Dust Sensor with Large Detection Area Using Polyimide Film and Piezoelectric Elements. M. Kobayashi[1], O. Okudaira[1], K. Kurosawa[1], T. Okamoto[1] and T. Matsui[1], [1]Planetary Exploration Research Center, Chiba Institute of Technology (2-17-1, Tsudanuma, Narashino, Chiba, Japan 275-0016; kobayashi.masanori@it-chiba.ac.jp).

Introduction: Dust that escapes from gravitational sphere of the celestial body exists in the interplanetary space and is observed as various events. For instance, there are some dust particles from comets, satellites and so on.

Dust particles from comets are observed as a meteor stream when their orbit intersects with the earth orbit, the night sky will be colored as a meteor stream. However, the dust trail of comet has never directly been observed except for such special case as meteor stream.

On the other hand, for dust particles from satellites, some previous theoretical studies predict dust torus that Phobos and Deimos supply with dust particles over those satellites orbits. However, they have not been discovered yet.

Those are important events for understanding the material transfer of inside the solar system. However, sensor to be onboard on spacecraft is difficult from the viewpoint of the resource requirement to the spacecraft system because large detection area (> $1m^2$) is necessary to observe dust particles (tens of micron to millimeter) which exist in low spatial density. Pegasus mission had such large detection area for observe meteoroids in space as environment assessment before Apollo mission [1], and there have been no similar mission performed after that.

For enlargement of detection area, previous works used a metallic plate at which incident dust particles collides and vibration is induced and the vibration is detected with piezoelectric elements as dust particle hit signals [2]. Assuming aluminum plate, sensor using metallic materials with > $1m^2$ detection area has a mass of greater than 2 kg which is unreasonably heavy just for detecting medium.

Using non-metallic materials, we developed several type of large area dust sensors [3] [4]. ALADDIN uses piezoelectric polyimide PVDF having 30cm x 30 cm detection area and had successful observations in the interplanetary space. The PVDF sensor converts mechanical impact of incident dust particle to electrical signal and the following electronics read out the signals as dust particle impact. However, PVDF has a large permittivity and a thin film sensor has a large capacitance which is like to induce electrical noise. On the other hand, SDM is a penetration type sensor which is a polyimide film having thin strip electrodes on [4]. When the incident dust particle penetrates the sensor film and breaks electrode(s), the broken electrodes can be detection by applying current and then one can estimate the size of the incident dust particles from the number of broken electrodes. SDM has been onboard HTV-5 (5th H-II transfer vehicle) for demonstration flight. SDM worked extremely well. However, the electronics is not simple and needs more resource requirement.

In this paper, we describe a dust particle sensor with a large detection area (1m x 1m scale) using just a film of polyimide (10 – 20 μm in thickness) attached with pieces of piezoelectric elements (~2 cm) as pick-up sensor.

Measurement principle: Figure 1 illustrates measurement principle of a sensor of our current work. We use a polyimide film (no piezoelectricity, no electrodes, and just normal polyimide) and small tips of piezoelectric element adhesively attached on the film. When an incident dust particle hit on the film and penetrate, stress waves occur in the film material and propagate away from the penetration points. When the stress wave reaches a tip of piezoelectric sensor and some of the stress wave energy transfer to the piezoelectric sensor, oscillation is induced in the sensor and is converted to electric signal which is read out by the following electronics. The piezoelectric sensor picks up the stress waves caused by the incident dust particle. Assuming the pick-up sensor has a dimension of 20 mm x 20 mm x 2mm, the electric signal has two components in frequency; 200 kHz and 1.1 MHz for thickness and radial direction oscillation, respectively.

