MOON ELECTROSTATIC POTENTIAL AND DUST ANALYSER (MESDA) FOR FUTURE LUNAR MISSION.

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Introduction: The lunar surface is exposed to the solar wind and solar UV radiation, causing photoemission and developing a positive surface charge during the daytime. The surface is negatively charged due to space plasma currents on the nightside. The surficial fine dust grains have very low dielectric losses and electrical conductivity, which can permit retention of electrostatic surface charge for comparatively longer time. The dust particles are levitated due to repulsion force caused by positive charge on the lunar surface during the lunar day and may settle down towards the terminator. In the dead zone [1] near the terminator, there is no surface charge and dust particles are not levitated. On the night side, the particles are levitated due to the negative charge on the lunar surface. The levitated dust particles may undergo preferential deposition onto areas of the lunar surface or equipment, with different electrical properties. This can lead to a net transport [2] as well as contamination of sensitive equipment for future missions. The dust levitation modelling [1] may help study the scenario on the moon.

To understand lunar surface charging and dust levitation, we have proposed a Moon Electrostatic Potential and Dust Analyser (MESDA) for future lander mission to the moon. The MESDA has two independent instruments, viz. Lunar Surface Potential Detector (LSPD) and Lunar Dust Detector (LDD). This article presents the dust levitation modelling results as well as the developmental status and initial results of LSPD and LDD for the future mission.

Lunar Dust Levitation Modelling: One dimensional electric field is generally assumed [1] for lunar surface charging with plasma sheath bounded upto Debye length height from the surface. We have derived the dependence of particle radius on the plasma parameters. Typically, the maximum radius of the charged dust particles is given by

$$r_{max} = 4.067 \times 10^{-8} \left(\frac{n_e}{T_e}\right)^{1/4} \left|\ln \frac{149.485}{n_e \sqrt{T_e}}\right| \quad (1)$$

during the daytime (or sunlit region) and by

$$r_{max} = 2.712 \times 10^{-8} \left(\frac{n_e}{T_e}\right)^{1/4} \left|T \ \ln \frac{4.286 \times 10^{7} \ n_e \sqrt{T_e}}{n_i \sqrt{T_i}}\right| \quad (2)$$

during the night time (or shadow region), where the symbols used have usual meanings and temperatures are in eV.

We have carried out extensive simulations and found that the day time lunar surface potential in extreme conditions [3] remains up to about 21 V with the radius of charged and levitated dust particles up to about 1.1 micron. There is a sharp gradient in electric field near the terminator due to transition of surface potential from positive to negative, causing the dust particles to form thin cloud. The night time surface potential could be as high as -3.8 kV with comparatively larger size dust particles in the environment. There is a possibility that the instruments on future lunar lander missions may be affected by floating electrostatic dust, some time before and after the lunar terminator. It is encouraging us to study such complex scenario on the moon using in-situ measurement techniques.

Lunar Surface Potential Detector: The surface potential on the moon can be measured by the LSPD mounted on a lander near the lunar surface. It is based on the principle of electric field mill [4], in which a chopper is rotated by a motor and the electric field lines are cut. The charge is induced on the sensing electrode, which provides the information about potential existing on the lunar surface. The breadboard model of LSPD has been demonstrated in the laboratory and engineering model is underway. Figure 1 (a) shows photograph of the LSPD package and Figure 1 (b) depicts the linearity of initial results.

Lunar Dust Detector: We have suggested an Inter Digitated Transducer (IDT) sensor to detect the presence of charged particles in the lunar environment. The fabrication technology used for realization of the IDT is thin film processing and patterning using lift-off technology. Whenever a charged dust particle falls on the detecting surface, it generates a short pulse which is processed and counted by the instrument to derive the flux rate of the charged particle at the landing site. The instrument may be mounted on a lander near the surface at an appropriate height for the detection. The idea of the size of the particles and the height may be obtained from the lunar dust levitation modelling results. The sensitivity of the instrument is limited by the manufacturing capability of the sensor as well as the detection electronics. Typically, one micron size dust particles may be detected by the instrument. Figure 2 (a) shows a snapshot of the IDT

