Physics

Atomic scouring to dissolve a surface

Removing the blackened, baked-on crust at the bottom of a pot is no one's idea of a pleasant kitchen chore. The task often takes successive rounds of scouring, soaking, and rinsing to get rid of the thick coating.

Soaking a crystal in water to dissolve it similarly causes layers of atoms or ions to detach from its exposed surfaces. Now, researchers have discovered that scouring a crystal's surface on an atomic scale can hasten dissolution, just as scrubbing a pot makes it easier to wash away the crud.

J. Thomas Dickinson and his coworkers at Washington State University in Pullman report their findings in the Sept. 1 Journal of Applied Physics.

Crystals of calcium carbonate, the main constituent of chalk, have nearly smooth, flat surfaces. Immersed in water, these crystals typically dissolve very slowly, with calcium and carbonate ions preferentially leaving the crystal at steps where one layer of ions sits atop another to form a plateau or where the surface has been etched to create a channel or pit.

Dickinson and his colleagues found that drawing the tiny, sharp tip of an atomic force microscope back and forth across a step on a crystal soaking in water greatly increased the rate at which ions leave the crystal and go into solution at that location. In contrast, they detected no evidence that dragging the microprobe's tip across a dry crystal surface dislodged any atoms.

The researchers suspect that pushing down on the crystal at a step causes a few ions to move apart slightly, making them vulnerable to removal by water molecules. Once a few ions are gone from a row, water interactions very quickly unzip the rest of the ions along the step's edge.

"The harder one pushes, the faster the step dissolves," Dickinson notes. The effect is known as stress-enhanced dissolution.

The researchers are now checking whether a similar wear mechanism applies to calcium phosphate, which makes up the crystalline part of bone and teeth. "It may make a difference in how and with what you brush your teeth," Dickinson comments.

Bringing nanomagnets into quantum step

Quantum mechanics rules the behavior of atoms and subatomic particles, whereas Newton's laws of motion govern the actions of billiard balls and other macroscopic objects. There is, however, a middle ground where quantum effects can sometimes be observed in the macroscopic realm. Researchers have now identified such a quantum effect in a crystal of nanomagnets.

Bernard Barbara of the Louis Néel Laboratory of Magnetism in Grenoble, France, and his collaborators report their discovery in the Sept. 12 Nature.

In recent years, chemists have synthesized a variety of large molecules that behave like miniature magnets. One such macromolecule is manganese acetate, which includes a cluster of 12 manganese ions and 16 acetate ions. Each macromolecule is in a single magnetic state, generally described as its spin state.

When a large number of these manganese clusters aggregate into a single crystal, the spin state of each cluster points in a random direction. The application of an external magnetic field, however, can bring these spin states into alignment, giving the crystal itself a definite magnetic field, or spin.

Slowly changing the direction of the external magnetic field forces the spin states of the clusters to shift in direction. Barbara and his colleagues have demonstrated that at extremely low temperatures, these shifts don't occur smoothly; they take place in abrupt steps between different magnetic states via a quantum mechanical process known as tunneling.

These observations give clear evidence of the quantization of the crystal's magnetic field, the researchers conclude.

Technology

At the tone, the time will be . . .

Tired of a VCR that constantly blinks 12:00? A year from now, that VCR and other small devices could synchronize themselves to one of the most accurate clocks in the world, the one at the National Institute of Standards and Technology (NIST) in Boulder, Colo.

NIST now broadcasts a time signal from an atomic clock through its radio station in Fort Collins, Colo. (SN: 5/1/93, p. 276). Electric power companies, computer systems, and others receive the signal and use it as a reference; however, in places far from the transmitter, such as Florida, the signal is very weak and detection requires fairly large antennas, says Don Sullivan, chief of NIST's Time and Frequency Division.

By September 1997, NIST plans to have installed a new transmitter to increase the signal's power fourfold. Sullivan expects this upgrade to improve coverage of the continental United States as well as parts of Mexico and southern Canada. After the power boost, antennas small enough to fit inside a wristwatch should be able to pick up the signal.

Oregon Scientific, a company in Portland, makes a travel alarm clock that sets the time and date from the NIST signal, but it needs an external antenna. "There are pockets in the East and in urban areas with reception difficulties," says spokesman Jesse Rotman. The planned boost to the signal would be "outstanding news for us," he adds.

Other countries, such as the United Kingdom, Germany, and Japan, have built industries around products that take advantage of the time signals they broadcast, Sullivan says. "It's not as though the idea is new, but it takes substantially more power to get coverage in the U.S.," he explains.

Imaging method really shows some nerve

A new imaging technique that can help doctors distinguish between healthy and damaged nerves may cut down on the need for exploratory surgery in cases that would otherwise be difficult to diagnose.

Aaron G. Filler and his colleagues at the University of Washington in Seattle first demonstrated the technique, called magnetic resonance neurography, 3 years ago (SN: 3/20/93, p. 183). It works like standard magnetic resonance imaging (MRI) with some modifications to the machine and control software, Filler says.

Although the researchers knew they could see grossly damaged nerves with the technique, they weren't sure it could distinguish between less severely damaged nerves and normal ones. Filler, now at the University of California, Los Angeles, and his colleagues in Seattle and at St. George's Hospital Medical School in London report their most recent findings in the August Journal Of Neurosurgery.

They took 242 images of peripheral nerves in 148 people, both healthy volunteers and patients with specific nerve complaints. The images confirmed many conventional clinical diagnoses and helped resolve inconclusive ones. Neurography proved to be particularly useful for locating problems in the brachial plexus, a "blind zone" where nerves run from the neck to the arm. "There's no safe way to stick a needle in there" to measure nerve impulses in the standard way, Filler says. Exploratory surgery is normally the only reliable option.

An existing MRI machine could be modified to perform neurography at a cost of $80,000 to $400,000—10 to 20 percent of the machine's original price, Filler says. The technique is still a long way from being widely applicable, says Michael N. Brant-Zawadzki, a radiologist at Hoag Memorial Hospital in Newport Beach, Calif. "This extends the capability of MRI to visualize peripheral nerves and to show damage in those nerves," he says. "Whether it will work over and above existing technology remains to be seen."