Physical Sciences

Ivars Peterson reports from San Francisco at the American Physical Society/American Association for the Advancement of Science meeting

Ripples in a crystalline copper bed

The deposition of an oxygen layer on a copper surface has a disturbing effect on the copper: Each oxygen atom sinks into the gap between two adjacent copper atoms, pushing up the copper atoms. The result is a corrugated copper surface embedded with oxygen.

This picture of the formation of a one-atom-thick oxygen film on a copper crystal surface follows from the recent work of Young Kuk and his team at AT&T Bell Laboratories in Murray Hill, N.J. Using a scanning tunneling microscope, the researchers tracked the step-by-step formation of an oxygen layer, providing for the first time a detailed picture of how the process occurs at the atomic level.

A single crystal of pure copper can be pictured as a stack of cubes. Each cube has a copper atom at each corner and one copper atom at its center. Adjacent cubes share corner copper atoms. Looking down on the surface of a single crystal reveals a top layer made up of copper atoms in a checkerboard arrangement. Kuk and his team are interested in where oxygen atoms fit into such an arrangement and how surface copper atoms adjust to the arrival of oxygen atoms.

In their experiment, the researchers sent pulses of oxygen gas into a chamber containing an initially clean, single crystal of copper. These oxygen molecules split up into atoms when they arrive at the copper surface. To track the deposition process, the investigators scanned the surface between pulses, which occurred every 30 seconds.

The first signs of deposition are the formation of long, hairy filaments, all oriented in the same direction. The filaments gradually thicken, and features resembling rungs on a ladder sometimes appear between adjacent filaments. These structures turn out to be rows of copper atoms being pushed up out of their original positions on the crystal surface. The researchers also see small clumps that appear to move about freely on the copper surface. The clumps probably represent clusters of up to six oxygen atoms that have yet to settle into place on the crystal surface, Kuk says.

Careful measurements show the copper atoms rise about 0.77 angstroms above their original positions on the copper surface, whereas oxygen atoms sink into positions 0.6 angstroms below the surface. The deposited oxygen atoms also slightly displace the copper atoms in the first layer below the surface layer.

These results and the accompanying picture of oxygen "chemisorption," as the process is called, fit with and readily explain practically all data obtained previously by other researchers using more indirect techniques, Kuk says. Moreover, Kuk's team has lots more data to analyze. The experiments are likely to yield many more interesting details, such as the influence on the deposition process of tiny defects in the copper crystal structure.

Kuk's research on oxygen chemisorption is part of an effort to develop scanning tunneling microscopy for studying metal surfaces. By obtaining images showing the positions of individual atoms, researchers hope to determine the geometric structure of clean metal surfaces and to track the changes caused by processes such as chemisorption and oxidation.

Using scanning tunneling microscopy to study metals is more difficult than using the same technique for studying semiconductor and graphite surfaces, Kuk says. To obtain useful results, the gap between the needle-like probe and the surface being scanned must be smaller, and the results have to be interpreted carefully. Even the structure and chemical composition of the probe, which comes to a point only a few atoms across, can affect the images produced. For example, experiments have shown that gold, tungsten and silicon tips may produce somewhat different patterns for the same surface.

Science & Society

Banking on African conservation

A major problem plaguing developing countries is immense foreign debt. When much of their money is diverted to servicing debt, little is left for investments in conservation — such as reforestation, creation of nature reserves or the policing of rhino poachers. The solution, some analysts now believe, is "debt-for-nature swaps"— in which the lender writes off some share of a debt in exchange for the debtor's promise to make specified investments in resource conservation (SN: 10/10/87, p.238). Three U.S. environmental groups have just linked up with a multilateral development bank to forge such swaps in Africa.

The few previously arranged debt-for-nature swaps involve debts owed to private commercial banks, and none affects Africa, says Paul Weatherly of the Washington, D.C.-based American Farmland Trust. That's because the "carrot" for writing off a debt has been a tax deduction for the bank's "charitable deduction." However, "few countries in Africa owe significant money to private commercial banks in the United States or Europe," notes Weatherly, U.S. coordinator for the new African program. For debts owed to governments or to multilateral development banks, a new incentive for debt forgiveness had to be developed.

Their solution is creation of "environmental bonds." While these could take many forms, one possibility Weatherly describes would allow debtors to continue paying what they owe into a local account. These funds would then be used to fund grassroots resource-conservation programs approved by the African Development Bank in Côte d'Ivoire and its U.S. partners: the Farmland Trust, Sierra Club and Natural Resources Defense Council.

A second major activity of those U.S. partners will be working with Congress and the new Bush administration to get U.S. acceptance of such "bonds" as partial payment of the debt owed Uncle Sam.

In effect, debtor nations will be asked to "give up a little of their sovereignty in return for help with their foreign debts," Weatherly notes. Because what's given up would be negotiated with the African Development Bank—an institution controlled by African nations — Weatherly says he hopes "this bitter pill may be a little easier to swallow."

U.S. and Soviets sign 'unique' accord

While attending the Toronto economic summit earlier this month, Soviet Foreign Minister Edward Shevardnadze and outgoing Secretary of State George P. Shultz signed a new "framework" for cooperative basic research. The five-year agreement, described by State Department officials as "unique," allows individual U.S. and Soviet scientists to initiate joint ventures. Researchers seeking to participate are encouraged to contact their foreign counterparts and work out a proposal for collaborative study. Each then would submit the proposal for review by the agency authorized to fund it. In the United States, that's the National Science Foundation and U.S. Geological Survey.

Deborah Wince-Smith, assistant international-affairs director in the White House Office of Science and Technology Policy, describes the accord as a "landmark" agreement in seeing that both nations get "equal value" from their collaboration. The accord covers basic research in geosciences, engineering sciences, arctic studies, biology, science policy, chemistry, math and theoretical physics. Absent from the list is materials science — an area in which the Soviets are acknowledged research leaders. Says one State Department official, "There was some discussion of materials" at a meeting last year with the Soviets, but "no consensus" that this area was yet appropriate for joint study.