SPUTTERING OF SURFACE MATTER FROM EUROPA

H. Lammer [(1)], P. Wurz[(2)], I. L. ten Kate[(3)], R. Ruiterkamp[(3)]

[(1)]Space Research Institute, Austrian Academy of Sciences, Schmiedlstr. 6, A-8042 Graz, Austria
Phone: +43 316 4120641, Fax: +43 316 4120690, Email: helmut.lammer@oeaw.ac.at
[(2)]Physics Institute, University of Bern, Sidlerstr. 5, CH-3012 Bern, Switzerland
E-mail: peter.wurz@soho.unibe.ch
[(3)]Sackler Laboratory for Astrophysics, Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands
E-mail: tenkate@strw.leidenuniv.nl, ruiterka@strw.leidenuniv.nl

ABSTRACT

At the Jovian satellite Europa; the intense radiation bombardment of the surface produces a gas exosphere of sputtered molecules and volatile composition products. Only a couple of species in the exosphere have been identified: O_2 from water/ice, Na and K from decomposition of hydrated minerals, and likely, H_2O, SO_2 and CO_2 . A detailed study of the Na/K ratio in Europa's exosphere will give a better understanding about the fractionation on freezing and up welling of subsurface ocean material. It is suggested that this exosphere must contain many other molecular species, which should be detectable, by a future space probe. This presents an exciting possibility of identifying surface constituents by detecting gas-phase products. Since the surface sputtering yields by heavy energetic ions like O or S are of order unity, we study if even heavy organic molecules imbedded in ice of Europa's surface can be ejected into the gas-phase and detected with a spacecraft orbiting Europa.

1. SALTS AND ORGANICS ON EUROPA'S SURFACE

Europa's surface consists mainly of H_2O-ice and non-ice material. Prior to the Galileo data the only non H_2O-ice matter that was identified in the spectral features was SO_2 and Na. Based on the near infrared spectral data acquired with the Galileo NIMS instrument, hydrated salts and CO_2 were also found. In addition volatiles such as CO, CH_4 and NH_3, silicates and organics have been suggested [e.g., 1].

Salts: The presence of salts on the surface of Europa is suggested from spectral signatures of the Galileo NIMS data. The spectra match roughly:

$$Na_2CO_3 10H_2O \quad \text{and} \quad MgSO_4\, 6H_2O, \qquad (1)$$

or their mixtures. After confirmation, this supports the suggestion that hydrated salts would be deposited on the surface of Europa by cryovolcanic flows from the subsurface brine ocean. Laboratory data on the sputtering of salts are limited, although one can consider the ejecta from hydrated salts exposed to energetic particles.

Organics: Laboratory studies of the desorption of organic molecules by energetic ion bombardment indicate that, in addition to smaller and more volatile fragment molecules, heavy ion bombardment of organic samples leads to the ejection of whole molecules [e.g., 2]. The incident ions are 45 keV Ar^+ which have energy deposition profiles comparable to those of Jovian energetic S^+ and O^+ ions. From these experiments exist SIMS spectra of ions produced by bombarding a sample of the amino acid cysteine (m=121 amu) with 45 keV Ar^+ ions [3]. One can see strong signals for ion compounds like HCN^+, CO_2^+ and also for the whole molecule. If such molecules are presented in or on the surface-ice of Europa, whole organic molecules, including small and large fragments and stable decomposition products will be sputtered into Europa`s exosphere. Its detection, therefore, may be indicative of the presence of organic molecules. To confirm this, the detection using a mass spectrometer on an orbiting spacecraft is required. Further such an instrument can also measure isotope ratios to determine the surface age, micrometeorite impacts and may identify surface areas where such molecules are located.

2. TIME OF FLIGHT MASS SPECTROMETER

A Measurement Analyzer for Ions and Atoms (MAIA) instrument is intented for ESA`s Mercury Planetary Orbiter (MPO) mission where it will be a part of the SERENA package. MAIA will study the neutral atoms and ions in Mercury's exosphere. The instrument is a time of flight mass spectrometer, which will measure the isotopic and chemical composition along the MPO trajectory around the planet. MAIA's resolution is sufficient to resolve all elements up to Mass 300 amu.

