Perspectives

Ion-Surface Interactions: From Channeling to Soft-Landing

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Collisions of ions with surfaces rarely are gentle but rather are crash landings. This is because of the high energies (kilo- to megaelectron volts) usually used in surface science experiments. The corresponding physical picture is that of a point charge moving in an ordered array of other well-separated point charges. The interaction is determined by Coulomb repulsion between the nuclei. In surface science, fast ions are used in surface crystallography. From the patterns of 0.1- to 1-MeV protons or alpha particles reflected from solids, the structure of the first layers can be determined, for instance, by using the technique of channeling (1) (see figure). In addition to scattering from the surface region, implantation into this region is very probable. Thus, the surface and subsurface of a material can be modified by ion implantation with a variety of usually atomic ions (see figure). In all of the processes mentioned so far, the energies involved exceed chemical binding energies; thus, survival of a molecular ion in a collision with the surface is extremely unlikely, and a soft landing of a polyatomic ion would be unheard of; it has never been observed. Practically different conditions are needed to allow soft landing, an accomplishment reported on page 1447 of this issue by Miller et al. (2).

A look at other types of ion-surface interactions can put the observation of molecular soft landing in perspective. Implantation will have a side effect: The energy transfer between the incident projectile and atoms at or close to the surface will be so large that the lattice atoms and, for instance, molecules in overlayers get sufficient energy to overcome the surface binding energy and escape. This is the well-known phenomenon of ion sputtering (see figure), used to prepare atomically clean surfaces in ultrahigh vacuum and diagnose the composition of surfaces in the well-established technique of secondary-ion mass spectrometry (3). When the energy of the sputtering projectiles is chosen to be sufficiently low, molecules, thermally deposed intact on the surface, can be lifted off intact for analysis in a mass spectrometer (see figure); this is the process that was used by Miller et al. (2) to verify that soft landing had occurred.

When one wants a fair chance of a polyatomic ion surviving its collision with a surface, the energy of the ions should not exceed the bond dissociation energies of individual bonds in the molecule by much. Therefore, ions with energies in the 10- to 100-eV range are necessary. What is the nature of the molecule-surface interaction in this case? The forces between the ion and the surface are now dominated by the Pauli repulsion between the electrons. This interaction makes the effective repulsive potential felt at a larger distance (see figure). The solid is no longer seen as an ordered gas of point charges but as a continuum. The projectile interacts with more than one surface atom at the same time and can no longer penetrate the surface. This regime is that of surface rainbow scattering (4).

Dissociation in molecular ion surface collisions has been studied extensively. A number of mechanisms can be discerned (see figure). An impulsive collision with the corrugated surface can lead to a direct rupture of a bond: The molecule is smashed to pieces. (7). It has been demonstrated recently that these clusters can be deposited at the surface intact; that is, the cluster did not lose many atoms. The shape of the cluster was modified by its strong interaction with the surface and by the violent collision of the cluster ion with the surface. In such a collision, a cluster is tremendously heated internally and melts (8, 9). To make a better soft landing, spacer layers of noble gas atoms at cryogenic temperatures were adsorbed at the surface. The softer energy transfer to these layers caused the cluster to lose its integrity more slowly, and allowed it to be chemisorbed intact (10). The shape of the cluster changed as a result of the strong chemical interaction (see figure). So, the deposition of a molecular ion intact on a surface remains a formidable task: We require a low energy to prevent impul-
Unresolvable Endings: Defective Telomeres and Failed Separation

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In chess games and mystery novels, the focus is always on the end. A similar captivation with endings has directed the attention of geneticists and cytologists to the ends of chromosomes, the telomeres. The question has always been, Just how are telomeres special, in particular in the telomere problem. In most organisms the telomeres are on the end of the chromosome (once it is circular), and the telomeres are the ends of an otherwise linear DNA molecule such that the chromosome does not shorten with each round of replication. Telomeres are at least two general forms, each of which appears to solve the problem of replicating chromosome ends in a different manner. In most organisms the telomeres consist of tandemly repeated copies of a G-rich simple repeat sequence (for example, TTGGGG in Tetrahymena thermophila). The ends of the chromosome are prevented from shortening by the ability of an enzyme, called telomerase, to synthesize more repeats at each end (3). This de novo synthesis of new telomeric repeats is mediated by a corresponding RNA template within the telomerase holoenzyme.

Curiously, Drosophila melanogaster, the organism in which telomeres were first discovered, possesses a very noncanonical telomere.

References and Notes

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