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Development of an energy analyzer for the characterization of neutral and ionized upper atmospheres.

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Overview

The Martian exosphere is essentially composed of Oxygen and Hydrogen. These atoms are either thermal or suprathermal. The suprathermal population is mainly formed through one of two processes : the atmospheric sputtering and the dissociative recombination. Both processes contribute to the erosion of the Martian atmosphere. Measuring the energy of these suprathermal particles would be key to understanding the history of Mars' atmosphere.

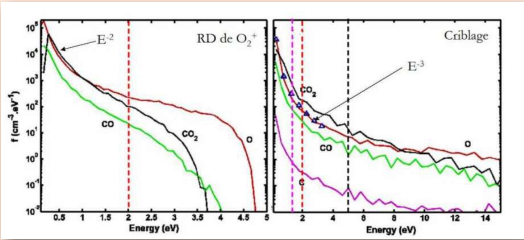

Figure 1 : Energy distribution of the main components of Mars' exosphere from dissociative recombination (left) and sputtering (right) for altitudes between 185km and 215 km. The dotted lines represent the escape energy (F. Cipriani, 2006)

Measuring suprathermal particles : INEA

Ion and Neutral Energy Analyzer (INEA) is an energy spectrometer with mass analysis capability. The main target of INEA is to measure the distribution function (density, temperature and drift velocity along the axis of sight of the instrument). INEA can also roughly measure the mass composition of the thermospheric neutral components and of the ionospheric ions in the mass range of 1 to 32 amu. The instrument is composed of an ionization source, an energy analyser and a detector.

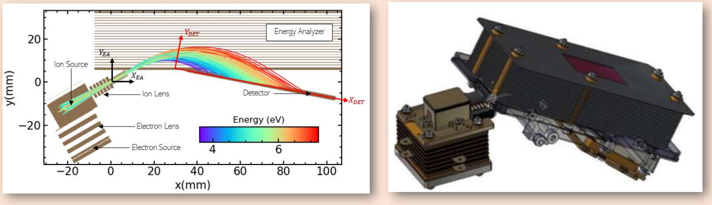

Figure 2 : Schematics of INEA with particle trajectories (left panel) and mechanical design (right panel) of INEA prototype

A New Type of Ion Source

The ion source can be separated into 3 elements:

1. The electron source using a carbon nanotubes forest (CNT)
2. An electrostatic lens focusing the electron beam
3. The ionization volume where the electrons collide with the neutral gas

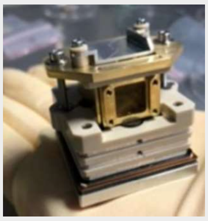

Figure 3 : Ion source's photography

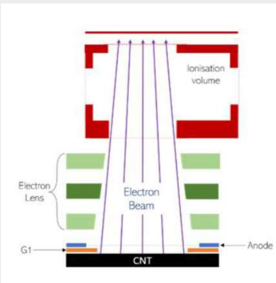

Figure 4 : Block diagram of the ion source with every electrostatic element

Filaments for the emission of electrons are classically used in space instrumentation but have two major drawbacks: power consumption, and significant outgassing. We therefore developed a new type of ionization source with a CNT cold cathode as emitter using the field enhanced emission principle.

How to distinguish the energy of particles?

In the energy analyzer, ions are deflected by a constant electric field along parabolic trajectories and exit through the base plate. Subsequently, they enter the drift space between the grid and the entrance plane of the detector inclined at an angle α = 10.9° with respect to the base plate. The shape of the parabola is defined by the electric field E inside the EA, the particle energy Ec at the source and the angle θ between the base plate and the particle velocity vector.

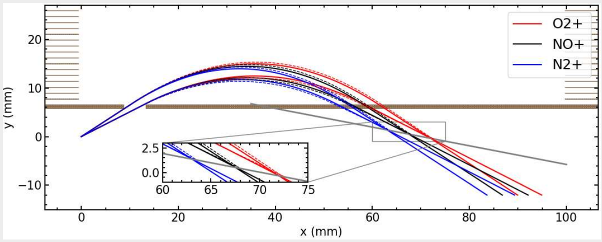

Figure 5 : Trajectories of O_2^+, NO^+ & N_2^+ ions inside the energy analyzer with a velocity of 10 km/s and oriented by $\pm$ 3°. The plain lines represent the trajectories of the particles using the analytic equations. The dashed lines are the trajectories as simulated with the model. The gray line corresponds to the focal plan.

Retrieving the energy of particles

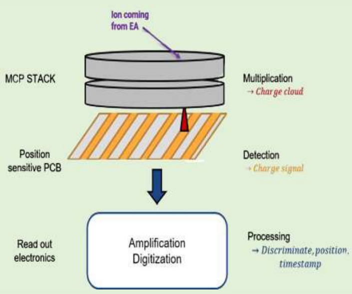

Figure 6 :Schematic of the detection chain

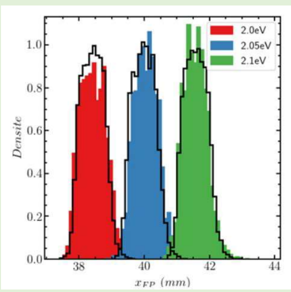

Figure 7 : Typical simulated distribution of impacts on the detector. Beams are separated by 0.05eV, demonstrating INEA's typical energy resolution.

Conclusion

Measurement requirements :

- Temperature : 200K to 1000K with a resolution of 50K
- Velocity : +/- 2 km/s with a resolution of 50 m/s
- Mass : 1 to 32 amu with a resolution >10

Resource objectives :

- Mass : < 2 kg
- Power : < 5 Watts
- Size : 110mm x 70 mm x 40 mm

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