DEVELOPMENT OF A LIGHT WEIGHT, LARGE AREA IN-SITU DUST/DEBRIS DETECTOR

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1. Introduction

There exists inner- and extra-solar origin cosmic dust (hereafter “dust”) in the solar system. These dust particles have pristine material information and are the clues to understand the evolution of the solar system. High speed dust and/or debris impact on the satellite might hazardous to the operation of the satellite; therefore dust/debris study is important to evaluate the possible risk on the human activities in space.

There are two types of in-situ dust/debris detector; 1) a counter to measure the physical parameters such as mass, velocity and incident direction, as onboard GALILEO, NOZOMI, 2) an analyzer to measure chemical composition of the dust, as onboard HELIOS, STARDUST, CASSINI, etc. In both cases high velocity dust particles are impacted on the metal target plate, plasma cloud was formed (impact ionization), positive/negative ion are collected and measured. Impact ionization type of detector is the main stream for in-situ dust/debris measurement.

Future dust measurement in space, some restrictions such as “effective dust measurement with large aperture”, “light weighed to minimize the cost” are required. To fulfill these requirements, simplification of the structure is necessary. Determination of target shape, distance between target and grid, applied voltage are crucial for the development. But conventional detector, such as MDC onboard NOZOMI was box shaped with low symmetry, this caused the impact position dependence of signal and was the deficit of this detector. Our objective of study is to determine the optimum shape and applied voltage condition based on the experiment for the impact ionization detector (IID).

2. Principle of impact ionization detector

The first generation IID is composed of a circular metallic plate (target) of 5cm in diameter, side wall and an entrance grid. Dust with velocity higher than a few km/s impacting on the target generates plasma. For the easiness of handling, entrance grid is grounded, while the target is biased with high voltage (Fig.1). From the target signal, we can calculate rise-time t and generated total charge Q. Where t and Q/m are functions of dust impact velocity v, and is empirically noted as follows:

$$t = c_g v^{\alpha} \qquad (1)$$

$$Q/m = c_r v^{\beta} \qquad (2)$$

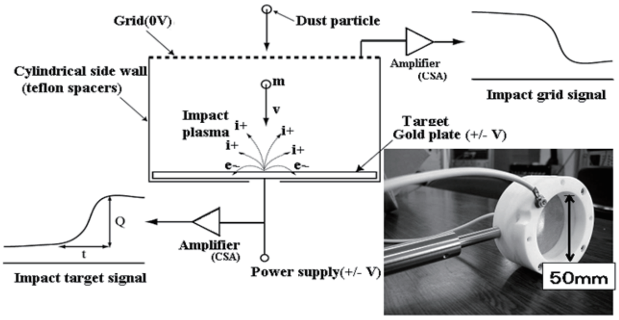

Fig.1 Principle of impact ionization detector

where c_g, c_r, α and β are determined by the calibration experiment [1,2]. From the measured rise-time *t*, we obtain impacting dust velocity *v* by applying *v*-*t* calibration curve, and this *v* is applied to *v*-*Q/m* curve we can obtain impacting dust mass *m*, while generated charge *Q* is already known.

3. Experiments

Van de Graaff accelerators at HIT (High Fluence Irradiation Facility, the University of Tokyo, Tokai-mura, Japan) and MPI-K (Max-Planck Institute for Nuclear Physics, Heidelberg Germany) are used for calibration experiment. Micron sized conductive particles are accelerated to a few km/s to tens of km/s and are impacted onto metallic target. Inserted photograph in Fig.1 is the first generation IID. Applied voltage on the target, and target-grid distance were changed. Basic study proved this parallel-plane type of detector is superior to MDC which is asymmetric inside the detector.

