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Large area mass analyzer

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Abstract

A new time-of-flight spectrometer for the chemical analysis of cosmic dust particles in space has been simulated by Simion 7.0. The instrument is based upon impact ionization. This method is a reliable method for in situ dust detection and is well established. Instruments using the impact ionization flew on board of Helios and Galileo and are still in operation on board of the Ulysses and Cassini–Huygens missions. The new instrument has a large sensitive area of 0.1 m^2 in order to achieve a significant number of measurements. The mass resolution $M/\Delta M > 100$ and the mass range covers the most relevant elements expected in cosmic dust. The instrument has a reflectron configuration which increases the mass resolution. Most of the ions released during the impact are focused to the detector. The ion detector consists of a large area ion-to-electron converter, an electron reflectron and a microchannel plate detector.

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Keywords: Time-of-flight masse spectrometer; Electron multipliers; Electrostatic field; Dust particles

1. Introduction

Most material contained in the Earth and the other planets today resided in galactic interstellar dust grains 5×10^9 years ago before it was altered during the process of planetary formation. The composition of the grains is largely unknown. The analysis of interstellar dust grains can give important insights into the formation process of our planetary system.

Dust particles are characterized by their properties such as composition, structure and directionality. The dust particles can be collected in the Earth's atmosphere. However, the particles are altered or even destroyed when they enter the Earth's atmosphere with speeds in the range of km/s. Therefore the unaltered micro-meteoroids should be investigated in interplanetary space or in the Earth's vicinity.

2. Instrument

The goal of the Large Area Mass Analyzer (LAMA) is to perform an in situ chemical analysis

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of dust particles. As the dust flux in space is of the order of $10^{-4}\,\mathrm{m^{-2}\,s^{-1}}$ the dust sensor has to have a large sensitive area [1]. The mass resolution $M/\Delta M > 100$ should be high enough to resolve and identify the most relevant elements contained in cosmic dust (H,C,O,N,Si,Mg,Fe,Ni). Therefore, LAMA should fulfill two main requirements:

1. The instrument must have a sensitive area of at least $0.1\,\mathrm{m}^2$.
2. The instrument must provide composition analysis of each impacting grain with a mass resolution $M/\Delta M > 100$.

Like previous instruments [2] LAMA is based upon hypervelocity ($v > 5\,\mathrm{km\,s^{-1}}$) impact ionization [3,4,7]. When a dust particle hits the target they are both vaporized and ionized. Then the ions are accelerated by an electric field towards the detector. The electrons are collected at the target. By using a time-of-flight method where the electrons give the ‘start’ signal and the ions give the ‘stop’ signal it is possible to measure the mass of the ions.

The LAMA consists of an impacting target, a reflectron and an ion detector. The impacting target is assumed to be made of Rhodium. This element does not contribute to the particle composition and will give a clear calibration peak in the spectra. The ions are accelerated between a target and a grid over a distance of 50 mm. The long acceleration distance ensures a charge separation for high impact charges ($> 10^{-10}$ C) which are generated by 10-μm particles (Figs. 1 and 2).

From experiments [5], it is known that the hyper-velocity dust impacts (about $10\,\mathrm{km\,s^{-1}}$) produce ions with initial kinetic energies in the range of several eV. In order to reduce the difference in the initial ion energies and to increase the time resolution, a reflectron is implemented [6] in the ion path. The ions having higher energies go deeper into the reflectron and hence have a longer path. Thus they need the same time as the low-energy ions and reach the detector at the same time.

A space instrument should have a low weight and it would be efficient to use a microchannel plate detector as an ion detector, which is a fast and compact electron multiplier. However, the LAMA design requires a large detector size. For this purpose a large ion-to-electron converter together with a small MCP detector is used. The ion-to-electron converter consists of two dynodes only. The dynodes have a perforated structure which helps to focus the released electrons through

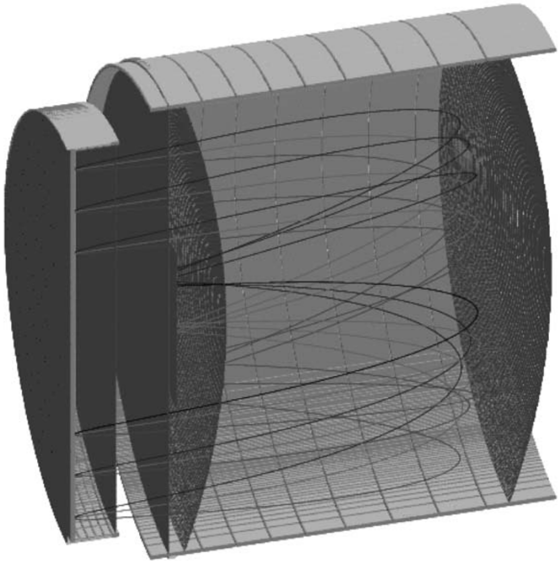

Fig. 1. Cross-section of Large Area Mass Analyzer. The lines are ions trajectories.

