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PHOTON SPUTTERING OF H_2O ICES: A PRELIMINARY REPORT

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ABSTRACT

A preliminary measurement of the total yields of ejected ions and electrons from H_2O ices has been carried out using the He I 584Å resonance line as the incident photon beam. The H_2O ices were prepared at 77K in an ultrahigh vacuum system. The total yield of the ejected ion species and electrons was determined to be 8.8×10^{-5} and 4.2×10^{-4}, respectively.

INTRODUCTION

Sputtering of atoms and molecules from surfaces of cosmic materials is an important process for mass transfer and evolution in a number of astronomical environments, e.g., comets, asteroids, planetary satellites and rings. The excitation sources for sputtering are primarily solar photons, the solar wind, and magnetospheric particles. Experiments on sputtering by energetic ions have been carried out in several laboratories[1-6] and the results have been applied to astrophysical problems.[7] However, this is not the case for solar photon sputtering. In fact, there exists very limited data in the VUV-EUV region.[8] Current theories and model calculations assume that the solar photon energies are directly converted into heat which controls the vaporization of the cosmic material.[9,10] Mass loss due to photon sputtering has not been included since the required data are not available.

We have initiated an experimental program to study solar photon sputtering of molecular ices, such as H_2O ice, NH_3 ice, SO_2 ice, CO_2 ice, etc., from the VUV through the EUV region. The temperature for the ices will be chosen to simulate realistic planetary conditions. We plan to measure the total photon sputtering yield which includes yields for producing ions and neutrals from molecular ices. However, in the initial study we have only measured the total yield of ejected ions and electrons from water ices at the He I 584Å line.

EXPERIMENTAL SETUP AND EXPERIMENTAL PROCEDURES

A schematic diagram of the experimental setup is depicted in Fig.1. Detailed diagrams of the photon flux monitor and the photon-water ice interaction region are shown in Fig.2. The vacuum system consists of an isolation chamber which is pumped by an 80ℓ/s turbomolecular pump and an interaction chamber which is pumped by a 25ℓ/s VacIon pump. The base pressure of the vacuum system is 2×10^{-8}Torr. A liquid nitrogen dewar system provides a cold finger at 77K which is used for the preparation of water ices. The light source used in this preliminary study was a DC glow discharge which was operated at the optimal conditions for the He I 584Å line.

The photon flux monitor is made of a nickel mesh with 90% optical transmission. The calibrated nickel mesh signal corresponds to 11.7 (±0.4)% of the total photon flux. The photon flux can be constantly monitored in this way since the mesh was permanently installed in the path of the incident photon beam. The ion detector in the interaction region consists of an ion collector wire maintained at a negative potential with respect to the cylindrical cell which surrounds it. The detector has a unity collection efficiency when an appropriate voltage has been applied and has previously been used in our laboratory.[11] This ion detector can be used to detect electrons by simply reversing the voltage polarity of the cylinder and the collector wire. The ion collector was mounted on a bakable linear motion feedthrough. When the water ices were being prepared, the ion detector was retracted to avoid water condensation on the detector surfaces.

The high purity water was provided by Stohler Isotope Chemicals Company. The deposition rate of water vapor onto a quartz substrate was kept constant by immersing the water sample reservoir in an isopropanol-dry ice bath. A thick (several μm) water ice sample was used in the present study.

RESULTS AND DISCUSSION

The electron current from the nickel mesh due to 584Å photons is shown in Fig.3a as a function of collector bias voltage. In the present work a bias voltage of 80 volts in the plateau region was selected for the incident flux measurements, giving an absolute value of 7.89×10^{10} photons/sec.

