Photoelectric Current Density Measurement for Lunar Daytime Simulation: Guiding Large-Scale Experiment Design

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Introduction: The charging behavior of the lunar soil is a significant challenge for lunar exploration missions, with its transition from positive charging during the day to negative charging at night[1-3]. Despite numerous researchers studying this phenomenon[4-8], the complexity of simulating lunar soil behavior in a vacuum environment has kept most research restricted to laboratory scale experiments.

KICT has developed the Dirty Thermal Vacuum Chamber (DTVC), one of the most sophisticated testing chambers developed for simulating lunar condition containing regolith simulant(figure 1). The DTVC has the capability to achieve 1e-6 mbar without reolith simulant and with the use of halogen lamps and a shroud, it can replicate lunar day and night temperature variations. In the future, KICT plans to expand the DTVC's capabilities by incorporating additional equipment to simulate the electrical environment of the lunar surface, further improving the testing facility's advanced capabilities.

Fig. 1 An image of KICT's dirty thermal vacuum chamber (DTVC). The photograph shows the chamber, revealing a container holding artificial lunar regolith positioned inside the chamber.

In this study, we conducted experiments using a laboratory-scale vacuum chamber to replicate the charging environment of the moon and a basic system to simulate the photoelectric effect on the lunar surface. Our focus was on measuring the photoelectric current generated by photoelectron emissions on the surface of various test pieces made of different metals. We will provide an overview of the experiments conducted in this study.

Experiment method: Figure 2 shows the lab-scale vacuum chamber used in this study. The chamber was specifically designed to achieve a high vacuum pressure level of 1e-7 mbar, utilizing a turbo pump and molecular pump. At the top of the chamber, an ultraviolet lamp has been incorporated to simulate solar radiation, while an electron flood gun has been employed to replicate the night environment. Additionally, feedthroughs are located on the right-hand side of the chamber, allowing for various measurements to be connected.

Fig. 2 An image of the laboratory vacuum chamber and measurement units. The chamber features a UV lamp for replicating solar radiation and a molecular pump for achieving high vacuum levels (less than 1e-7 mbar). The measurement units include vacuum guage, electrometer, DC voltage supplier, etc.

The measuring unit utilized in this study comprises several components, including an aperture that controls the irradiation area of ultraviolet rays, a base that supports the test piece, a collector that gathers the photoelectrons generated by the ultraviolet irradiation, and an enclosure encompassing all of these elements. The base and enclosure are grounded to maintain zero potential, whereas the potential of the test piece metal and collector is regulated by respective power supplies.

The measurement process is carried out by downward irradiation of ultraviolet rays from the UV lamp mounted on the chamber's upper part. When directed through an aperture onto a particular area of the test piece, these rays induce the emission of photoelectrons upon impact. The photoelectrons are then drawn towards the collector, which has a positive potential, and the electrometer quantifies the current flowing through it.

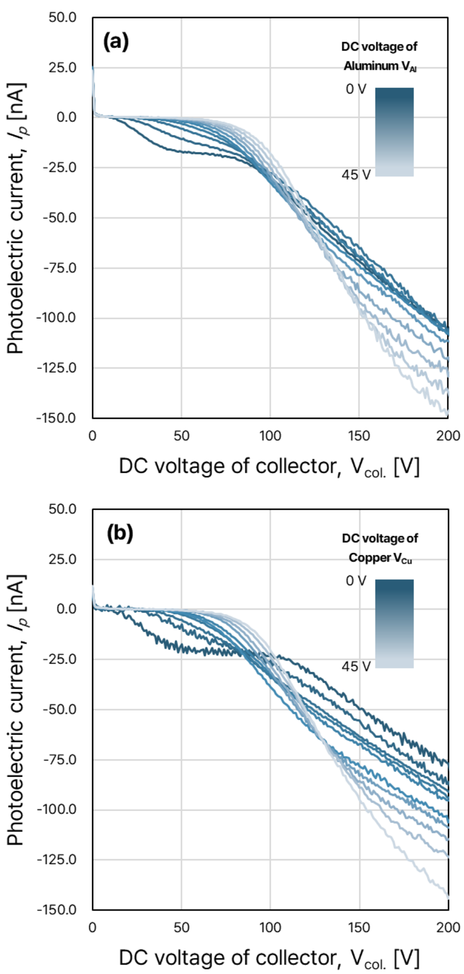

Fig. 3 The I-V curves of photoelectric current (I_p) versus DC voltage of the collector($V_{col.}$) obtained for two different metals: (a) aluminum and (b) copper. DC voltages applied to each metal while maintaining a constant positive potential on the electron collector. The DC voltage(V_{Al} and V_{Cu}) was induced in the metals, with values ranging from 0 to 45 V.

Result and discussion: Figure 3 shows the photoelectric current (I_p) generated by the application of DC voltage ($V_{col.}$) to the collector while DC voltage (V_{Al}, V_{Cu}) is applied to aluminum and copper, respectively. The current is assumed to be positive in the direction of electric current going out from the collector, in other words electrons entering the collector from the outside, resulting in a negative expression of current density of photoelectrons generated on the lunar surface.

The curve pattern, as is in the figure, varies depending on the DC voltage applied to the metal. For instance, in the case of aluminum, I_p initially decreases until $V_{col.}$ reaches around 50 V, after which it stabilizes until $V_{col.}$ reaches about 70 V, and then starts to decrease again. A similar phenomenon is observed in copper, where secondary attenuation starts when $V_{col.}$ reaches 100 V.

However, as the voltage applied to the metal increases for both aluminum and copper, the curve pattern gradually disappears, and no secondary damping is observed at a voltage of 45 V. This suggests that the phenomenon is related to the metal surface properties and the voltage applied to the metal.

Conclusion: The measuring unit has demonstrated its capability to quantitatively represent the photoelectric effect induced by UV light. In the early stages of our study, we have explored the photoelectric currents generated by different metals under varying DC voltages. Our findings indicate that the photoelectric current generated by aluminum is greater than that of copper, which can be attributed to the difference in their respective work functions. We plan to utilize this measuring unit to quantify the photoelectric effect of lunar regolith simulant in future studies and use the obtained data to design a lunar regolith simulant charging device at KICT's DTVC

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