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

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Abstract

We present new experimental results on the implantation of $^{13}C^{n+}$ (n =2, 3) ions at an energy of 30 keV in water ice at low temperatures (15 and 80 K). The results indicate that implantation produces H_2O_2, and $^{13}CO_2$. 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 and minor amounts of some volatile species such as H_2O_2, SO_2, and CO_2.
The formation mechanism of those molecules is a still open question. A possible way is via exogenic processes such as implantation of carbon or sulfur ions of Jovian magnetosphere, as suggested from several years on the basis of numerous experimental results, for a review see [1].
As a further contribution to answer those questions we started a new series of implantation experiments in which reactive ions, $^{13}C^{n+}$ (n =2, 3) in this starting case, are implanted into thick films (i.e. thicker than the penetration depth of the ions) of water ice. A series of experiments are being still performed at the date we prepare this manuscript. Preliminary results are here reported.

2. Experimental apparatus

The experiments are being performed at ARIBE, a facility of GANIL (Grand Accélérateur National d'Ions Lourds, Caen, France) where multicharged ions at low energy (8-30 keV) can be obtained.
Water vapor is deposited at low T (15 and 80 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 detail see [2]).

3. Results

In Fig. 1 we show the IR spectra of water ice as deposited at 15 K and after implantation of 30 keV $^{13}C^{++}$ ions at two different ion fluences .
In the bottom panel the formation of H_2O_2 is testified from the band centered at about 2850 cm^{-1}, that is superimposed to the dominant water band at about 3300 cm^{-1}. This band is due to the chemistry of irradiated water ice that starts with the dissociation to H+OH followed by the formation of many neutral, excited and ionized species: H, H_2, O, O_2, H_2O, HO_2, H_2O_2 [e.g., 3]. In the top panel of Fig. 1 the formation of $^{13}CO_2$ is evidenced from the appearance of its most intense fundamental vibration centered at about 2275 cm^{-1}. The formation of $^{13}CO_2$ occurs as well after implantation at 80 K as evidenced in Fig. 2 where it is also possible to see that ^{13}CO is not formed at 80 K (as well as at 15). The absence of ^{13}CO supports the hypothesis that CO_2 might be formed by direct addiction of C to O_2 that is one of the products of water radiolysis or by: $HO_2+C \rightarrow H+CO_2$.
As said the experiments are being still performed and analysed. The first results indicate that, irrespective of the temperature, the amount of formed $^{13}CO_2$ varies linearly with the ion fluences (we have implanted a maximum of about $1x10^{16}$ ions/cm^2).

4. Application to icy satellites

Experiments with multi-charged ions at energies of 10's keV are particularly relevant at simulating the

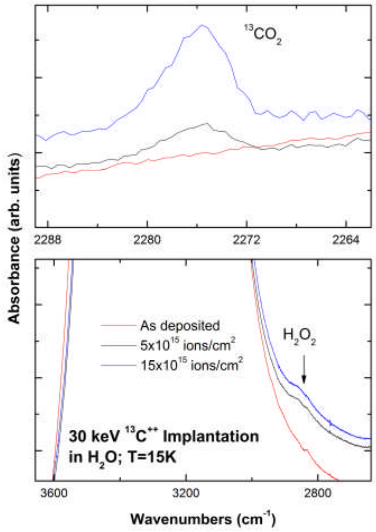

Figure 1: IR spectra of water ice as deposited at 15 K and after implantation of 30 keV $^{13}C^{++}$ ions at two different ion fluences.

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 [4].

It is usual to refer to ions and electrons below about 10 keV as "plasma" and above as "energetic particles". The plasma nearly corotates with Jupiter and then it flows preferentially onto the hemisphere trailing the satellite's motion. The less abundant but higher energy particles bombard the satellite in more complex ways exhibiting different spatial distributions depending on their energy, mass, charge, and the electric and magnetic fields near each moon. (see [4] and references therein).

The results of the present experiments will be used to better understand the distribution of carbon dioxide that can be formed on the icy moons by magnetospheric ion implantation. The results will also be compared with other available in the literature, namely implantation of single charged 30 keV carbon ions [5] and double charged 2-4 keV carbon ions [6-7].

Acknowledgements

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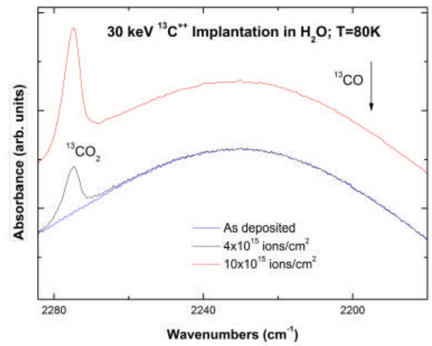

Figure 2: IR spectra of water ice as deposited at 80 K and after implantation of 30 keV $^{13}C^{++}$ ions at two different ion fluences.

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