Lunar Dust Migration by Electrostatic Charging: Key parameters and Tests. A. Champlain[1], J.-C. Matéo-Vélez[1], J.-F. Roussel[1], N. Giusti[2], C. Ortega[3] , B. Bonelli[4] and R. Lindner[5], [1]ONERA, BP74025, 2 avenue Edouard Belin, FR-31055 Toulouse (amandine.champlain@onera.fr), [2]ALTA S.p.A., Via Alessandro Gherardesca 5, 56121 Loc. Ospedaletto, Pisa, Italy (n.giusti@alta-space.com), [3]AVS Pol. Ind. Sigma Xixilion Kalea 2, Bajo Pabellón 10, 20870 Elgoibar, Gipuzkoa, Spain, [4] Politecnico di Torino, Corso Duca degli Abruzzi, 24, I-10129 Turin, Italy (barbara.bonelli@polito.it), [5]ESA/ESTEC TEC-MMG, Keplerlaan 1, 2200AG Noordwijk ZH, The Netherlands

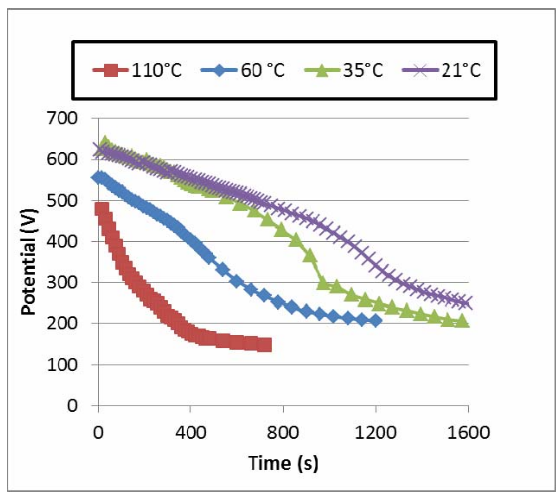
Introduction: Since the Apollo era dust contamination is clearly an identified risk for space objects exploration missions. The lunar Horizon Glow is believed to occur at the transition of sunlit and shaded surfaces due to the combination of charged dust and large electric field [1]-[2]. Human or robotic activities also remove dust from the soil with possible subsequent adhesion onto sensitive surfaces, by a combination of forces acting on them, including gravity and electromagnetic. Recent pictures of the Rosetta mission showed a large amount of volatile small dusts kicked up by Philae rebounds on the comet soil. Identifying the process leading to dust adhesion onto surfaces is a key aspect of space exploration. One of the main contributors is the electrostatic charging imposed by the space environment. This paper aims to describe the experimental setup and campaign led in Europe to extract the key parameters at the origin of lunar dust migration by electrostatic means and subsequent contamination.

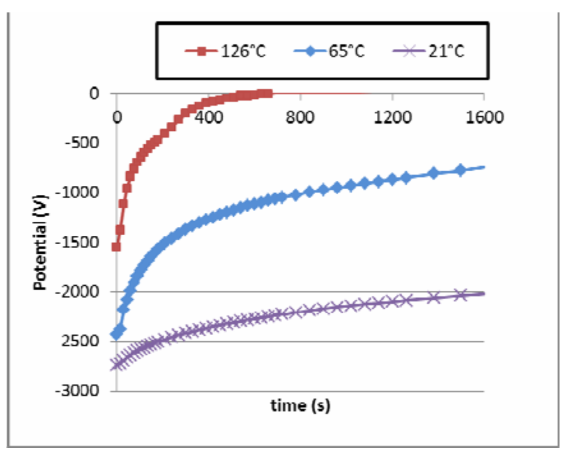
Lunar dust charging: The lunar regolith is composed of basalt in the lunar seas and feldspar rocks in the Highlands. The distribution of interest in this work is typically dust below 100 µm in diameter, composed of silica, ferrite, alumina and other components [3], with a global density of 1.5 g/cm^3. Charging occurs at different length scales: lunar surface, rocks and finally dust.

Ambient plasma collection: The important parameters are the distance to the Sun and the presence of a magnetosphere, defining the ambient electron and proton distributions. On the dayside, the main contributor to soil and dust charging is the photoemission. The surface floats to a few volts positive. On the night side, the ambient plasma makes the surface potential float to some tens or hundreds of volts negative. In between, the terminator is a region of increasing electric field, especially when taking into account the surface roughness and craters [4].