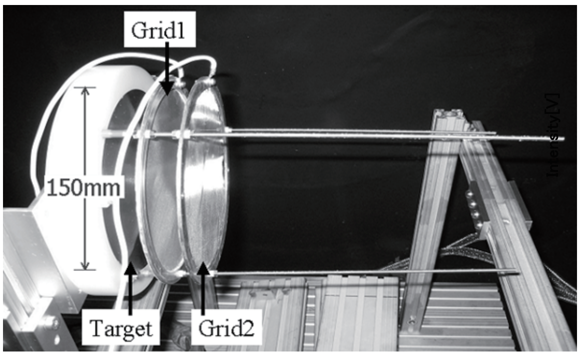

Fig.2 Second generation IID

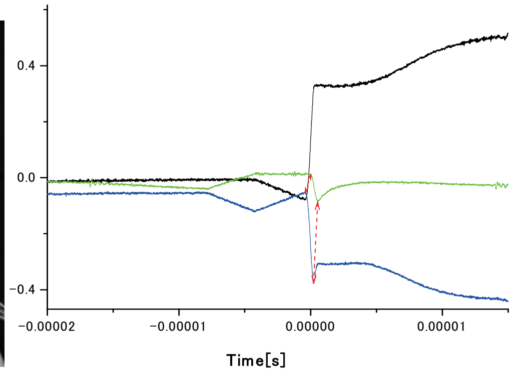

Fig.3 Typical signals

Second generation IID has an aperture of 15 cm in diameter, and has two grids to study the plasma cloud behavior. For charged particles, we can calculate their velocity from the signals. Side wall was removed to keep it light-weighed (Fig.2). Typical signals are show in Fig.3.

Third generation IID has an aperture of 30 cm in diameter, cylindrical side wall, and two grids with a total mass of 2kg (Fig.4).

Fourth generation IID has an aperture of 20 cm square, side wall, and two grids with a total mass of 2kg (Fig.5). Square type aperture was adopted to maximize the target area.

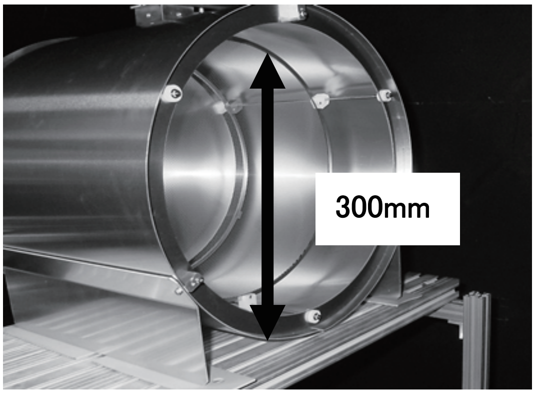

Fig.4 Third generation IID

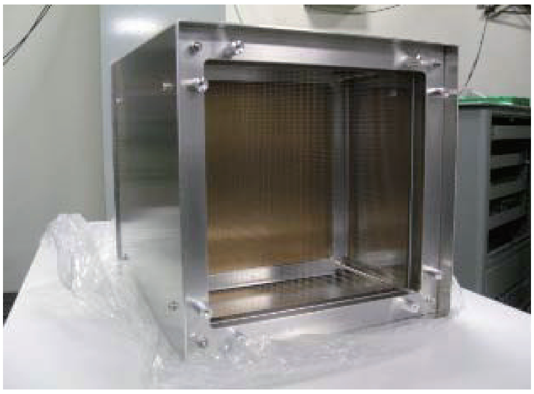

Fig.5 Fourth generation IID

4. Results and discussions

Rise-time t vs particle velocity v with different particles, different applied high voltages, and impact position dependence are shown in Fig.6 to Fig.8. Charge to mass ratio Q/m vs particle velocity v with different particles, different applied high voltages, and impact position dependence are shown in Fig.9 to Fig.11.

From these figures it is clear that empirical formulae (1) and (2) fit well in general. From Fig.6 and Fig.7, there is little dependence of the incident particle, nor applied high voltage. For the safety to satellite applied voltage is preferable as low as possible. From Fig.8 it is clear that there is little impact position dependence, therefore this type of detector has effective area nearly equal to that of the target area. Charge to mass ratio Q/m vs particle velocity v data (Fig.9) is incident particle material dependence. This feature proves us that this detector would work as a simple chemical analyzer. Cosmic dust with metallic composition

