technique was developed by John Moreland, Mike Cox and Sam Alexander. It can control the spacing to within a hundredth of an atomic diameter. With this Hansma and his students have probed for even finer and more delicate details — for instance, for phonons, vibrations in the lattice of the crystal that are important in superconductivity and other phenomena. The next level of subtlety is molecular vibrations. In the future they hope to be able to study surfaces, molecule by molecule.

Another project is the characterization of the properties of semiconductors, for example, the relation between capacitance and voltage in them. A gold electrode various distances above the surface will do this. — *D. E. Thomsen*

Anemia: A defense against cancer?

Scientists have long suspected that iron plays a role in cell proliferation processes, such as cancer. Now, University of Florida-Gainesville researchers have shown that supplemental iron can enhance tumor growth in laboratory animals, and they suggest that anemia may be a defense mechanism in cancer patients.

The researchers injected leukemia cells into mice treated with iron at levels "comparable to clinical doses for humans" and into untreated mice. They found that tumors grew faster in iron-treated mice and that these animals succumbed to the disease faster than did untreated animals.

Most living things, from microorganisms to cancer cells, need iron to grow, says Raymond J. Bergeron, who directed the research. When bacteria invade the body during an infection, the body removes iron from the bloodstream and "hides" it in the liver, making it unavailable for bacterial growth. Such a mechanism might also take place in certain cancers and explain why many cancer patients have anemia, according to the report in the March JOURNAL OF NUTRITION.

Indirect evidence for anemia's role as a defense against cancer abounds. For example, the researchers note, people with hemochromatosis, a disease of iron overload, often die of cancer; South African Bantus, who drink beer brewed in iron pots, have a high incidence of liver cancer; and tumors often develop at sites of iron injection in animals and people.

Bergeron reported in an earlier study that iron chelators — molecules that tightly bind iron — prevent it from being incorporated into ribonucleotide reductase, an iron-dependent enzyme that catalyzes a step of DNA synthesis. Because cancer cells require rapid DNA synthesis to multiply, iron chelators slow cancer growth. The mechanism partly explains how anticancer drugs work, although scientists didn't realize it for many years, Bergeron says.

The researchers warn against extrapolating the results of the present study to humans. "We were really reticent to publish the results because the implications are incredible," Bergeron says. "We don't want people calling and asking us 'Am I going to get cancer from taking [iron supplements]?'"

Bergeron and colleague Richard R. Streiff, a hematologist, answer with an emphatic "no," explaining that iron has never been shown to cause cancer. For cancer patients who are taking iron supplements, the current mode of clinical therapy should not be changed, they add. The study involved only one type of cancer — mouse leukemia — and, they note, "different cancers have different biochemical requirements." — *D.D. Bennett*