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A new design of charged particle trajectory sensor

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Abstract

We described an new dust particle trajectory sensor design based on charge induction effect. It is a low mass trajectory sensor, and also can be used to perceive the particle velocity. The instrument consists of three planes of segmented grid electrodes and each electrode is connected to an individual charge sensitive amplifier. Our simulations show that although the number of electrodes is significantly lower than for the formerly developed trajectory sensor, a high trajectory accuracy is achieved. The trajectory accuracy of the boundary regions is higher than that of the center regions on the grid electrode. A simple laboratory model with three sensitive grids were built up recently, after preliminary tests, which shown very similar results with simulations.

Introduction

One of the highest-priority issues to be addressed is that of the lunar dust for future human landing mission. The current knowledge about the dust environment at the Moon was recently summarized [1]. Fine grains from the lunar surface can be lifted due to human activities, and there are indications that lunar fines can be electrostatically charged and naturally transported under the influence of near-surface electric fields. Observations by the Apollo astronauts of sticking of dust to their space suits even after short extravehicular activities demonstrated the importance of control of dust contamination [2]. A dust detector on lunar surface would allow a direct observation all dust related process.

In this paper, we will describe a new design of segment grids trajectory sensor for charged particle detection. The COULOMB software was used for the signal simulation and analysis.

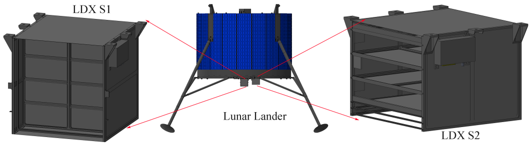

Figure 1: Sketch of the LDX sensors mounting position at the lunar lander. A position close to the lunar surface allows the search for levitated dust and dust transport phenomena. One side of the LDX S2 sensor is open to show its inside structure.

1 Instrument description

A laboratory trajectory sensor model with wires electrodes was built by our group[3]. To meet the new requirement of Lunar lander, we developed the Lunar Dust eXplorer (LDX). LDX uses charge induction electrodes as well as an impact ionisation target. In our design, two separate sensors (LDX-S1 and LDX-S2) are required, as shown in Figure 1. One sensor (LDX-S1) points sidewards, which is used for the measurement of transported dust, surface ejecta from micrometeoroid impacts and interplanetary dust. One sensor (LDX-S2) points downwards to the surface in order to detect dust levitation and dust transport up to an angle of 45° with respect to the surface normal. This detector also acts as a reference for the noise of the sunrise and sunset, as solar UV influx to this side is very small. Both instruments contain an electron reflector and three planes of charge sensitive electrodes. The individual sensitive areas of these two instruments are equal (Approximately 400 cm^2).

All electrodes are formed by etched grid segments, and these segments on Plane A and B have a size of approximately 10 cm × 5 cm. The two large electrodes of center plane have a size of approximately 10 cm × 20 cm. The distance between each segment is 3 mm in order to allow for a mounting structure and a low capacitance between the electrodes.

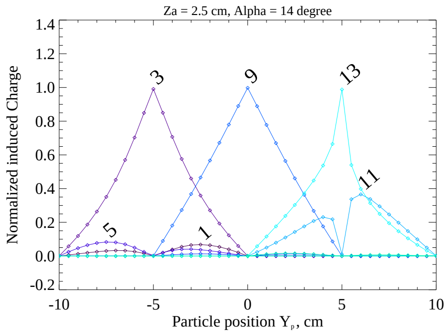

Figure 2: The induced charge signal from simulation.

2 Trajectory determination

Up to 10 different incident angles were studied for each insertion point. Figure 2 shows the results for 14 degrees. We distributed two types of signals: signals showing one maximum, and signals with two maxima. The signals on segment 3 and 13 only have one maximum, which lead to amplitudes of 100 % of the particles primary charge. These segments were crossed by the particles and we call this type of grid segment "Main Segment". The shapes of signals on main segment change with particle trajectory conditions. Conversely, the maximum values remain unchanged, hence these segments can be used to determine the charge and velocity of the particles.Another type of signals appear on segments 5 and 11, which are next to the insertion points on the main segments. This type of segments is called as "Neighbor Segment". The signals on neighbor segment have normally two maxima, e.g. Q1 and Q2 on segment 5, or Q3 and Q4 segment 11, as shown in Figure 2. The values of these maxima have relationships with both insertion points and incident angles. Figure 3 shows the results from a simple lab model with three sensitive grid.

3 Incident angle calculation

We do define a average amplitude Q$_{alpha}$ and Q$_{beta}$for the signals, which are the normalized average values of the maxima induced charge (Q$_{alpha}$=(Q1+Q2)/2Q,Q$_{beta}$=(Q3+Q4)/2Q). Q is the maximum of the signal on main segment, which also the particle primary charge. Figure 3 gives the method for insertion point position calculations from the the simulation results.

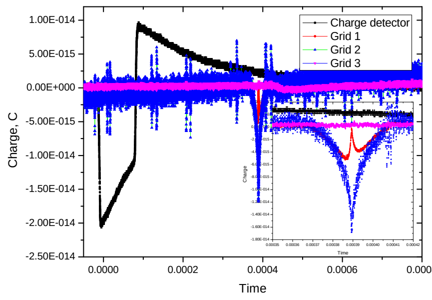

Figure 3: The induced charge signal from lab test.

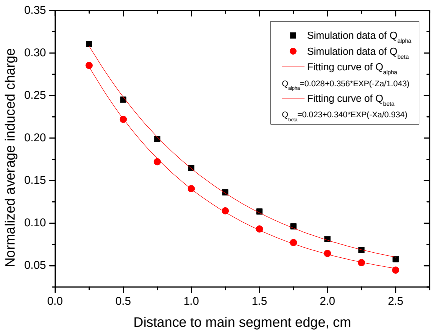

Figure 4: Fitting curves for Q$_{alpah}$ and Q$_{beta}$

4. Summary and Conclusions

We described a charged dust trajectory sensor using a array of grid segments, which will be an important payload on the future ESA Lunar Lander mission. The charges and velocities of particles could be detected by the induced charge signals of the main segments. Using the induced charge signal of the neighbor segments, the position parameters of insertion points on plane A and plane B are available. Particles incident angles are derived from the information of these insertion points.

References

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