The ion and electron currents produced by 584Å photon sputtering of water ice at 77K are shown in Fig.3b. Similar to the case of nickel mesh, the measured

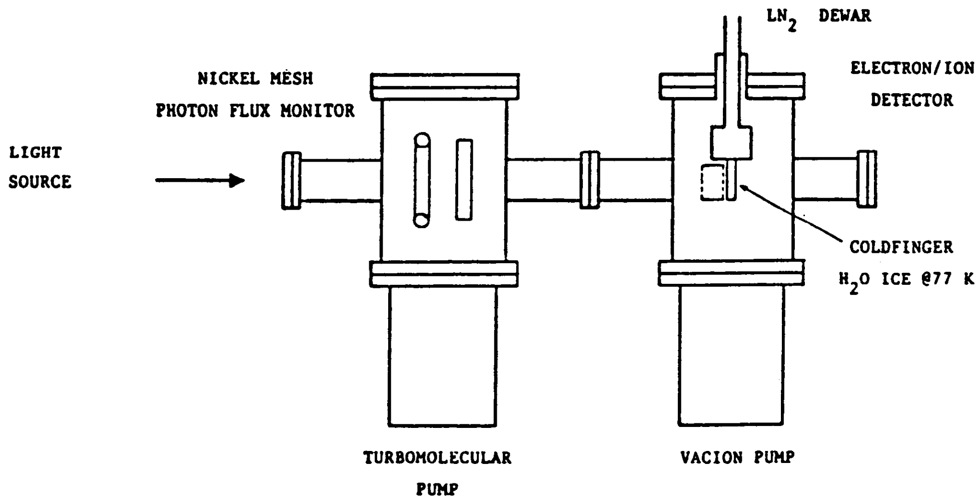

Fig. 1. Schematic diagram of the experimental setup.

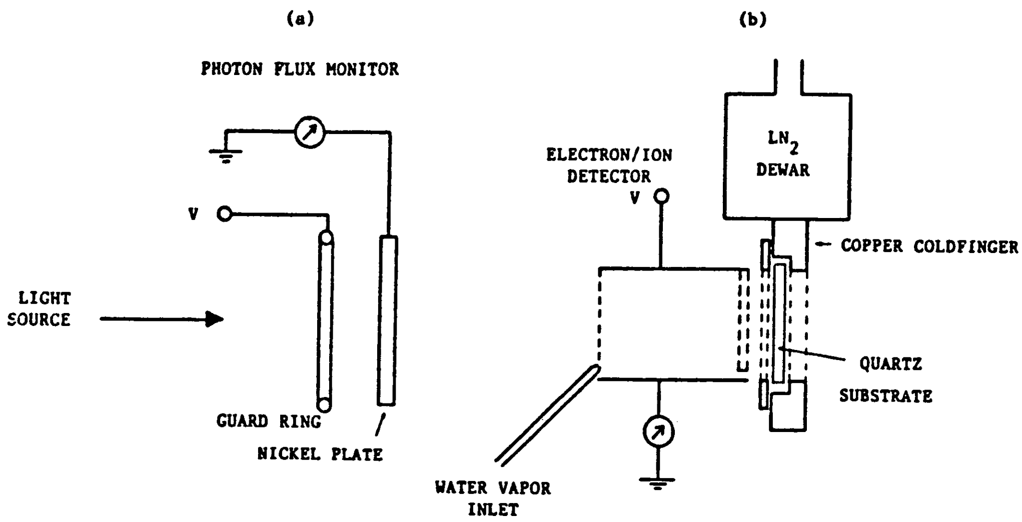

Fig.2. Detailed diagrams for (a) the photon flux monitor and (b) the photon-water ice interaction region.