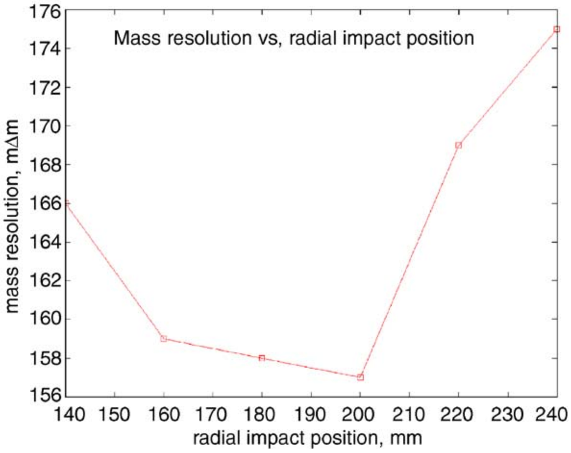

Fig. 2. Mass resolution of Large Area Mass Analyzer. The mass resolution depends on a position where the impact occurred.

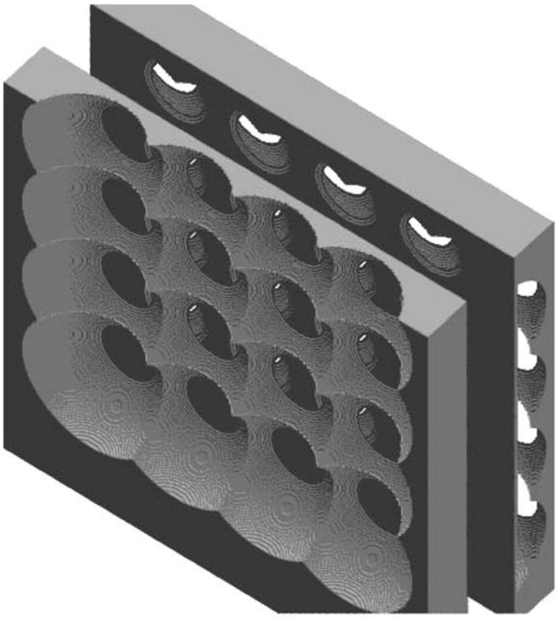

Fig. 3. The ion-to-electron converter. The special structure of the dynodes form an appropriate configuration of electric field.

the aligned holes. Afterwards the electron beam is focused onto a small microchannel plate detector. The simulated ion-to-electron converter has about 240 mm diameter. A part of the multiplier is shown on (Fig. 3).

3. Conclusion

The design of a TOF Mass Spectrometer with a sensitive area of 0.1 m^2 has been optimized using the Simion3D software package. The time-of-flight mass spectrometer uses a reflectron and has a mass resolution above 100. The spectrometer measures the ion of the impact plasma generated by hyper-velocity dust impact. The spectrometer requires a special 400 cm^2 ion detector.

References

[1] E. Grün, H.A. Zook, H. Fechtig, R.H. Giese, Icarus 62 (1985) 244.

[2] H. Dietzel, G. Eichhorn, H. Fechtig, E. Grun, H.-J. Hoffmann, J. Kissel, J. Phys. E Sci. Instr. 6 (1973) 209.

[3] D.E. Austin, T.J. Ahrens, J.L. Beauchamp, Rev. Sci. Instr. 73–1 (2002) 185.

[4] J. Kissel, D.E. Brownlee, K. Buchler, B.C. Clark, H. Fechtig, E. Grun, K. Hornung, E.B. Igenbergs, E.K. Jessberger, F.R. Krueger, H. Kuczera, J.A.M. McDonnell, G.M. Morfill, J. Rahe, G.H. Schwehm, Z. Sekanina, N.G. Utterback, H.J. Volk, H.A. Zook, Nature 321 (1986) 336.

[5] P.R. Ratcliff, F. Allahdadi, Adv. Space Res. 17 (1996) 87.

[6] B.A. Mamyrin, V.L. Karataev, D.V. Shmikk, V.A. Zagulin, Zh. Eksp. Teor. Fiz. (Sov. Phys—JETP) 64 and 37 (1973) 82 and 45.

[7] P.R. Ratcliff, F. Gogu, E. Grün, R. Srama, Adv. Space Res. 17 (1996) 111.