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We have recently completed construction of an energy- and angle-resolved detector for neutral particles desorbed from ion bombarded surfaces. It is based on a time-of-flight measurement for the neutral energies, multiphoton resonance ionization (MPRI) for the angular information. Using this detector, we have initiated a series of experiments aimed at determining the energy and angular distributions of the Rh atoms ejected from clean and adsorbate covered polycrystalline and single crystal surfaces. From the polycrystalline material, we find the velocity distribution of Rh atoms follows closely the form predicted by Thompson with a peak intensity occurring at approximately 5 eV and a high energy tail decreasing in intensity as $v^{-2}$. Polar angle distributions exhibit nearly a cos$^2$ shape. From a Rh(001) crystal, the velocity distribution generally peaks at a higher value than that found from the polycrystalline surface, and depends strongly on the value of the polar collection angle. In addition to energy distribution measurements into a given angle, we are able to extract angular distribution measurements of particles with a given azimuth from Rh(001) show three peaks of preferred ejection angles. The position of these peaks are predicted well by the classical dynamics calculations.
FINAL SCIENTIFIC REPORT

for
Period Ending 31 October 1984

Secondary Ion Mass Spectrometry Studies of
Solids and Surfaces

Grant No. AFOSR-82-0057

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I. ABSTRACT

This proposal is aimed toward the development of novel surface analysis methodology through fundamental investigations of secondary ion mass spectrometry and related phenomena. The proposed experiments are based on predictions of a classical dynamics model of the ion bombardment process. Of special interest is to develop suitable theories of ionization of the ejected species which can be incorporated into the classical dynamics model and tested by experiment. These studies will involve both angle-resolved SIMS to examine ion trajectories as well as multi-photon resonance ionization to determine neutral atom trajectories. Furthermore, we will focus on expanding our understanding of the molecular cluster ion process in SIMS. These studies will include the analysis of clusters ejected from a variety of materials including alloys, semi-conductors, organic monolayers on metals as well as a number of well-defined molecular solids. Throughout these investigations we plan to exploit a number of the unique features of SIMS in developing new applications of the technique in the fields of heterogeneous catalysis and electrochemical science.
II. SUMMARY OF OBJECTIVES AND ACCOMPLISHMENTS

Angular distributions of atoms emitted from ion bombarded single crystals have been known for 20 years to reflect the symmetry of surface atoms. (1-3) These angular anisotropies have also been observed for ions emitted from adsorbate-covered single crystals using angle-resolved SIMS. (4) In the latter case, there are distinct surface channeling mechanisms of the desorbing particle that when coupled to classical dynamics calculations of the ion impact event allow the bonding site of the adsorbed atom or molecule to be determined. Due to the lack of sensitive detectors, no studies have ever been reported on the angular distributions of neutrals desorbed from monolayers. These studies are important for gaining a basic understanding of ion/solid interactions and for making comparisons to trajectories obtained for the secondary ions.

We have recently completed construction of an energy- and angle-resolved detector for neutral particles desorbed from ion bombarded surfaces. It is based on a time-of-flight measurement for the neutral energies, multiphoton resonance ionization (MPRI) for the angular information. The detector is operated in an ultra-high vacuum environment, on well-characterized surfaces, and with low primary ion dosages onto the sample. A schematic representation of the experiment is illustrated in Figure 1. The
desorption is initiated by a 0.2 μs, 5 KeV Ar⁺ ion pulse incident on the sample at 45° focussed to 0.1 cm², and ionization is accomplished by absorption of photons from a 5 ns laser pulse obtained from the output of a Nd:YAG pumped dye laser. Under the present operating conditions we can detect neutrals whose kinetic energies vary from 0.2-50 eV into a total enclosed angle of over 100°. A complete analysis may be performed using a total dose of less than 10¹² incident Ar⁺ ions/cm². A detailed description of the apparatus will be given elsewhere. (5)

Using this detector, we have initiated a series of experiments aimed at determining the energy and angular distributions of Rh atoms ejected from clean and adsorbate covered polycrystalline and single crystal surfaces. Rh atoms may be efficiently and selectively ionized using 312.4 nm laser light, obtained by frequency doubling the output of the dye laser. From the polycrystalline material, we find the velocity distribution of rh atoms follows closely the form predicted by Thompson with a peak intensity occurring at ~5 eV and a high energy tail decreasing in intensity as E⁻². Polar angle distributions exhibit nearly a cos² shape. From a Rh{001} crystal, the velocity distribution generally peaks at a higher value than that found from the polycrystalline surface, and depends strongly on the value of the polar collection angle. For example, the energy of the emitted atoms tend to be distributed about higher kinetic energies when the polar angle is chosen to
coincide with a peak in the atom intensities, a result in qualitative agreement with classical dynamics calculations.

In addition to energy distribution measurements into a given angle, we are able to extract angular distribution measurements of particles with a given energy. Polar distribution measurements at a given azimuth from Rh(001) show three peaks of preferred ejection angles. The position of these peaks are predicted well by the classical dynamics calculations. Of particular interest is the peak observed normal to the surface. This normal ejection peak is more prominent at 30 eV than at 10 eV which corresponds to an energy distribution with a larger high-energy tail. Variations in the relative intensity of this center peak relative to the side peaks are observed when an absorbate such as oxygen or sulfur is placed on the crystal surface. It is hoped that these variations, when coupled to computer simulations of the ion impact event, will lead to a new approach for characterizing such adsorbates.

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CUMULATIVE LIST OF PUBLICATION


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LECTURES AND TRAVEL RELATED TO GRANT


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