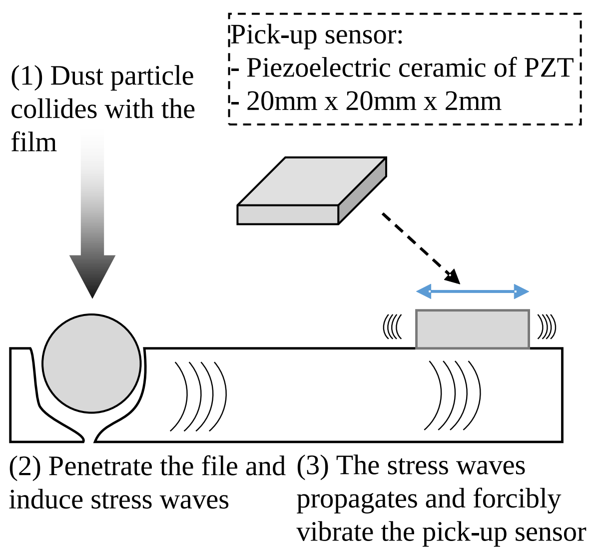

Figure 1 Principle of dust particle detection

Experiments: We performed two experiments that microparticles were accelerated to hypervelocity speed using two-stage light gas gun, one is from ISAS, JAXA and another from PERC, CIT. In the experiments, we had micro particles (150 μm to 3 mm) accelerated up to 4 – 5km/s. The first experiments used a sensor of SDM prototype and four pick-up sensor on the corners, while the second experiment used a multi-layer insulator, typical thermal device for spacecraft, three pick-up sensors were attached at the apex of a triangle on a rectangular MLI. Figure 2 shows an example of results, the measurement of raw signal from a pick-up sensor (top), calculated FFT spectrum (middle) and filtered signal with 200 kHz band pass (bottom). Applying the band pass filter makes clearer signal detection and timing determination.

The propagation speed of stress wave in the film is constant (~2.6 km/s) and the penetration point as "sound source" can be positioned by a typical algorithm of sound source positioning using the arrival times of stress waves at multiple pick-up points. Figure 3 shows four examples of actual penetration points (star) and ones derived from positioning algorithm (red diamond). In that example, there are three pick-up sensors located at "+" positions to detect signals to determine arrival timing of the stress waves. Actual penetration points and calculated ones have a good agreement within 1 cm.

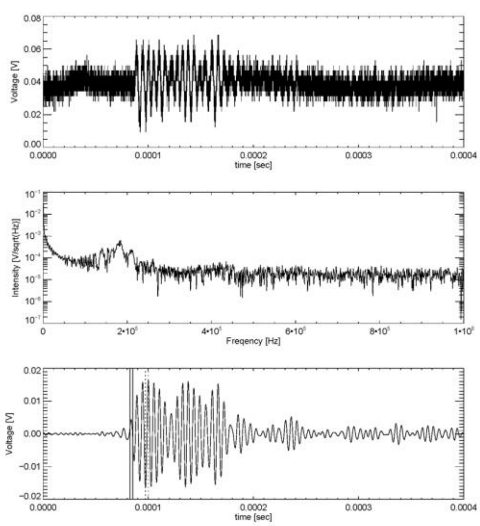

Figure 2 Example of experimental results

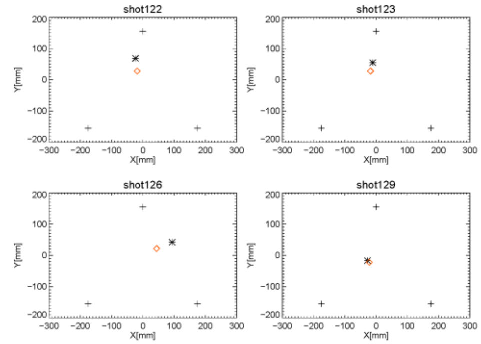

Figure 3 Positioning of penetration point

Future prospective: The polyimide film as detection medium can be easily expanded to observe large-sized micro particles (> 10 μm) of which the statistics is lower than one of smaller particles. The sensor of the current works uses just a typical polyimide film and piezoelectric elements as pick-up sensor. Exploiting those characteristics, MLI which covers a spacecraft can be a large-area dust particle sensor being attached piezo electric elements without significant resource impact on spacecraft system.

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