Surface Diffusion With a Hop, Skip or Dip

On the atomic scale, a smooth metal surface has the undulating appearance of an orderly layer of ball bearings. Scientists have long assumed that individual atoms deposited on such a surface readily shift from place to place, moving about like hard spheres rolling across bumpy terrain.

A series of theoretical studies and experiments now reveals that on certain surfaces, a deposited atom actually trades places with a surface atom. Any motion across such a surface consists of a sequence of exchanges, in which an atom momentarily on top of the surface ends up in the surface layer, and the atom displaced from that layer finds itself on top, a short distance away from the deposited atom's initial position.

"We've discovered a new phenomenon which seems interesting and important," says Peter J. Feibelman of the Sandia National Laboratories in Albuquerque, N.M., who used an elaborate computer model to predict this effect.

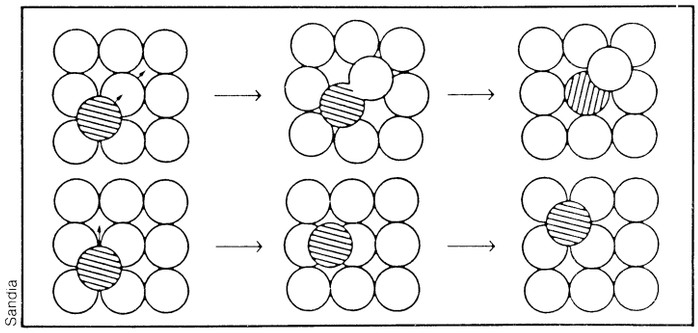
The discovery adds a new dimension to studies of surface diffusion. Such investigations – which focus on the motion of adsorbed particles across a surface – are valuable for materials scientists interested in growing novel crystalline materials layer by layer.

"It's a new mechanism, and that makes it important," says Tien T. Tsong of Pennsylvania State University in University Park. Studies of this mechanism and its consequences have already prompted the publication of several papers in PHYSICAL REVIEW LETTERS, with more papers to follow.

Feibelman started by theoretically determining the energy required for an adsorbed aluminum atom to "hop" over the energy barrier separating one location from another on an aluminum surface. The value he obtained proved significantly higher than expected on the basis of empirical data.

He then turned to an idea that had first surfaced more than a decade before in connection with the diffusion of adsorbed atoms on a grooved crystal surface. In certain cases, adsorbed atoms appeared to move readily from one groove to another instead of following the grooves, suggesting that some kind of exchange was taking place between the adsorbed atoms and the slightly elevated surface atoms defining the grooves.

Applying a similar idea to the smoother aluminum crystal surface he was considering, Feibelman found that an adsorbed aluminum atom actually starts forming a chemical bond with a neighboring substrate atom. The energy required for the entire exchange process proves considerably less than that required for an aluminum atom to roll from hollow to hollow as if it were a ball bearing.



Sandia

An atom deposited on a surface can move either by "hopping" an energy barrier to get from one location to another (bottom) or by trading places with a substrate atom (top).

"The key is to think of [the process] as a chemical phenomenon rather than in terms of a hard sphere moving on a bumpy plane," Feibelman says.

He also predicted that the exchange mechanism would produce a distinctive pattern of sites visited by a diffusing atom, and that this pattern should be apparent in data compiled from field-ion microscope observations. His Sandia colleague Gary L. Kellogg found such a pattern for a platinum atom diffusing on a platinum surface, and Tsong and his group observed a similar pattern for an iridium atom on an iridium surface.

More recent observations by Kellogg reveal that individual, adsorbed platinum atoms displace nickel atoms from a nickel surface. A similar process involving rhenium atoms on an iridium surface has allowed Tsong and his co-workers to observe directly the intermediate steps in the exchange process.

"It's very exciting because we can see the exchange taking place step by step," Tsong says. "We can now see the intermediate state – an adsorbed atom pushing up a substrate atom."

But the picture is complicated by the fact that some combinations of atoms, such as palladium on platinum, don't trade places. Furthermore, recent experiments show that although pairs of platinum atoms migrate by a series of exchanges, three-atom clusters move by a combination of exchanges and hopping.

