SIMULATION AND EXPERIMENTAL INVESTIGATION OF LUNAR DUST CHARGING AND ADHESION. J.-C. Matéo-Vélez[1] (mateo@onera.fr), P. Oudayer[1] (pauline.oudayer@onera.fr), L. Monnin[1] (loanne.monnin@onera.fr), A. Roggero[2] (aurelien.roggero@ensiacet.fr), J.-F. Roussel[1] (roussel@onera.fr), S. Hess[1] (sebastien.hess@onera.fr), E. Dantras[3] (eric.dantras@univ-tlse3.fr). [1]ONERA, the French Aerospace Lab, 2 Avenue Edouard Belin, Toulouse, France. [2]ENSIACET, 4 Allée Emile Monso, 31030 Toulouse, France. [3]CIRIMAT, Université Toulouse 3, France.

Introduction: Since the Apollo era, contamination by dust has been identified as a significant risk for lunar, and more generally airless body, exploration missions ([1]-[2]). For the next missions to the Moon surface to come, dust mobilization generated by rover and or robotic activity needs thus to be considered carefully. It may originate from the Horizon Glow ([3]-[4]). In both cases, the mechanisms at play in adhesion or removal of dust are controlled by electrostatic forces. These forces are induced by charges stored at the surface of dust and of covering materials. Electrical charge carriers are generated by the lunar plasma environment, with significant differences between shade and sunlit surfaces, and by triboelectric effect as well. Mitigation techniques should benefit from a better understanding of these processes.

The objective of this work is to conduct and analyze numerical and experimental investigations of dust charging in space-like condition, within the frame of the SPIS project (www.spis.org) that have made available an open-source software to the community [5].

Charge modelling: Dust charging is the result of the balance between competitive contributors. Ambient solar wind electrons of a few (tens of) eV impose a negative potential, with differences induced on materials of different secondary emission yield. Photoemission generates high density positive charges on sunlit surfaces, leading to differential potential of a few (tens of) volts between shaded and sunlit surfaces for both large scale structures, such as craters, and intermediate scale structures, such as exploration units covered with insulating materials. At the micron scale of the lunar regolith top surface composed of fine dust, or at the scale of a dusts deposited on equipment, the modelling of charge levels is complicated by the porous nature of agglomerated dust and by the shape of single dusts. Fine charge structures have been predicted by numerical simulations [6]. A series of negative and positive patches can explain dust transport amplification [7]. Charge transfer through or at the surface of the dust, as well as conduction at dust to dust interface prevent however excessive local differential potentials.

Experimental setup : The DROP facility mimics lunar environment conditions. This vacuum chamber is equipped with a turbomolecular pump allowing tests at 10^{-6} mbar. Dust charging is obtained with a bias potential applied to their metallic holder in combination with a VUV photon beam impacting the dust layer. Several sets of lunar dust simulants have been used. The average dust potential is measured with a contactless Kelvin probe after VUV irradiation.

Numerical Results : the experimental setup geometry is simulated at two different scales with SPIS. At macroscopic scale, part of the electron cloud generated by the impact of VUV on dust and on the substrate is collected back by the dust layer, mimicking lunar environmental conditions (electrons from the solar wind). The equilibrium surface potential correlates the experimental data in DROP. At microscopic scale, the electron out flux induced by VUV is responsible for positive charging on the dust top surface. The photoelectrons emitted by dusts partly covered by the top surface dusts are collected by the top dust rear side, leading to negative patches. Furthermore electron from the electron cloud above can reach dust deeper inside the layer and produce negative charging. It leads to a complex non-monotonic structure, as presented in Figure 1 that shows the potential of the top five layers of dust, here simulated by spheres 50µm in diameter.

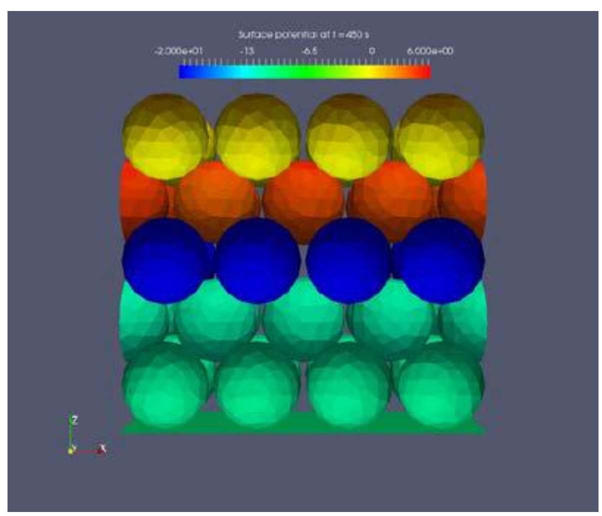

Figure 1 – Simulation of dust layer potential after VUV irradiation inside the DROP lunar dust environment chamber

Dust electrical properties characterization : Dust to dust charge transfer and dust to substrate charge transfer is assessed by measuring the electrical current conducted between two electrodes separated by a dust layer. Two techniques are used: broadband dielectric spectroscopy under nitrogen atmosphere and direct current measurement under vacuum ([8]-[9]). The measured electrical permittivity and conductivity of some dust exhibit a behavior typical of disordered dielectrics [10]. Figure 2 presents the electrical conductivity of DNA-1 lunar dust simulant. It exhibits a Maxwell-Wagner-Sillars behavior possibly induced by dust-to-dust interfaces or inhomogeneity in the dust physical composition. These differences between dust simulants may explain different charging behaviors observed when dust are immersed in lunar like conditions.

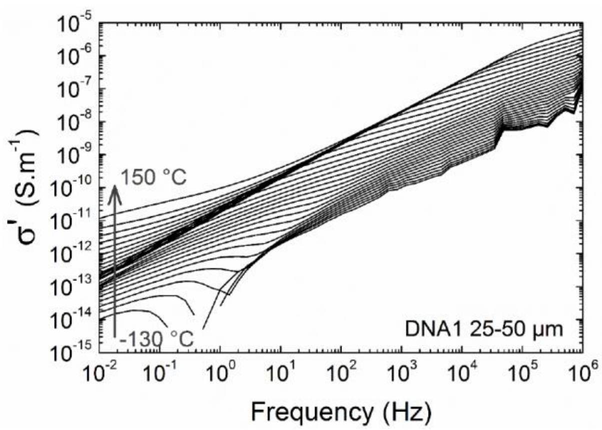

Figure 2 - Isothermal dielectric conductivity of lunar dust simulant against frequency.

This work is the basis of current activities dealing with the assessment of electrical and adhesion forces.

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