Dust Sensor with a Large Detection Area Using Polyimide Film for Martian Moons Exploration. M. Kobayashi[1], O. Okudaira[1], K. Kurosawa[1], T. Okamoto[1], H. Senshu[1], K. Wada[1], S. Sasaki[2], H. Kimura[3] and M. Nakamura[3], [1]Planetary Exploration Research Center, Chiba Institute of Technology (kobayashi.masanori@it-chiba.ac.jp), [2]Osaka University, [3]Nagoya University.

Introduction: There have been many attempts to discover Martian dust rings [1]. In the past missions, there were two major approaches of discovery; the one is optical observation to investigate indirectly by exploiting the phenomenon that sunlight and stars are scattered by dust, while the other is solar wind observation to observe disturbance by solar wind at the downstream. After all, it has not been confirmed that Mars has dust rings or torus yet.

Mission planned to Martian Moons: JAXA is planning Martian Moons Exploration (MMX) that is a mission performing an in-situ observation of Phobos and Deimos and also sample return from Phobos [2]. There are three mission objectives of MMX, (1) to clarify whether if the moons are captured or formed in situ after a giant impact, (2) to understand processes in circum-Mars environment, and (3) to exploit astronautics and exploration (technological) capabilities. For the purpose of (2), we propose a dust monitor to investigate dust environment around Mars.

In this paper, we describe Circum-Martian Dust Monitor (CMDM) that we propose to MMX, which is for in-situ and direct observation of dust impact, unlike the observation conducted in the past mission. With CMDM, we will directly investigate whether there is a significant increase of dust flux in between the surrounding environment (interplanetary space) and the orbit of Phobos and Deimos.

Instrumentation: According to the previous studies, the major component of dusts in the dust rings or torus has 10 – 20 μm in size [1]. In order to clarify the increase in dust flux around Mars, CMDM must have adequate sensitivity to detect interplanetary dust with that size (10 – 20 μm) with statistical significance. To have an impact of interplanetary dust or more per day, the sensor of CMDM shall have a large detection area (1 m^2). It is very difficult to secure such a large sensor area as 1 m^2 on a spacecraft, especially for investigation of object which has not been discovered yet. The sensor of CMDM exploits the outermost polyimide film of MLI (multi-layer insulation) which is a thermal blanket. The surface of spacecraft typically is surrounded by MLI except for solar panel part.

Measurement principle. The sensor consists of a polyimide film (no piezoelectricity, no electrodes, and just normal polyimide) and multiple piezoelectric PZT elements [3]. Fig.1 shows an image of the sensor of CMDM, the PZT sensors are glued on the outermost film as pick-up sensor. In Fig.1, a concept is just shown and the position of the pick-up sensors maybe changed and cables for signal reading must be connected.

When a dust particle hits and penetrates the film at a high speed, enhancement in pressure occurs in the film material leading to ultrasound wave (or stress wave in materials) and it propagates isotropically. The piezoelectric PZT elements can detects the wave. 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 10 mmϕ × 2mmt, the electric signal has two components in frequency; 200 kHz and 1.1 MHz for thickness and radial direction oscillation, respectively. The penetrating position as the wave source can be derive from the time difference of the signals on the plural pickup sensors by a typical algorithm of sound source positioning.

By positioning the penetration, it is possible to distinguish whether it is a dust signal or noise due to others; it can be false event if the position is not converged to be one position.

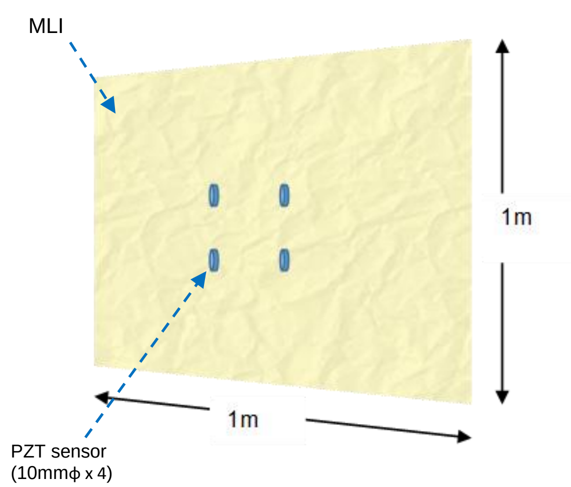

Fig.1 Conceptual drawing of sensor part of CMDM.

Function and performance. CMDM has a sensor part and an electronics part, and they are connected by a harness. The electronics processes signals from the sensor, records data and transfers it to the spacecraft system. The signal processing is as follows;

- If signals from any of the pickup sensors exceeds the threshold level, it is a trigger to have an event recognized to be processed. The trigger occurrence time is recorded.
- For each event, time difference information and waveform information on each pickup sensor shall be recorded.
- For each event, "sound source" position shall be derived from the time difference of each pickup sensor signal.
- If the sound source position is not converge to one point, the event is rejected as a false signal (noise caused in the sensor(s) or signal processing circuit section).
- True/false event judgement result shall be recorded as event information. For events judged to have a high possibility of dust collision, the priority is increased.
- Those events are downlinked in descending order of priority.

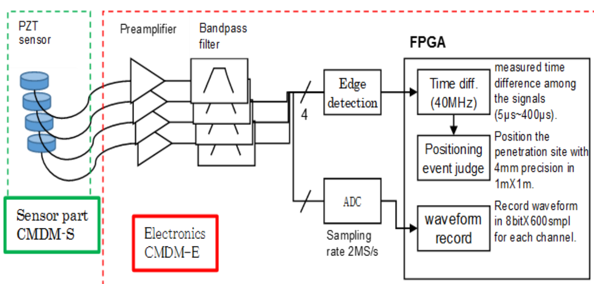

Fig.2 Simplified function block of CMDM.

Technical viability. We will use the same type of piezoelectric PZT element by the same manufacturer as one of Mercury Dust Monitor of BepiColombo MMO [4], which has been qualified to be in space. The piezoelectric PZT elements functions from -196 ° C to + 170 ° C and also it has been confirmed that the sensitivity is hardly deteriorated by radiation around Mercury. Thus, the PZT element has sufficient tolerance of radiation and can be exposed to harsh space environment on the outermost layer of MLI during the entire mission period of MMX, five years.

The signal processing circuits for reading the signal from the PZT sensor, ADC sampling of the signal waveform and recording has been established in the development of MDM of BepiColombo [4].

System and Resource requirements. Table 1 shows (rough) estimation of resource requirements of CMDM as of now. The estimation shown in Table 1 is based on the MDM [4]. Mounting position of the sensor has not been decided yet, it will be decided taking into account of relative velocity between the dusts and the normal direction of the sensor in orbit.

Table 1 Resource requirements on CMDM

Item		value
Mass	Sensor	0.05 kg
	Electronics	0.35 kg
	Harness	TBD
Power	Standby	< 2W
	Operation	< 3W
Size	Sensor (PZT)	10mmφ×2mm×4pcs.
	Electronics	200mm×120mm×40mm
	Harness	TBD

Summary and 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.

References: [1] Zakharov et al., PSS, 102, p. 171-175, (2014) [2] Miyamoto, MEPAG meeting #31 on March 2-3 2016 in Silver Spring, MD, (2016) [3] M. Kobayashi et al., IPM2016, Abstract No. 4047, (2016). [4] Nogami et al., PSS, 58, 108–115 (2010)