"It depends on what the materials are," Feibelman says. "But at this point, we don't know the rules." – *I. Peterson*

Dueling proteins fuel Alzheimer's debate

A key mystery of Alzheimer's disease revolves around the unusual protein deposits found in patients' brains during autopsy. For years, scientists have debated whether these protein "plaques" actually cause the neurological disorder or are simply a by-product of the disease-fostered deaths of nerve cells.

Now researchers who have injected the protein, known as beta amyloid, into the brains of rats report that it triggers cell death resembling that seen in Alzheimer's victims. This finding establishes for the first time a direct link between beta amyloid and neuron destruction in live animals, says study coauthor Neil W. Kowall of Massachusetts General Hospital in Boston.

Moreover, the investigators discovered that another brain protein, called substance P, prevents the induced brain damage in rats. This raises the tantalizing, though still remote, prospect of an effective treatment for a disease that robs many elderly of their memories and minds.

The new report "is another piece of the puzzle," Kowall says. "But there are many other pieces to be found and put together."

Earlier findings indicated that beta amyloid is toxic to lab-cultured nerve cells (SN: 7/29/89, p.68). In the new study of 69 rats, the protein showed similar toxicity when injected into the hippocampus of the brain, Kowall and his colleagues report in the Aug. 15 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

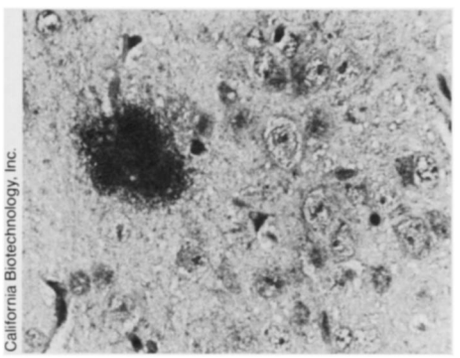
One week after the injections, the researchers killed the rats and analyzed samples of brain tissue. In addition to toxicity, they noted that brains injected with beta amyloid showed antibodies similar to those detected in Alzheimer's patients. Despite these similarities, the injections do not duplicate Alzheimer's in rats, says Kowall. For example, clots or "tangles" of insoluble proteins within neurons – another feature characteristic of Alzheimer-afflicted brains – did not appear in the rat tissues studied.

Substance P – injected directly into the brain with the beta amyloid or a day or so later – reduced the extent of toxicity, preventing amyloid-induced neuron

death and the arrival of Alzheimer's-like antibodies, Kowall says. Abdominal injections of substance P elicited similar results, suggesting that it can cross the blood-brain barrier, he adds.

Kowall also notes that substance P's actions were dose-dependent: The more injected, the stronger the protection. Previous research indicated that this protein, a neurotransmitter naturally present in the brain, is depleted in Alzheimer's patients, says Bruce A. Yankner of Harvard Medical School in Boston, who directed the rat study.

Substance P's effect "is going to be an important clue or avenue for drug development," says Zaven Khachaturian of the National Institute on Aging, which helped fund the new study.



Researchers have created a strain of mice whose brains develop Alzheimer's-like protein deposits known as pre-amyloid plaques (left of center).

Scientists still need to replicate the new results and extend them to higher animals. And most researchers remain cautious about the protein's potential as a treatment. "Whether substance P is practical to use is very open still," Kowall says. "It's very premature to be thinking about therapy," agrees Donald L. Price, a neuropathologist at Johns Hopkins University School of Medicine in Baltimore.

In a related development that underscores the importance of amyloids, investigators report in the July 18 NATURE that mice genetically engineered to overproduce an amyloid precursor protein (of which beta amyloid is a fragment) develop plaques similar to those seen in Alzheimer's. If these mice show memory loss and other signs of the disease, researchers will have a new model in which to pursue their studies of Alzheimer's, asserts study director Barbara Cordell of California Biotechnology, Inc., in Mountain View.

Price calls Cordell's paper "important" and suggests that researchers could settle the beta amyloid debate by creating mice with the amyloid gene mutation recently found in some cases of inherited Alzheimer's (SN: 2/23/91, p.117).