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3. SIMULATION OF PARTICLE TRAJECTORIES

Most particles which are released from Europa's surface move on ballistic trajectories, where the ejection angle a is:

$$\alpha_0 = \arcsin\left(\frac{v_{z0}}{v_0}\right) \qquad (3)$$

We trace the atoms and molecules as a function of altitude by calculating their flight time t and velocities v_i and v_{zi} (index i=0, 1, 2,...) [4]:

$$t = \frac{v_0 \sin(\alpha_0)}{g(z)} - \sqrt{\left(\frac{v_0 \sin(\alpha_0)}{g(z)}\right)^2 - \left(\frac{2z_1}{g(z)}\right)} \qquad (4)$$

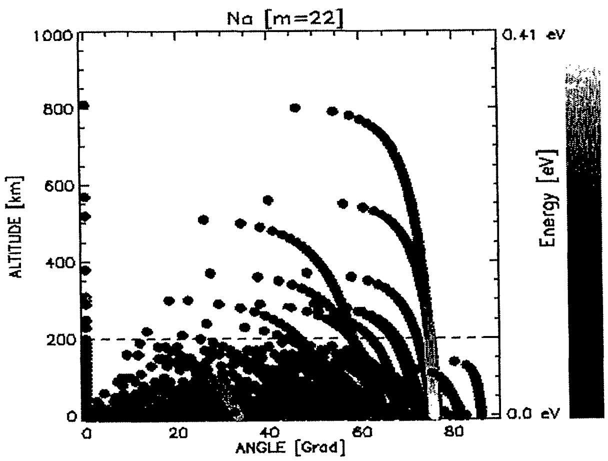

Fig. 1. Energy and ejection angle distribution as function of altitude for Na particles, which are released by electron, desorption [3] with an average energy of about 0.04 eV. The dashed line shows the proposed orbital altitude of the Europa Orbiter. One can see that our instrument would detect Na particles, which are sputtered by this process.

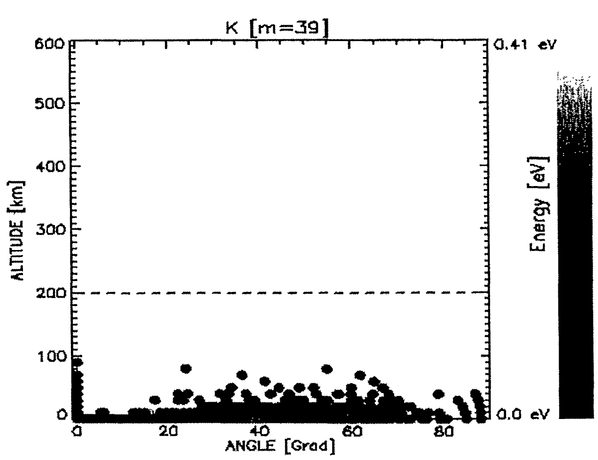

Fig. 2. Energy and ejection angle distribution as function of altitude for electron desorped K particles.

The K atoms in Fig. 2 are released by electron desorption with an average energy of about 0.01 eV. One can see that a mass spectrometer on board of an Europa Orbiter cannot detect heavy K particles, which are released by this low energetic process.

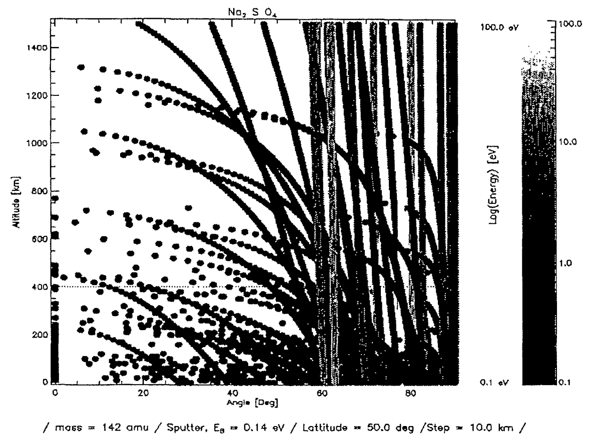

Fig. 3. Energy and ejection angle distribution as function of altitude for heavy Na_2SO_4 molecules which are released by high energy ion sputtering [2] with an average energy of about 0.14 eV.

One can see from Fig. 3 that a mass spectrometer on board of an Europa Orbiter would be able to detect heavy molecules if they are released from Europa's surface-ice by energetic ion particle interaction processes.

CONCLUSION

Our preliminary study show that a MAIA-type time of flight mass spectrometer on board of an Europa Orbiter is an important instrument which can detect heavy organics and salt molecules from Europa's subsurface ocean.

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