Materials modification by electron beams and the desorption of surface-bound species induced by electronic transitions (DIET) are phenomena of both fundamental and technological interest, including electron-beam induced processes in materials growth and etching, lithography, hot-electron induced defects in devices, radiation damage, stimulated catalysis, and even astrophysics. Stimulated desorption is also a concern for damage effects when attempting traditional surface probes such as photoemission, low-energy electron diffraction, and electron microscopy on radiation-sensitive materials, such as oxides and molecular solids. One issue central to understanding stimulated desorption is the relationship between the atomic and electronic structure of a surface species and its desorption probability.

In our recent article “”, we describe experiments demonstrating that total electron-stimulated desorption (ESD) yields are a function of incident electron direction, due to quantum-mechanical scattering and interference of the incident electron to form a surface standing wave in the initial state of the desorption process. This electron standing wave exhibits spatially localized maxima and minima in the electron density. Whether a particlar site on a surface experiences a maximum or a minimum depends on the energy (wavelength) and direction of incidence of the electron, and the arrangement of nearest-neighbor atoms surrounding the site. Since the probability of desorption is proportional to the incident electron density at the site of the “absorber” (the site of the excitation which leads to desorption), the total yield depends upon the local atomic structure and the k-vector of the incident wave. Comparison of experimental data to theoretical calculations can then reveal the atomic bonding geometry of the surface site involved in desorption, and the atomic site whose excitation is responsible for initiating the desorption process. Measurements made in this way reveal information about the desorption complex with sub-angstrom resolution of bond vectors. This Electron Standing-Wave Stimulated Desorption (ESWSD) technique makes possible a new surface spectroscopy with diverse applications. The ESWSD technique is especially useful for surface characterization of radiation-sensitive materials, such as oxides, salts, and molecular solids. ESWSD is a general technique, applicable to any system exhibiting ESD, and combines the chemical sensitivity of secondary-ion mass spectrometry with the structural sensitivity of LEED or photoelectron diffraction. .

ESWSD is not a passive structural characterization technique, since material is actively removed from the surface during analysis. In our paper, we demonstrate that it is, at least in principle, possible to selectively desorb atoms from specific surface bonding. The applications of such a capability are numerous. Besides the obvious utility in the basic sciences, it may be possible to manipulate the growth of materials to produce surfaces having unique structural properties. For some systems, growth proceeds only on areas of the surface on which a chemical passivation layer has been removed. ESWSD makes it possible, in theory, to remove passivation preferentially on selected atomic sites, and therefore to stimulate different growth modes, depending on the energy and direction of an incident electron beam. Changing the incident electron energy or direction may then allow growth to be "switched" between different modes. Such a capability does not now currently exist, and would represent a tremendous advance in our ability to manipulate materials on the atomic scale. To demonstrate this capability, we propose to use ESWSD to control the growth mode of silicon surfaces in a chemical vapor-deposition (CVD) environment.

Structural characterization of surfaces is, of itself, nothing new. However, given the importance of stimulated desorption, very little is known concerning the relationship between the structure of a surface and its sensitivity to ESD. Previous studies have examined ion desorption trajectories, related to initial state bonding geometry because desorption trajectories typically follow bond axes. While these studies have been successful in measuring the bonding geometry of several adsorbate systems, it is a semi-quantitative probe at best, and gives no information regarding bond distances or nearest-neighbor atom locations. As a consequence, ESD has not been a widely utilized probe of surface structure, when compared to other surface spectroscopies, and the structure-function relations involved in desorption are poorly understood. In addition to information about surface structure, ESWSD is potentially a very powerful technique for illuminating the relationship between localized states and excitations leading to desorption.

Potential applications could include assissted growth CVD. For example, passivated Si(100) surfaces have two reconstruction domains. Illumination with low-energy e-beams in carefully selected directions and energies could be used to preferably remove passivation from selected surface sites. While the interference effects do not afford total selectivity, in an active growth environment the scales can be tipped to favor a selected mode of growth over others, potentially producing novel surfaces and substrates for nanotechnology.