A STUDY OF ELECTRON AND UV PHOTON SURFACE INTERACTIONS

Progress Report

for Period March 1, 1977 - February 28, 1978

David Lichtman

University of Wisconsin-Milwaukee

Milwaukee, Wisconsin 53201

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, sub-contractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately owned rights.

November 1977

Prepared For

THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER
CONTRACT NO. EY-76-S-02-2425

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *eb*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

"A Study of Electron and UV Photon Surface Interactions"

Principal Investigator: David Lichtman

PROGRESS REPORT

ABSTRACT

Considerable data on ESD from 304 stainless steel have been obtained. Cross sections as a function of bombarding electron energy, surface temperature, desorbing species, etc. are now available. Energy distributions of desorbing ions have also been tabulated. It is interesting to note that regardless of sample material and sample preparation H^+ and F^+ were always predominant ESD species. Electron induced dissociation of metal oxides, noted during AES measurements, has been studied for a variety of materials including oxides of molybdenum, niobium and tungsten.

Photodesorption is detected from niobium and is related to the thick niobium oxide surface layer. CO_2 is again the dominant desorbing species.

Ion impact desorption studies have begun and both positive and negative desorbing ions have been detected. Preliminary simultaneous electron and ion bombardment measurements indicate definite but quite complex synergistic effects.

The critical reviews on ESD and photodesorption have been updated and accepted for publication.

"A Study of Electron and UV Photon Surface Interactions"

PROGRESS REPORT

Introduction

This past year saw continued activity in electron stimulated desorption and photodesorption. Experiments were begun on ion impact desorption. The critical reviews on ESD and photodesorption were updated and accepted for publication. Specific information in these areas are detailed in the following sections.

Electron Stimulated Desorption

Considerable data was obtained on type 304 stainless steel as a substrate. A detailed description appears in the Ph.D. thesis⁽¹⁾ of Dr. Monte Drinkwine and the pertinent results have been written up and accepted for publication.⁽²⁾ Typical of the type of data obtained are the results shown in Table I and Figs. 1 and 2. Additional data were obtained on other substrates such as platinum and niobium. Some of these results are reported in ref. (3) (copies enclosed). A summary of the specific data obtained this past year follows.

1. Bombarding electron energy (E_e) vs. ion yield curves for H^+ and F^+ from S.S., Pt, and Nb. All curves show the same general behavior, i.e. a maximum yield at low E_e (<500 eV) with a slowly decreasing yield after the maximum, as the bombarding electron energy is increased. Data for O^+ from Nb was also obtained. It shows the same general behavior as the H^+ and F^+ data.
2. Total cross section vs. E_e data for ESD of hydrogen from S.S. was obtained. This data is indirectly indicative of neutral desorption. The general behavior was similar to the ion desorption data.

3. Ion yields, ion cross sections, and total cross sections were measured for various ESD species from various substrates. The results are shown in Table I.
4. For materials having an oxide surface (e.g., S.S. and Nb), ESD ion yields were often quite large even at elevated sample temperatures (~400°C), whereas ion yields from Pt were negligible at 400°C. This result is significant in terms of cleaning CTR first walls.
5. Regardless of sample material and sample preparation (i.e. cleaning) H^+ and F^+ were always predominant ESD species.
6. The Ion Energy Distributions (IED) of ESD ions were investigated. The IED of a particular ion species (e.g., H^+) was independent of the bombarding electron energy (over the range investigated, i.e., $E_e = 300-4000$ eV).
7. Electron bombardment of the Nb sample did not result in a decrease of all ESD ion signals with time. In fact, the O^+ ESD ion signal increased with continued electron bombardment.
8. SIMS results show a change in the surface character of S.S. during heating in vacuum to 450°C. The surface concentration of Cr decreases while that of Fe increases.

Photodesorption

The main progress this past year involved a theoretical modeling of the photodesorption process which provided excellent agreement with the experimental results obtained on ZnO.⁽⁴⁾ Experimentally, very interesting data was obtained on niobium. This material reacts with oxygen very strongly to produce a rather thick oxide layer which then acts as a semiconductor thus allowing photodesorption to occur. Early results have been published⁽⁵⁾ (copies enclosed).

Ion Impact Desorption (IID)

The main experimental system was modified to allow the detection of ion induced desorbing positive and negative species. Preliminary results have been obtained on stainless steel and molybdenum substrates. This work is just beginning and considerable effort has gone into optimizing the system for obtaining good IID data. Some of the preliminary measurements have also been made using simultaneous electron and ion bombardment. It seems that these types of measurements will be quite feasible in our system.

