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OF PHOTODESORBED NEGATIVE IONS*

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92

Techniques for the Detection of Photodesorbed Negative Ions

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1. Introduction

The negative ion channel in stimulated desorption has been the subject of very few studies. The existing experimental data, consisting entirely of electron-stimulated desorption (ESD) experiments, have been summarized in a recent review by KNOTEK [1]. Systems studied have included H^- from H/W [2], O^- from CO/W [3], O^- from O/W [4,5], O^- from O/Mo [5], and O^- from Mo(100) [6] (the other substrates being polycrystalline). For the surfaces investigated above, the ion yield for negatives was one to two orders of magnitude smaller than that for positives. In some cases, both positive and negative ions could be assigned to the same chemical state on the surface through coverage dependence of the signal, for example [2]. There is also a report of ESD of H^- from potassium-dosed polycrystalline Mo in an investigation relating to the conversion of proton beams to negative ions at surfaces [7]. The associated application is in the production of intense neutral beams for fusion experiments. It is also noteworthy that negative ions could have deleterious effects on the performance of forthcoming synchrotron radiation sources utilizing positron beams because of trapping and scattering effects.

This paper reports the direct observation of H^- ions released from a Cs-dosed W(100) crystal by photon-stimulated desorption (PSD). This study utilized the 3m toroidal grating monochromator beamline at the University of Wisconsin-Madison Synchrotron Radiation Center. The main technical problem to be overcome in such experiments is the large background from photoemitted electrons which dominate the weak anion signal by many orders of magnitude. The solution ultimately employed utilized both magnetic suppression of photoelectrons and time-of-flight (TOF) mass separation. No internal modifications to the basic cylindrical mirror analyzer (CMA) [8] were required. We are not aware of any previous reports of the detection of negative ions released from surfaces via photon bombardment, with the exception of high flux laser experiments, in which plasma formation is involved in the ionization process [9].

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2. Experimental

The separation of electrons from negative ions by the application of a magnetic field is a well-known technique based on the expression for the Larmor radius R of a particle of mass m in a magnetic field B :

$$R_{[cm]} = 144.0 \{m_{[u]}E_{[eV]}\}^{1/2} / B_{[Gauss]} \quad (1)$$

where E is the component of particle kinetic energy perpendicular to the direction of B . Such a momentum analysis is effective in the separation of electrons from ions at a comparable energy, the electron orbits being much more strongly perturbed. In the case of stimulated desorption, where the ions have characteristic kinetic energies of a few eV, interference from photoemitted electrons of high energy can still occur, as was found to be the case in the present work. Instruments employing a magnetic mass spectrometer have the intrinsic characteristic of removal of electrons from the negative signal [10,11]. More flexibly, apparatus applying magnetic discrimination just prior to the detector has been used to provide the capability to monitor electrons or anions selectively [12].

In the present instance, a coil of 12.5 mm radius consisting of 5 turns of 0.8 mm dia. copper wire was placed near the sample, as shown in Fig. 1. The coil was axially aligned with the CMA and placed near its entrance aperture. This orientation preserves the conical symmetry of the transmitted trajectories. The axial magnetic field of a loop falls off as $1/r^3$ asymptotically, r being the axial distance from the coil center. The computed range (FWHM) of $|B_{axial}|$ is 19 mm., giving selective electron deflection principally near the CMA entrance. This design avoids the necessity of modifying the CMA, but has the drawback of failing to suppress electrons produced away from the vicinity of the sample.

Fig. 1. Magnetic coil and sample configuration for negative ion detection

Typically a coil current of ~5 A was employed, giving a maximum on-axis magnetic field of 12 Gauss, and corresponding Larmor radii, at $E = 1$ eV, of 3 mm for electrons and 11 cm at 1 atomic mass unit. An experimental check with desorbed H^+ showed little influence of the magnetic field at these levels. The electron suppression achieved in the region of low kinetic energy proved to be about two orders of magnitude. This was significant for the reduction of channeltron fatigue [13] when operating at the high gains desirable for the detection of negative ions. CMA energy scans showed a rise in transmitted signal due to energetic electrons

beginning at ~ 8 eV. The presence of significant residual electron signal below this energy (apparently mainly due to electrons released in the CMA) required the use of the background-subtraction method described next.

Operation in the mode illustrated in Fig. 2 provided electrostatic suppression of sample photoelectrons during most of the TOF cycle. The flight time for unit mass desorbed at low energy was ~ 4 μ s in this instrument [14] (CMA pass energy: 60 eV). The target bias was therefore reset to a value sufficient to retard all sample photoelectrons at the incident photon energy prior to the arrival of any H^- . At the start of each flight sequence a small negative potential was applied to the target for a few μ s, sufficient for low energy H^- to reach the CMA entrance aperture. Heavier anions at similar energy are prevented from reaching the analyzer entrance by the re-application of the strong retarding potential. A relatively long signal gate (A in Fig. 2) was used to collect the weak ion + background electron signal and a second gate (B), in a region where ion signal could not be present, allowed background subtraction. In this method, a higher mass of interest could be selected for observation by lengthening the sample negative pulse duration and adjusting gate A (the lower masses then being obscured by target electrons). However, due to the $\sqrt{m}$ dependence of flight time, the H^- case is the most favorable in terms of separation from heavier species.

Fig. 2. The pulse sequence employed for the special TOF mode employed. A photoelectron burst, partially suppressed magnetically, is detected during the interval of negative sample bias. The strong retarding potential applied over most of the cycle results in a low-pass TOF mass spectrometer (see text).

3. Results and Discussion

Experiments were performed in 10^{-11} Torr vacuum on a W(100) crystal, cleaned and dosed with 1 monolayer of Cs as described previously [15], then exposed to 5 Langmuirs of hydrogen. A brief description of the principal results follows; a more extensive discussion is given elsewhere [16]. Figure 3a shows the kinetic energy distribution of H^- ions obtained by scanning the energy-transmission window of the CMA (pass energy: 60 eV), at a fixed incident photon energy of 50 eV. The distribution is seen to be characterized by small values of the kinetic energy values for the peak (~ 1 eV) and FWHM (~ 3 eV). In Fig. 3b is shown the dependence on incident photon energy of the H^- signal, taken with the analyzer energy window at the maximum signal position of Fig. 3a. Within the noise limits, no dependence on the metal core levels could be observed. No corresponding ESD data for hydrogen on tungsten was reported [2]. A further observation of the present work was that the H^- signal was subject to decay with a half-life of ~ 2 minutes at $\sim 1 \times 10^{-10}$ Torr chamber pressure, indicating the ease with which the active desorption sites could be poisoned. Of course, there may have remained other negative ion desorption

processes at lower rates, which were hidden by the residual photoelectron arrival rate (typically 1 to 10 per second) in the present apparatus. This situation can be substantially ameliorated by relocating the electron suppression to a position just prior to the detector [12].

Fig. 3. (a) Kinetic energy distribution of H⁻ ions desorbed at a fixed incident photon energy of 50 eV; (b) dependence of the H⁻ signal on the energy of the desorbing photon

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