

**Lunar Dust Monitor for the orbiter of the next Japanese lunar mission SELENE2.** M. Kobayashi<sup>1</sup> (kobayashi.masanori@perc.it-chiba.ac.jp), H. Ohashi<sup>2</sup>, S. Sasaki<sup>3</sup>, H. Shibata<sup>4</sup>, T. Iwai<sup>5</sup>, M. Fujii<sup>6</sup>, K. Nogami<sup>7</sup>, H. Kimura<sup>8</sup>, M. Nakamura<sup>5</sup>, and T. Hirai<sup>2</sup>, <sup>1</sup>PERC, Chiba Inst. Tech., <sup>2</sup>Tokyo Univ. Marine Sci. & Tech., <sup>3</sup>NAOJ, <sup>4</sup>Kyoto Univ., <sup>5</sup>Univ. of Tokyo, <sup>6</sup>Waseda Univ., <sup>7</sup>Dokkyo Univ., and <sup>8</sup>CPS.

**Introduction:** The next Japanese lunar mission SELENE2, after a successful mission Kaguya (a project named SELENE), is planned to launch in mid 2010 and to consist of a lander, a rover, and an orbiter, as a transmitting satellite to the earth [1]. A dust particle detector is proposed to be onboard the orbiter.

Dust particles around the Moon include interplanetary dust,  $\beta$  meteoroids, interstellar dust, and possibly lunar dust that originate from the subsurface materials of the Moon. It is considered that several tens of thousands of tons of dust particles per year fall onto the Moon and supply materials to its surface layer. “Inflow” and “outflow” dust particles are very important for understanding material compositions of lunar surface. In past missions, dust detectors onboard the Hiten and Nozomi (Hiten-MDC and Nozomi-MDC) measured the fluxes of dust particles in the lunar orbit [2,3]. These observations by Hiten- and Nozomi-MDCs created a small dataset of statistics of dust particles excluding earth-orbiting dust once in a week, because the dust detectors had small sensitive areas, 0.01 m<sup>2</sup> and 0.014 m<sup>2</sup>, respectively. The Hiten orbited the Moon from February 1992 to April 1993, and its MDC detected about 150 dust particles; however, the origin of which was not identified. Nozomi was a Japanese Mars explorer; the Nozomi-MDC observed dust particles while the spacecraft was in a parking orbit of the Moon fly-by for only five months.

The Lunar Dust Experiment (LDEX) is designed to map a spatial and temporal variability of the dust size and density distributions in the lunar environment and will be onboard LADEE, which will be launched in 2012 [4]. LDEX will observe the lunar environment for 90 days in a nominal case or for a maximum of 9 months. It has a sensor area of 0.01 m<sup>2</sup> at 50 km altitude.

For a quantitative study of circumlunar dust, we need further statistics. In this paper, we summarize the significance of circumlunar dust and report an overview of our instrument proposed to the SELENE-2 mission, which has a large detection area to increase amount of data.

**Instrumentation of Lunar Dust Monitor:** For more statistics of dust observation, we propose a dust monitoring device with a large aperture size and a large sensor area, called the lunar dust monitor (LDM). We are now creating its conceptual design. The LDM is an impact ionization detector with dimensions 25 cm × 25 cm × 30 cm, and it has a sensor part (LDM-S, upper module) and an electronics part (LDM-E, lower

module). The LDM-S has a large target (gold-plated Al) of 400 cm<sup>2</sup>, to which a high voltage of +500 V is applied. As shown in Fig. 1, the LDM-S also has two meshed grids parallel to the target. The grids are 90% transparent: the inner grid is 2 cm apart from the target and the outer grid is 15 cm from the target.

This impact ionization type detector is designed to detect charged dust particles. When a charged dust particle passes through the outer and inner grids, it induces an electric signal on the grids separated by a certain time interval that is determined by the velocity of the incident particle and the distance between the outer and inner grids. Measuring the time interval, we can determine the velocity of the particle, although there is an uncertainty in the velocity because the path length between the grids depends on the incident angle. When the incident particle impacts on the target, the impact generates plasma gas of electrons and ions. The electrons of the plasma are collected by the target and the ions are accelerated toward the inner grids as a result of the electric field. Some of the ions drift through the inner grid and reach the outer grid. The outer and inner grids and the target are each followed by charge-sensitive amplifiers, which convert charge signals induced by the electrons and ions to voltage signals that are fed to a following flash ADC driven with 10 MHz. The waveforms from the outer and inner grids and the target can be stored and be sent back to ground and used for data analysis. We can deduce the mass and velocity information of the impacted dust particle from the recorded waveforms.

The orbiter of SELENE-2 is planned to be in operation for one year or more, and the LDM will observe circumlunar dust for as long as possible.