Critical Reviews

The critical review on ESD was updated through December 1976 and was accepted for publication.⁽⁶⁾ It should appear before the end of 1977. The critical review on photodesorption was updated through the middle of 1977 and will appear in the proceedings⁽⁷⁾ of the 3rd ISISS (held on our campus in August 1977). These proceedings will be published by CRC and should appear in early 1978.

Electron Induced Dissociation

While studying a number of metal oxides using Auger Electron Spectroscopy (these oxides are being evaluated in the photodesorption program), we became aware of considerable surface chemical modification due to the electron beam. Specifically, the oxygen is preferentially removed leaving regions of elemental metal. This process could have significant effects on the operation of a controlled fusion device and should be studied in some detail. We have obtained some data in this area. Results on molybdenum oxides,⁽⁸⁾ niobium foil, and niobium oxides⁽⁹⁾ have been submitted for publication. Data has also been obtained on tungsten, bismuth, and thallium oxides. Considerations of the general decomposition processes are being evaluated.

References

1. "Bombarding Electron Energy Effects in Electron Stimulated Desorption Studies. Electron Energies 50-6000 eV," M. J. Drinkwine, Ph.D. Thesis, University of Wisconsin-Milwaukee (1977).
2. "Study of ESD From Type 304 Stainless Steel In Relation to CTR First Wall Applications," M. J. Drinkwine and D. Lichtman, J. Vac. Sci. Technol. 15-1, 1978 (to be published).
3. "High Electron Energy ESD of H^+ and F^+ From Stainless Steel, Platinum, and Niobium," D. Lichtman and M. J. Drinkwine, Proc. 7th Intern. Congr. and 3rd Intern. Conf. Solid Surfaces (Vienna, 1977).
4. "Relationship Between Photodesorption and Surface Conductivity in ZnO ," Y. Shapira, R. B. McQuistan, and D. Lichtman, Phys. Rev. B15, 2163 (1977).
5. "Photodesorption From Niobium Surfaces," Proceedings of the 7th IVC and 3rd ISSC in Vienna, Austria, Sept. 12-16, 1977.
6. "Electron Stimulated Desorption: A Critical Review," M. J. Drinkwine and D. Lichtman, Prog. Surf. Sci. 8 (to be published).
7. "Photodesorption: A Critical Review," 3rd ISISS (1977) (to be published).
8. "Electron Impact Induced Reduction of Molybdenum Oxides Observed by AES," has been submitted for publication.
9. "Electron Irradiation Effects on Oxidized Nb Foil and Nb_2O_5 ," has been submitted for publication.

TABLE I.

Ion Yields and Cross Sections for ESD of
Hydrogen, Fluorine, and Oxygen From 304 S.S., Nb,
and Pt (Using 1000 eV Electrons)

		hydrogen	fluorine	oxygen
$Y_{\max}$ (ions/electron) H^+ , F^+ , or O^+	1	$2-5 \times 10^{-7}$	$0.4-2 \times 10^{-6}$	-
	2	$2-5 \times 10^{-7}$	$1-3 \times 10^{-6}$	$1-4 \times 10^{-6}$
	3	$\sim 2 \times 10^{-7}$	$\sim 2.5 \times 10^{-7}$	-
Q^+ (cm^2) for H^+ , F^+ , or O^+	1	$\sim 10^{-19}$	$\sim 10^{-17}$	-
	2	$\sim 10^{-19}$	$\sim 10^{-17}$	$\sim 5 \times 10^{-19}$
	3	$\sim 10^{-19}$	$\sim 10^{-17}$	-
Q_T (cm^2)	1	$\sim 1 \times 10^{-16}$	$\sim 1 \times 10^{-17}$	-
	2	-	$\sim 1 \times 10^{-17}$	-
	3	-	$\sim 1 \times 10^{-17}$	-

Samples: 1. 304 S.S.
2. Nb
3. Pt

Fig. 1. Our results of Fig. 24 for the relative behavior of Q^+ vs bombarding electron energy for ESD of H^+ from S.S. is compared to the cross section for dissociative ionization of gas phase H_2 by electron bombardment (producing H^+)⁷⁶ vs bombarding electron energy. The ESD H^+ curve (H_s^+) has been arbitrarily normalized to match the peak height of the gas phase H^+ curve (H_g^+). The general shape of the curves appear similar, but the ESD H^+ curve is broadened compared to the gas phase H^+ curve.

Fig. 2. Our results for the behavior of total cross section (Q_T) vs bombarding electron energy for ESD of hydrogen from S.S. (Fig. 28) are compared with the behavior of cross section vs bombarding electron energy for production of H_2 from gas phase H_2 by electron bombardment⁷⁶. The cross section scale for the two sets of results has been adjusted so that the maximum of each curve has the same vertical height. The general shape of the curves appear very similar. However, the apparent maximum for the ESD results occurs at a higher electron energy (~ 200 eV as compared to ~ 100 eV).