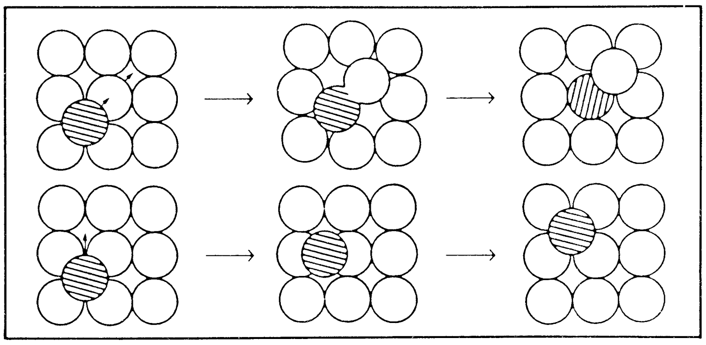
Surface Diffusion With a Hop, Skip or Dip

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.



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).

"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.

"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 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