Numerical Analysis of Intense Surface Charging inside Deep Cavities on the Moon

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This study focuses on charging characteristics of non-conducting lunar surfaces directly exposed to solar wind plasma flows. In particular, we investigate the charging and electrostatic environment near an uneven, cavity topography in consideration of the strong dependence of a floating potential on the surface topography.

In general, an equilibrium floating potential of the lunar surface is determined such that all relevant currents are balanced with each other. It follows that the lunar surface acquires a negative floating potential when the surface collects only the charges of a solar wind plasma, while it acquires a positive floating potential when electron emission processes such as the photoelectric effect work. Actually, in-orbit observations from lunar exploration satellites have suggested that the dayside of the lunar surface is positively charged, whereas the nightside is negatively charged.

However, the lunar surface has cavities of various spatial scales, ranging from terrain scales such as craters and longitudinal pores to smaller ones such as boulders, rocks, and regolith layers. Recent simulations have shown that these cavities alter plasma motions in space and the surface charging characteristics due to solar wind plasma and emitted electrons, resulting in the formation of distinctive electrostatic environments. These topography-specific electrostatic environments may also affect the transport of small dust grain on the lunar surface. For example, as well as topographic-scale surface features, microcavities formed by smaller-scale rocks and regolith particles are also interesting targets in terms of dust transport by electrostatic forces. At such spatial scales, the inadequate capacity of Debye shielding generates a stronger electrostatic field, which is considered to be one of the key factors in the mobilization and suspension of charged regolith particles.

In our study, plasma particle simulations were carried out assuming a situation in which solar wind plasma pours down from the sky onto the lunar surface, which has a cavity with a size comparable to, or smaller than the Debye length. We investigate the dependence of the electrostatic environment on the geometry of the space in the cavity. We focus not only on the steady state of the environment but also temporal fluctuations in the electric potential and charged particle flux distribution. It was found that the solar wind plasma flow forms a positive potential in the depths of a simple rectangular cavity, reaching up to several 100 V as the depth-to-width ratio of the cavity increases [1]. The identified potential energy is similar in magnitude to the kinetic energy of ion particles.

In this presentation, we report the physical mechanism for the formation of the distinctive electrostatic environment inside the cavity. The detailed analysis has elucidated the dependence of the charging properties on the cavity geometry and the formation of current paths for the relaxation of the internal cavity potential by photoelectrons. We also discuss the future prospects of this research, including applicability of the present results to topographic features in smaller spatial scales models and an ongoing project toward the development more sophisticated numerical simulations for charging analysis targeting sub-Debye scale surface topology.

References

[1] J. Nakazono and Y. Miyake, "Unconventional Surface Charging within Deep Cavities on Airless Planetary Bodies: Particle-in-Cell Plasma Simulations," [preprint] *Authorea*, November, 2022, doi: 10.1002/essoar.10512644.1.