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Implantation of S^{n+} ions on the Galilean moons

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Abstract

We present new experimental results on the implantation of S^{n+} (n = 7, 11) ions at energies between 105 and 176 keV in water ice at low temperatures (80-150 K). The results indicate that implantation produces sulphuric acid. SO_2 and H_2S have not been detected by IR spectroscopy. The results are discussed in the light of their relevance to understand the effects of the variegated irradiation environments the icy Galilean moons are embedded in.

1. Introduction

Earth based and space observations indicate that on the surface of Europa, Ganymede and Callisto water ice is the dominant species along with hydrated materials (particularly abundant is sulfuric acid) and minor amounts of some volatile species such as H_2O_2, SO_2, and CO_2.
The formation mechanism of those molecules is still an open question. A possible way is via exogenic processes such as implantation of carbon or sulfur ions present in the Jovian magnetosphere, as suggested since several years on the basis of numerous experimental results, for a review see [1].
As a contribution to the field, here we present the results of new implantation experiments in which sulfur ions, S^{n+} (n = 7, 11) are implanted into thick films (i.e. thicker than the penetration depth of the ions) of water ice. A series of experiments are still being performed at the date we prepare this manuscript. Preliminary results are reported here.

2. Experimental apparatus

The experiments are being performed at ARIBE, a facility of GANIL (Grand Accélérateur National d'Ions Lourds, Caen, France) where multiply charged ions at different energies (176 and 105 keV in the present case) can be obtained.

Water vapor is deposited at low T (80 and 150 K) onto IR transparent substrates (CsI) in an high-vacuum chamber (P~$2x10^{-8}$ mbar). The chamber is faced through IR-transparent windows, to a FTIR spectrophotometer (Nicolet Magna 500), the sample-cryostat system can be rotated and is fixed at three different positions to allow: (a) gas deposition, (b) FTIR measurement and (c) ion irradiation (for details see [2]).

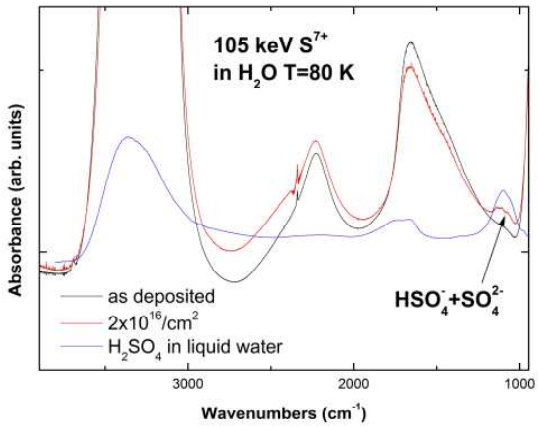

Figure 1: IR spectra of water ice as deposited at 80 K and after implantation of 105 keV S^{7+} ions. Also shown is the synthetic spectrum of sulfuric acid hydrate (32%wt, 210 K) (see text).

3. Results

In Fig. 1 we show the IR spectra of water ice as deposited at 80 K and after implantation of 105 keV S^{7+} ions.
For comparison the synthetic spectrum of sulfuric acid hydrate (32%wt, 210 K) is also shown. This has been obtained by using the temperature and composition dependent optical constants of H_2SO_4 in water [3].
The synthesis of hydrated sulphuric acid after sulphur ion implantation in water ice is made clear from the

observations of HSO_4^- and SO_4^{2-} (the products of the dissociation of sulfuric acid in water). A detail of the multiply peaked band due to sulphuric acid is shown in Fig. 2. Although the analysis of data is still in progress it seems that, at least at the investigated fluences (S-ions cm^{-2}) the area of the band increases linearly with the ion fluence. The formation yield has not yet been estimated .
We have also searched for SO_2 and H_2S formed by implantation but, up to now, we have no evidence of the formation of any significant amount of those species.

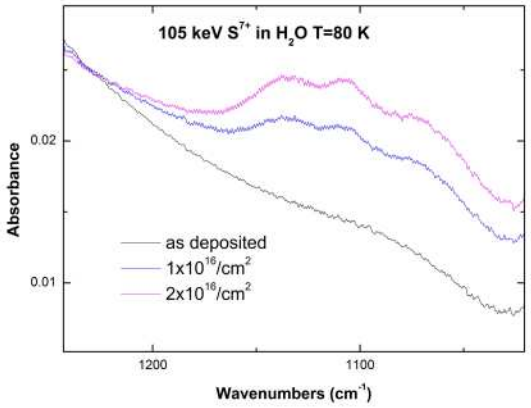

Figure 2: IR spectra of water ice as deposited at 80 K and after implantation of 105 keV S^{7+} ions at two different ion fluences.

4. Discussion

Experiments with multi-charged ions at different energies are particularly relevant to simulate the complexity of the irradiation environment the icy Galilean satellites are embedded in.
They orbit within Jupiter's giant magnetosphere and their surfaces are subjected to intense bombardment by electrons, protons and multi-charged ions and the abundance of some chemical components of the surface seems to be correlated with that of energetic ion fluxes at the surface.
The results of the present experiments confirm and extend those previously obtained using single ionized sulfur at 200 keV [4] and will be used to better understand the distribution of sulfuric acid and sulfur dioxide on the surface of the Jovian moons.
In this scenario the recent finding of a very good relationship between the amount of sulfuric acid measured in different regions of Europa and the local flux of magnetospheric sulfur ions is particularly significant [5]. Also extremely interesting is the question of the exogenic nature of SO_2 that seems to be correlated with the cumulative flux of energetic ions and electrons [6] and, based on the present results, would not be directly correlated to the implanted sulfur fluxes.

Acknowledgements

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