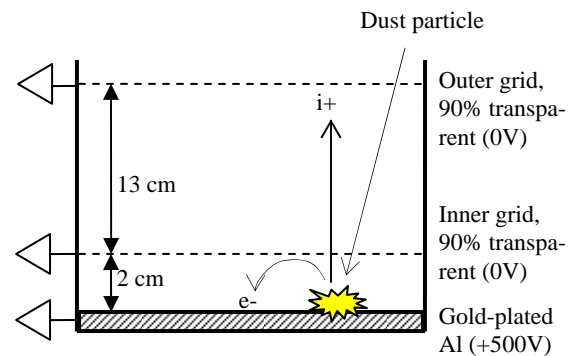


Fig. 1 Schematic of the cross-sectional view of the LDM-S, the sensor part of the LDM.

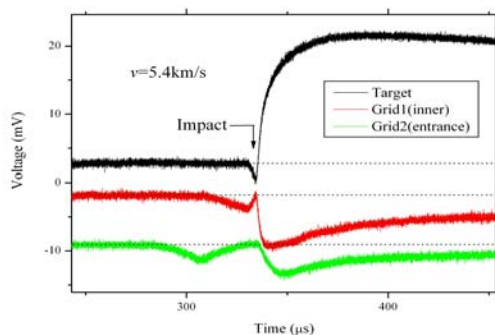


Fig. 2 Example of a typical event measured with a bread-board model in laboratory.

**Significance of observation of dust particles around the Moon:** Dust particles around the Moon are classified based on their origins: interstellar dust, interplanetary dust,  $\beta$  meteoroids, and possibly dust that originated on the Moon. Table 1 summarizes a rough criteria of identification of dust particles around the Moon. They can be inferred from their kinematic properties: the velocities and the arrival directions. If the proportion of dust components around the Moon is determined by observation, we can increase our knowledge of the contribution of inflow and outflow dust particles to lunar surface materials.

(i) *Source of supply of Moon materials.* Materials on the lunar surface contain volatiles, and there is a sodium atmosphere on the Moon. The volatiles should already be exhausted if their only origin is the interior of the Moon. The sodium atmosphere, however, still remains because cometary dust can be one of the supply sources. Past observation shows that the sodium atmosphere of the Moon changes in synchronization with Leonids. Furthermore, it seems that cometary dust is a contributing source of water ice in the pole regions of the Moon. The dust detector onboard the spacecraft in lunar orbit can obtain data, which is necessary to infer contributions as the origin of the volatiles on the Moon.

(ii) *Evolution of lunar regolith.* Dust particles play an important role in space weathering of airless bodies such as the Moon. Bombardment of high-velocity dust particles on the lunar surface contributes to the production of its regolith layer. Space weathering affects its spectral properties. As the surface undergoes space weathering, the albedo is reduced, reflectance increases with increasing wavelength, and the depth of its diagnostic absorption bands is reduced. Mineral compositions of lunar materials derived from the albedo spectrum by remote-sensing observation are ambiguous due to the space weathering effect. Bombardment of dust particles on the Moon, however, has been unknown, and any changes in reflectance of lunar surface materials have not been evaluated quantitatively.

It is important to measure the flux of inflow dust particles even in the present, using which the weathering effect in the past can be inferred. The latitude dependence of space weathering is unknown and may reveal a leading cause of space weathering. The latitudinal distribution of the inflow position of dust particles can be also interesting.

(iii) *Ejecta escaped from the Moon's gravitational sphere.* Surface materials might have escaped from the Moon, although they have not yet been directly observed. Small bodies such as satellites and asteroids have less gravity and are composed of materials that can easily escape as impact ejecta of meteoroid bombardment. The dust detector subsystem (DDS) onboard the Galileo Jovian explorer detected dust particles ejected from the Jovian satellites, Ganymede, Europa, and Callisto. Estimating total mass of impact ejecta is difficult because the ejecta mechanism is unknown; however, observation by a dust detector with a large aperture may determine the total mass of outflow materials.

Small ejecta from the Moon, of which the size is assumed to be less than 1  $\mu\text{m}$ , may be related to levitation dusts. It is expected that the grain size of levitation dust at a certain position in the lunar orbit depends on the grain size of regolith materials at the nadir.

(iv) *Inflow dusts related to meteor streams.* Recent studies suggest that the flux of inflow dust increases when meteor streams appear. An observation over more than one year may verify this hypothesis by examining the variation of the dust flux with meteor streams.

Table 1 Properties of Circumlunar dusts

Dust	Origin	Kinematic Properties
Interstellar dust	Interstellar medium	>10 km/s Omnidirectional
Interplanetary dust	Cometary and asteroidal materials	>5 km/s In plane of the ecliptic
$\beta$ meteoroid	Interplanetary dusts swept by solar radiation	>5 km/s Solar direction
Lunar dust	Materials on the lunar surface, regolith	<5 km/s Lunar direction

**References:** [1] Matsumoto, K. et al., Joint Annual Meeting of LEAG-ICEUM-SRR (2008) LPI Contribution No.1446, 86. [2] Iglseider H. et al., Adv. Space Res. 17 (1996) 177-182. [3] Sasaki S., et al., Adv. Space Res., 39 (2007), 485-488. [4] Horanyi, M. et al., (2009) *LPSC 40<sup>th</sup>*, Abstract #1741.