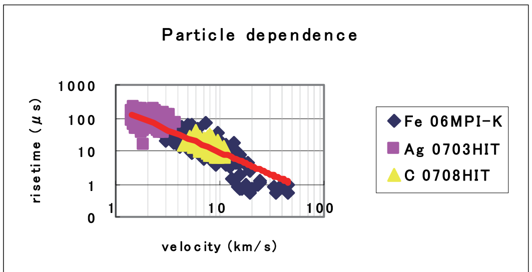

Fig.6 v-t Particle dependence

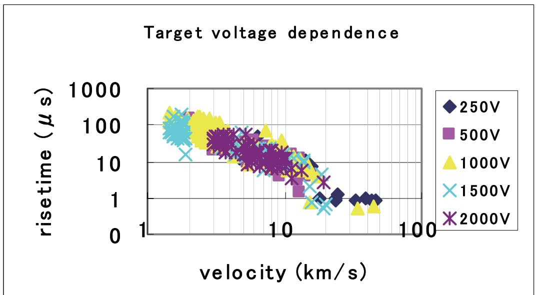

Fig.7 v-t Target voltage dependence

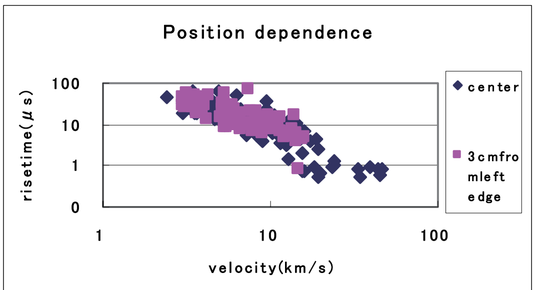

Fig.8 v-t Position dependence

and chondritic or stony composition would be differentiated by measuring Q/m vs velocity v for each impact signal. To prove this feature we are planning to perform further experiments with conductive latex particles to simulate chondritic dust particles.

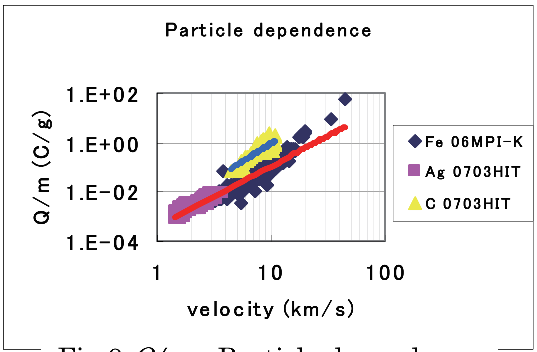

Fig.9 Q/m-v Particle dependence

5. Conclusions

There is a good correlation between target rise-time t, charge to mass ratio Q/m and impacting particle velocity v. From rise-time t, dust impacting velocity v is deduced. From total charge produced Q, we can deduce impacting dust mass m. There is little dependence on impact position, as well as incident angle. These features prove that parallel-plane type of detector has enough performance for dust/debris impact ionization detector. From impacting particle material dependence data of charge to mass ratio Q/m vs particle velocity v, tit might work as chemical analyzer. If this feature is proven, IID would work as a simplest chemical analyzer compared to the sophisticated instrument ever developed.

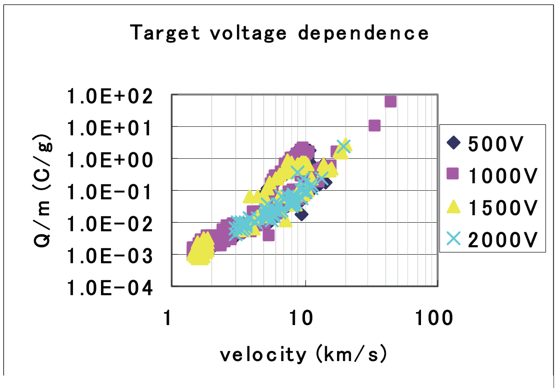

Fig.10 Q/m-v Target voltage dependence

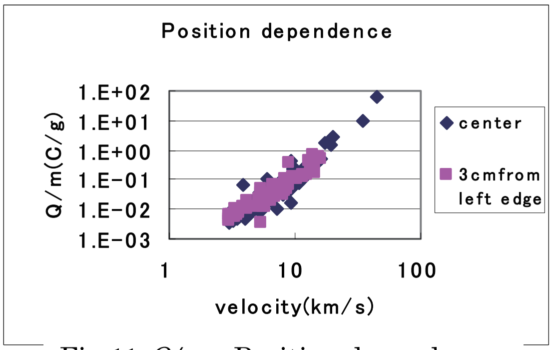

Fig.11 Q/m-v Position dependence

References

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[2] E. Igenbergs, et al., Mars Dust Counter, Earth Planets Space, 50 (1998) 241-245.