SPUTTER-INDUCED ATMOSPHERE AND MOLECULAR EJECTION ON IO, J. W. Boring, J. W. Garrett, E. Sieveka, and R. E. Johnson, Dept. of Nucl. Engr. & Engr. Phys., Univ. of Va.,Charlottesville, VA. 22901 W. L. Brown & L. J. Lanzerotti, Bell Labs., Murray Hill, NJ 07974

We have recently measured total yields, velocity spectra, and mass spectra of molecules ejected from SO_2 ice at low temperatures by low energy ions (1). This sputtering process has been proposed as the source of a neutral torus in the vicinity of Io (2,3,4) and a source of a tenuous atmospheric corona about Io (4,5). In earlier work, estimates of molecular ejection from Io and molecular transport across the surface were made using models of ejected molecule velocity spectra based on sputtering of metals and semiconductors or models assumed to be reasonable for other reasons. Recently, measured velocity and mass spectra for ion bombardment of D_2O (H_2O) ice were used to determine erosion of the surfaces of ice covering satellites of Jupiter and Saturn (6).

Using a mass spectrometer to detect the neutral molecules ejected from an SO_2 ice target by keV ions we have identified the principal sputtering products. Such measurements indicate that mass 32 (S,O_2), 48 (SO), and 80 (SO_3) are ejected from the bombarded surface, as well as the dominant, undissociated SO_2 molecules. The fraction of the total surface loss on ion bombardment dur to ejection of SO_3 molecules is relatively small (~2%). In earlier measurements of the erosion of SO_2 ice by MeV ions it was noted that the composition of the target material changed. On heating to remove the more volatile species a residue enriched in oxygen relative to sulfur remained (7). Moore, et al. (8) observed a band which they associated with SO_3 in the irradiated ice. They present measurements definitely indicating the production of SO_3. We have found the yield of SO_3 to be fluence dependent, reaching a constant, equilibrium value after receiving fluences of 50 keV argon ions of the order 10^{14} ions/cm^2. This equilibrium indicates that a new composition has been attained in the surface region. Noting that the erosion yield for SO_2 ice by the co-rotating sulfur and oxygen ions is somewhat smaller than that for 50 keV argon ions, the time to achieve an equilibrium state for a patch of fresh SO_2 on Io requires at least 3 hours. However, as the relatively slow co-rotating ions penetrate only a few monolayers into the surface the amount of altered material is small. Therefore the signal strength of SO_3 would be very small unless there was a significant flux of very energetic ions with larger penetration depths.

We have also made total yield measurements for keV argon ions bombarding SO_2 ice (Table I). Unlike the previous measurements of erosion yield, in which the dominant ejection process was associated with electronic excitation and ionization produced by fast ions, (4,7) in the present measurements the dominant energizing process is direct collisions with the atoms in the material. As expected (4) the observed yields are larger than those evaluated using an extension of a model for sputtering of metals. Based on the recent measurements the low energy yields for incident sulfur ions given in Figure 5 of Lanzerotti, et al. (4) are about 30% too small. The yield measurements imply a rate of depletion of condensed SO_2 on the surface of Io, locally deposited by a volcano on its trailing side, of the order of 3×10^{-4} cm/yr. This rate is comparable to estimates of the resurfacing rate (9).

In addition to the chemical changes induced and the removal, locally, of SO_2, the molecules sputtered by the co-rotating ions form a ballistic atmospheric corona. To describe this 'atmosphere' (10) we have modified our Monte

Carlo calculation of the sputter redistribution across the surface of Io (11). The model uses the measured energy spectra and yields, and assumes unit sticking probability, collisionless trojectories, and isotropically distributed condensed SO_2. The calculation of such an atmosphere permits realistic estimates to be made of total loss of SO_2 and its products to both the neutral cloud, by direct ejection from the surface, collisional ejection by ion impact, and the dissociation by electron impact. We have also calculated the supply of ions to the Jovian magnetosphere produced by electron ionization and charge exchange.

Table I
Sputtering Yields
SO_2

Incident Ion	Yield (molecules/ion)
1.5 MeV He^+	17
1.5 keV Ar^+	166
30 keV Ar^+	182
45 keV Ar^+	214

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