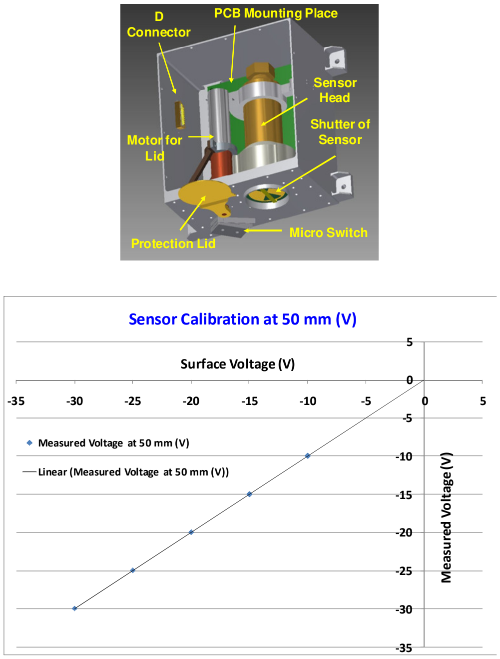

Figure 1: (a) Snapshot of LSPD package (top) and (b) initial results, showing linearity of the instrument (bottom).

detector for detection of one micron radius particle and Figure 2 (b) depicts the initial results obtained using alumina powder.

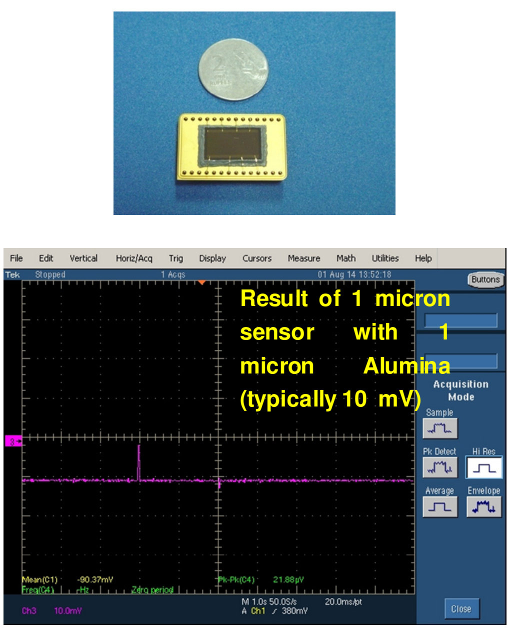

Figure 2: (a) Photograph of IDT dust sensor (top) and (b) initial testing result using one micron alumina powder (bottom).

Implications of Charged Lunar Dust on Future Exploration: The detection and movement of the charged dust in lunar environment needs attention for future exploration activities on the moon using either unmanned missions or manned missions. The breadboard model of MESDA has been developed and tested for proof of concept and the further work is underway. The movement of the charged dust in lunar environment is expected to be periodic over the day and night. Over the full lunar day and night, the charged dust particles would be levitated initially, come down during the decreasing phase of positive surface potential and again be levitated during lunar night. The particles which are able to cross the plasma sheath would follow the parabolic trajectories beyond the boundary and come back within the sheath to experience the existing electric field there again. These phenomena cause the oscillations of charged dust particles beyond the sheath region as long as the surface electric field remains unaltered. In this scenario, it is expected that during the lunar day, the particles should mostly remain outside the plasma sheath region as the surface potential is quasi-static in nature. Hence, a lunar dust detector possibly on a future lunar lander (which is expected to remain mostly within the plasma sheath) may not encounter more number of particles for detection. Towards the terminator, the charged dust particles are expected to be mostly near the surface as the surface potential would be decreasing from positive value. The lunar dust detector is now expected to receive more flux rate of charged particles. This is repeated on the night side beyond the lunar terminator but in reverse manner. During the lunar night, the charged dust particles initially would remain near the surface giving larger flux rate at the detector output and then would mostly remain beyond the plasma sheath. Thus, the sensitive instruments on future lunar lander missions are likely to be affected more during some time before and after the terminator. The MESDA instruments can provide essential information about the potential variation as well as the presence of charged dust in the lunar environment.

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