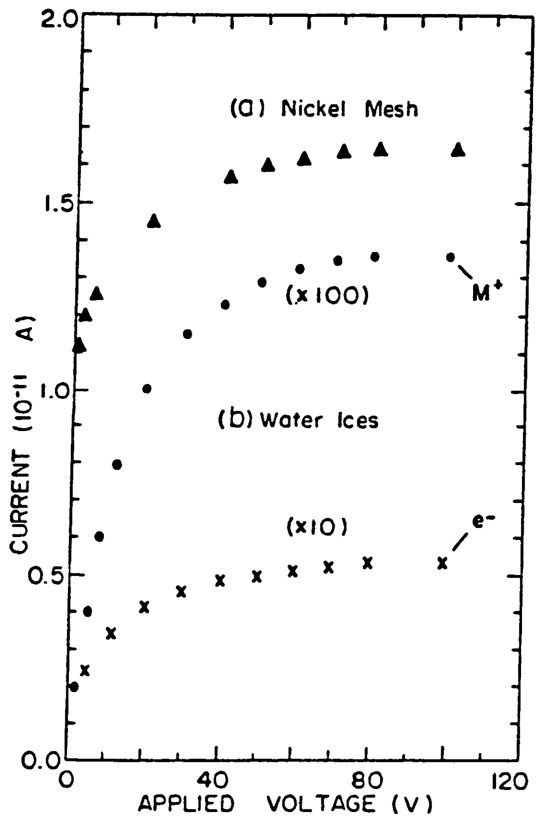

Fig.3. The ion/electron current as a function of the applied repeller voltage.

ion and electron currents approach a plateau at an applied voltage of ~ 70V. The measured quantities at V=80 volts were used to determine the total yields of ejected ions and electrons. As can be seen from Fig.3b, the ion and electron currents are 1.2×10^{-13} and 6.46×10^{-13} ampere, respectively. Knowing the absolute incident photon flux, the total yields of ejected ions and electrons from photon sputtering of H_2O ice at 77K, at a photon wavelength of 584Å, are found to be $8.8(\pm 1.1) \times 10^{-5}$ and $4.2(\pm 0.2) \times 10^{-4}$, respectively. The yield of ejected electrons is about a factor of five larger than that of ejected ions. Thus, upon absorbing a 584Å photon the water ice is preferentially left with an excess "ion" after ejection of an electron. The excited ro-vibronic energy of those "ions" may, however, convert into nuclear motion such that the surface binding energy can be overcome resulting in the ejection of ions. In the present case, this probability only amounts to 20%.

The absorption cross section[12] of H_2O vapor at 584Å is $2.18 \times 10^{-17} cm^2$. If we assume the absorption cross section of water ices is the same as that of water vapor, then the ion sputtering cross section of water ices will be $1.9 \times 10^{-21} cm^2$ at 584Å.

CONCLUDING REMARKS

In this preliminary report we have demonstrated the feasibility of measuring the total yield of ejected ions and electrons from photon sputtering of water ice at the He I 584Å line. Similar measurements using the NeI 736/743Å lines and others are currently in progress in our laboratory. However, the most difficult measurement will be the total yield of ejected neutral species which can be many orders of magnitude higher[4] than that of the ejected ion species reported here. We have plans to carry out such measurements from water ices and other molecular ices at temperatures to be chosen to simulate realistic planetary conditions.

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REFERENCES

1. W.L. Brown, L.J. Lanzerotti, J.M. Poate, and W.M. Augustyniak, Phys. Rev. Lett. 40, 1027 (1978).

2. D.B. Chrisey, J.W. Boring, J.A. Phipps, R.E. Johnson, and W.L. Brown, Nucl. Instr. and Meth. B13, 360 (1986).

3. D.J. Lepoire, B.H. Cooper, C.L. Melcher, and T.A. Tombrello, Rad. Effects 71, 245 (1983).

4. J. Schou, Nucl. Instr. and Meth. B27, 188 (1987).

5. F. Besenbacher, J. Bottiger, O. Graversen, J.L. Hansen, and H. Sorensen, Nucl. Instr. and Meth. 191, 221 (1981).

6. A. Bar-nun, G. Herman, M.L. Rappaport, and Yu. Mekler, Surf. Sci. 150, 143 (1985).

7. J. Klinger, D. Benest, A. Dollfus, and R. Smoluchowski, eds., Ices in the Solar System (Reidel Publishing Co., Boston, 1985).

8. P.K. Haff, A. Eviatar, and G.L. Siscoe, ICARUS 56, 426 (1983).

9. D.A. Mendis, H.L.F. Houpis, and M.L. Marconi, Fund. Cosmic Phys. 10, 1 (1985).

10. L.L. Wilkening, ed., Comets (The University of Arizona Press, Tucson, AZ, (1982).

11. R.W. Carlson, H.S. Ogawa, E. Phillips, and D.L. Judge, Appl. Opt. 23, 2327 (1984).

12. C.Y.R. Wu, and D.L. Judge, J. Chem. Phys. 89, 6275 (1988).