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PHOTON INDUCED FIELD DESORPTION OF HYDROGEN AND NOBLE GASES FROM TUNGSTEN

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Résumé:
Nous présentons les résultats des expériences au sujet de la désorption de gaz différents d'une pointe de tungsten dans des champs de haute tension stimulée pas la radiation de synchrotron (30 - 200 eV). La limite inférieure de la désorption indique une nature quantum-mécanique comme premier pas au cours de la désorption.

Abstract:
Photon induced field desorption of various gases from a tungsten emitter has been observed with synchrotron radiation (30 - 200 eV). The threshold behaviour of the desorption suggests a quantum process as the basic desorption mechanism.

Introduction:
In the conventional photon-induced field desorption experiments using laser light, the desorption mechanism is thermal activation of the adspecies-substrate complex (1). Substituting the laser by a synchrotron light source with higher photon energies, the desorption mechanism changes. The photon flux is not high enough to yield a temperature increase on the tip. Furthermore one observes e.g. in the case of the tungsten hydrogen system a threshold for the desorption at energies < 30 eV which indicates a qualitatively different desorption mechanism from that of the laser experiments.

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Experimental:

Experiments were performed at the storage rings DORIS at DESY (Hamburg/Germany) and BESSY (Berlin) at beamlines equipped with different types of monochromators. Due to the extremely small surface area under investigation and a small quantum yield, we were operating the monochromators in 0th order, therefore using them as broadband filters. The spectral composition of the "white" light is not well known, but from the design parameters of the optical elements in the beam lines it is unlikely that the "white" light differs considerably from the spectrum in the first order. Especially the transmission of the high energy photons in the 0th order is reduced, because their reflectance decreases with higher angles of incidence (2).

For the detection of the surface species we used the time-of-flight (TOF) machine previously described (3). The detection efficiency was enhanced by a few improvements: scattered light was reduced by inserting stops in the SR-beam, matching the detector acceptance angle to the tip by a grounded cone further decreased the number of photo-ions and fluorescence photons registered at the detector, and the use of the FIM-image processing system IP-888 (4) allowed to characterize and record the tip geometry during the experiment. The ultimate time resolution of 1 ns of the IP-888 allowed to explain the broad time correlated background observed in our TOF-spectra as being generated by ions emerging from the glass cold finger, which is charged to high potential by photon impact.

Results:

All desorption experiments were performed on tungsten tips at 80 K. We succeeded in obtaining photon-stimulated field desorption for a number of noble gases as well as for H₂ and CO. A summary of the results is given in table 1, which lists the systems investigated at the different monochromators. The "broadband filter" experiments gave a lower limit for the occurrence of the photon stimulated desorption of surface species: no particles were observed using the 3m NIM with a cutoff wavelength around

<table>
<thead>
<tr>
<th>monochromator</th>
<th>wavelength</th>
<th>observed species</th>
</tr>
</thead>
<tbody>
<tr>
<td>3m NIM BESSY</td>
<td>5 - 35eV</td>
<td>no surface species</td>
</tr>
<tr>
<td>1m NIM DESY</td>
<td>5 - 60eV</td>
<td>H₂⁺,H₂O⁺,H₂⁺⁺</td>
</tr>
<tr>
<td>TGM BESSY</td>
<td>15 - 150eV</td>
<td>H₂⁺,H₂O⁺,H₂⁺⁺</td>
</tr>
<tr>
<td>with Al-filter</td>
<td>25 - 80eV</td>
<td>H₂⁺,H₂O⁺</td>
</tr>
<tr>
<td>TGM DESY</td>
<td>20 - 200eV</td>
<td>H₂⁺,H₂O⁺,CO⁺,He⁺,Ne⁺,Ar⁺,H₂O⁺</td>
</tr>
</tbody>
</table>

NIM = normal incidence monochromator
TGM = torodial grating monochromator
30 eV; inserting an aluminium filter in the beam from the TGM proved that the necessary photon energy is lower than 80 eV, and the first spectrally resolved experiments with hydrogen show a lower limit below 72 eV.

In the TOF-Spectrum the photon-induced events show up as peaks superimposed to an uniform background due to normal field ionization (Fig. 1). One finds two different kinds of correlated signals: relatively broad bands which increase in intensity with increasing gas pressure, and narrow peaks whose intensity is almost pressure independent at pressures \( < 5 \times 10^{-9} \text{ mbar} \). The latter are attributed to species originating from the tip surface, whereas the former are due to atoms which are photoexcited and subsequently ionized in a region of moderately high field extending several 10 \( \mu \text{m} \) from the tip.

In every case, spectra were taken at several tip voltages to study the influence of the field on the desorbing species. In the case of the noble gases one observes a fairly narrow range for the appearance of the surface signals near the best image voltage.

Desorbing hydrogen, one observes three different species: \( \text{H}^+ \), \( \text{H}_2^+ \) and \( \text{H}_3^+ \) (5), the relative intensity of whose depends sensitively on the field at the tip surface.

Surprisingly, \( \text{H}^+ \) desorption was still observed at the highest possible fields corresponding already to slow field evaporation of the tungsten tip.

\( \text{He}^+ \) is observed at 38.8 - 51.8 V/nm and is neither found at lower nor at higher field strengths. This is understandable since He has an extremely low sticking
coefficient at the tip temperature used (77 K) and is only present at the tip in field-adsorbed form (6). At lower fields the He flux to the tip is too small to allow for sufficient adsorption, whereas at high field strength ionization takes place before the atom can accommodate to the surface.

Similarly, Ne\(^+\) desorption from the surface is found predominantly around 35 V/nm, and Ar\(^+\) below 32 V/nm. Kr\(^+\) could not be detected at any field in spite of the fact that krypton should condense as a film on the tip at 77 K.

CO\(^+\) was observed between 26 and 53 V/nm. The intensity of the surface desorption signal is almost independent of field strength over this range. No fragmentation products of CO nor tungsten carbonyls were detected. Also, the adsorption of CO quenches the otherwise omnipresent signals due to hydrogen. Obviously, CO is adsorbed in molecular form and competes for the same binding sites as hydrogen.

Conclusion:

It is possible to photo-desorb a number of noble and reactive gases from tungsten assisted by a high field. The necessary photon energies are in the range of W core excitations. The desorbing species are exclusively singly charged. The observation of the desorption of the light noble gases supports our previously proposed mechanism (7) via a localized excitation in the substrate rather than the adsorbate since it is well known that the excited or ionic state of these noble gases is more tightly bonded to the substrate than is the neutral ground state.

Acknowledgements:

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