

Electron and Photon Stimulated Desorption*

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Electron and photon stimulated desorption is a new and advantageous method of determining the properties of the surfaces of materials. The method is important because many emerging technologies for improved use of energy involve serious problems about the surfaces of materials. Surface scientists want to understand surfaces so that eventually they can design materials with very specific surface properties, for example, resistance to corrosion of wear, or ability to catalyze the decomposition of coal to gasoline or methanol, or improved adhesion of inexpensive metal films used as reflectors for solar energy concentrators.

While some chemical and physical properties of surfaces are very complex, surface scientists look first for answers to such basic questions as: Where are the atoms on the surface located? How are they bonded together? How does this arrangement and bonding affect surface properties? Stimulated Desorption studies can be used to help answer these questions in a particularly straightforward way. By studying a wide range of materials we can understand the factors governing these properties and

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provide a basis for designing materials better suited to many of the technologies that drive our economy.

Electrons are the glue that holds solids together. Much of surface science is concerned with the study of "electronic" properties, that is, how are the electrons on the surface distributed in space and energy on a surface and how do they hold the surface together. In electron and photon stimulated desorption experiments, we direct a beam of electrons or photons against a surface, exciting the electrons that bond the surface together, and causing atoms and molecules which are attached to the surface to be repelled (desorbed).

With this technique we can determine the mass of the desorbed particle and thus its identity. Also, the bonded species will desorb in exactly the same way that it was bonded. For example, three oxygen atoms evenly spaced around a tungsten atom on a tungsten surface will desorb in that same pattern, forming three well defined "beams" which can be detected, thus directly revealing the bonding pattern.

In the atoms of a solid we can define two distinct types of electrons, the so-called bonding electrons, which hold the atoms of the solid together but are weakly bound to the parent atom, and the core-electrons, which are very strongly bound to the parent atom and which do not feel the presence of neighboring atoms. The binding energies of the core electrons which can be easily detected by many techniques, serve as an accurate atomic signature of surface atoms.

For a number of years, scientists experimenting with electron stimulated desorption felt that desorption occurs predominantly by direct excitation of the bonding electrons. What we found was that in most cases desorption occurs by excitation of the core electrons of either the bonded species or its bonding-site atom. This made the desorption data readily interpretable and moreover revealed that it contained a wealth of previously unrecognized information, making it a valuable analytical probe of surfaces. Following our discovery of this core ionization mechanism in 1978,⁽¹⁾ we subsequently discovered in 1979⁽²⁾ for the first time that photons could be used for desorption, which is important because it opened the field to the use of synchrotron radiation, adding greatly to the breadth of studies possible with this technique.

Core ionization results in an enormous amount of energy being deposited in a single atom. This energy causes the emission of several bonding electrons (by the so-called Auger effect), which then results in bond breakage and desorption. The important consequence of this is that a species bonded to a specific bonding-site atom will desorb when the energy of ionizing radiation (electrons or photons) becomes great enough to ionize the appropriate core level of the bonding site atom.

By looking for desorption of a species while we increase the energy of the ionizing radiation, we see a threshold-for-emission which is characteristic of the core-level of the bonding-site atomic species and thus can specify the bonding site. This information can only be obtained very indirectly using other surface techniques.

In addition, the process of ionizing the core level is sensitive to both the electronic and geometric structure around the bonding-site atom so we not only specify the site and the species bonded to it, but can ascertain its detailed structure as well. This selectivity allows us to study very complex surfaces since we can single out a particular bonding species/site combination for study. This brings us closer to being able to examine the "real" surfaces encountered in catalysis and corrosion. This also allows us to selectively break bonds on a surface and tailor its chemistry with ionizing radiation, a sort of "atomic surgery".

In discovering and studying this desorption mechanism we also came to understand the kind of bonding between atoms which is necessary for desorption or decomposition to occur. We then examined the problem from the opposite viewpoint and asked ourselves what types of bonding yield a material that is stable in an ionizing environment. The answer to this question is important because the problem of radiation hardness of materials has been one where very few guidelines have emerged, even though it is of enormous technological significance.

The guidelines we have developed⁽³⁾ are simple and proceed directly from the solids electronic structure, which is better understood than the stability. They show straightforwardly the factors governing a wide variety of both stable and unstable materials. This work could have an important impact on the design of materials for use in fusion reactors, materials stable against electrical breakdown or more stable against the radiation encountered in space.

Possibly the most important result of this technique is the information it provides which none of the other, better established techniques do. It allows a completely new perspective to complement the information derived from other surface studies. In something as complex as the study of surface properties, new perspectives are sorely needed.

References

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