"If those animals develop behavioral difficulties and plaques and tangles," says Price, "then you can say [beta amyloid] causes Alzheimer's." *– J. Travis*

Energy duo takes on CF's chloride defect

Two naturally occurring substances appear to correct a cellular defect that may lie at the root of cystic fibrosis (CF). The new findings, although preliminary, hold out the hope of blocking the progressive lung damage wrought by CF and perhaps extending the lives of many children and young adults who suffer from this deadly inherited disease, the researchers suggest.

Cystic fibrosis strikes one in every 2,500 babies born in the United States. The disorder causes epithelial cells lining the lung's airways to absorb too much sodium and secrete too little chloride. This double defect leads to a buildup of thick, sticky mucus that clogs the breathing tubes. The mucus-layered lungs become vulnerable to frequent infections – a process that destroys healthy lung tissue, impairs breathing and usually causes death by age 30.

Last year, researchers at the University of North Carolina at Chapel Hill reported encouraging results in treating CF with an aerosol form of the diuretic drug amiloride (SN: 4/28/90, p.260). The study, which involved 14 patients, suggested that amiloride helps inhibit sodium absorption. Now, in the Aug. 22 NEW ENGLAND JOURNAL OF MEDICINE, the same group reports that two different compounds, both classified as triphosphate nucleotides, attack the other half of the CF equation: the chloride deficit. Together, the findings hint at a double-barreled approach to treatment.

"Ultimately our goal would be to give these drugs [amiloride and triphosphate nucleotides] in combination at a very early age to protect the airways," says Michael R. Knowles, who co-directed the new study. If all goes well, such treatment may prevent the devastating lung damage that leads to premature death for CF victims, he told SCIENCE NEWS.

In the new work, Knowles, Richard C. Boucher and their colleagues studied 12 men and women with CF and a control group of nine men and women in good health. Using a thin tube, the researchers squirted solutions containing either adenosine triphosphate (ATP) or uridine triphosphate (UTP) onto epithelial cells lining the nose – using the nasal tissue as a model of airway epithelial cells deep within the lungs.

In all volunteers, the ATP and UTP solutions increased the amount of chloride secreted by nasal epithelial cells. However, the CF patients showed such a strong response that they ended up with chloride secretions that equaled those of the controls. With the nucleotide treatment, "you fully correct the abnormal chloride transport," Knowles says.

ATP and UTP are energy-producing substances normally present within cells. But the new research suggests that these compounds can also bind with protein receptors sitting on the *exterior* of the epithelial cell, thereby triggering an increase in the cell's chloride secretion.

Boucher says his inspiration for the ATP-UTP experiment came from a "truly serendipitous" discussion with a researcher who worked with these nucleotides.

He and his colleagues acknowledge that they have yet to demonstrate the efficacy or safety of ATP or UTP for treating CF. However, their hope is that such compounds, used together with amiloride, would lower the number of lung infections and extend the life span of people with CF, Knowles says.

Pamela B. Davis, who studies cystic fibrosis at Case Western Reserve University School of Medicine in Cleveland, calls the new work an "excellent start" toward the goal of improved treatment for the disease. In an editorial accompanying the research report, Davis writes: "The need is urgent, because every day three more patients die of cystic fibrosis." *– K.A. Fackelmann*

Smoking out cigarette risk

Lung cancer has edged past coronary artery disease as the leading cause of "excess" deaths among U.S. cigarette smokers, according to a new report. One reason for the cancer's deadly new ranking: Smokers can rapidly lower their risk of coronary artery disease when they kick the habit, eliminating about half the risk during the first smoke-free year. By contrast, lung cancer retains 30 to 50 percent of its threat even a decade after quitting.

Using data from a prospective study of 1.2 million people, Donald R. Shopland of the National Cancer Institute and his colleagues projected that an estimated 157,226 cigarette-related cancer deaths will occur in the United States in 1991. The statistical analysis linked the vast majority of those deaths (123,111) to lung cancer. However, cigarette smoking was also associated with an estimated 34,000 lethal cancers at other sites, including the mouth, bladder and kidney, the team found.

These numbers, reported in the Aug. 21 JOURNAL OF THE NATIONAL CANCER INSTITUTE, include only cigarette-linked deaths and thus underestimate the true cancer burden associated with the full range of tobacco products, the researchers warn. They estimate that an additional 14,000 deaths in 1991 will result from the use of pipes and cigars, which raise the risk of several cancers, particularly those of the mouth and esophagus. □