Electron emission: The photoemission process depends on the sun flux and energy distribution as well as the material properties and surface state. The secondary electron emission (SEE) under electron impact is important to determine the potentials of shaded dust and soil. The SEE yield is a combination of primary electron energy, incidence angle and material properties. Experiments conducted at ONERA premises with the European DNA-1 and the American JSC-1A lunar dust simulants demonstrate that the second energy cross over, defining the limit at which the yield goes from more to less than unity, is achieved at several hundreds of eV. Charging dust negatively is possible for electron energy smaller than 100 eV or larger than 2000 eV.

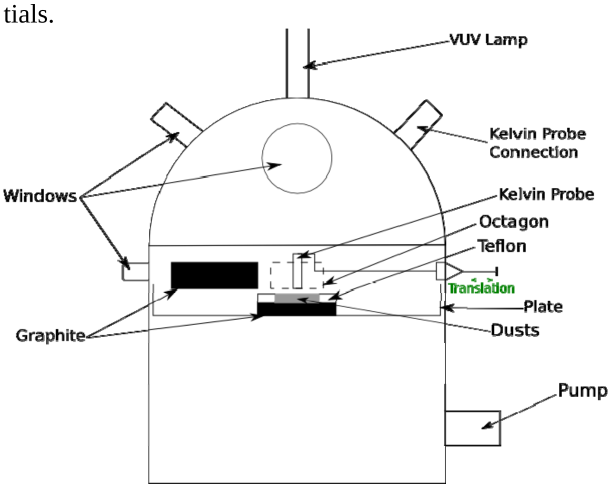
Conductivity: The conductivity of lunar dust simulants was measured under various experimental conditions (VUV and electrons) and temperature (room to +125 °C). The next picture represents the potential decay at the surface of a 6 mm thick DNA-1 layer, after VUV and electron irradiation respectively, and its evolution with temperature.





Dust migration due to electrostatics: Transports of dust over large distances is studied within the DROP chamber at ONERA. This setup was developed to control the charge of dust and their migration onto sensitive equipments.

Test setup: It is a cylinder 250 mm long and 350 mm wide with a hemispheric cover of 350 mm diameter. A cryogenic pump is used to obtain a pressure in the 10^{-7} mbar range. Several flanges are used to equip the tank with an electron gun (50 to 5000 eV) or with a VUV Deuterium source (with two specific lines at 120 and 160 nm). High voltage feed through, quartz windows for illumination and CCD camera complete the system. The dusts are mounted as a layer on top of a metallic plate. They are concentrated in a 30 mm diameter hole performed in the middle of a 6 mm thick dielectric material, permitting to get a flat dust surface. A translating Kelvin probe measures the surface potentials.



Conditions: In the VUV configuration, the dusts are irradiated vertically with the Deuterium source, which complements the experiments of [5]-[7] with plasma and electron gun. Two blocks are positioned at a distance of 10 mm from the dust layer edge (25 mm from the layer center). The first one is set positive in order to attract the photoelectrons emitted by the dusts. It helps increasing the potential and the positive dust charge. The second block is negatively biased to attract the dusts. This latter block is a rotating octagon equipped with several samples.

Sample contamination: The contamination is assessed on a series of different samples: graphite, aluminum, aluminum oxide (alox) and multi-layer insulator (MLI). The conditions leading to dust contamination were obtained and the adhesion onto the different samples produced important information on the selection of possible candidates for future missions.

The diagnostics of interest are the optical and scanning electron microscopy of samples, the adhered dust weight measurement plus extra tests to be investigated further (emissivity, absorption, reflectance...). The previous figure shows the state of a sample of graphite after testing. Dust contamination is responsible for the degradation of the sample surface properties after only a few minutes (with more impacts on the left side).

Perspectives: This study presents the first results in Europe to obtain dust electrostatic charging and contamination of samples, mimicking what is expected during mission landing on the Moon and asteroids. The modeled situations correspond to a sunlit surface surrounded by voltage gradients imposed by the Moon surface and by the lander. In the tank, the electrostatic charge and potentials lead to dust ejection from the layer into vacuum. Subsequent details of the conditions leading to dust emission and adhesion at micron scale are still necessary to better understand the physics and to design mitigation techniques. Charging effects will be assessed at lower temperatures. Finally, a complementary situation will occur during the missions: dust ejection due to rover displacement. This situation will also be investigated (dust in the gaseous phase however follows the same physics, i.e. photoemission and force balance).

References:

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