SURFACE EFFECTS ON PHOTOELECTRON SHEATH CHARACTERISTICS

A. Dove, S. Robertson, X. Wang, M. Horányi, Colorado Center for Lunar Dust and Atmospheric Studies, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, 80309 (adrienne.dove@colorado.edu)

Introduction: Surfaces of airless bodies and spacecraft in space are exposed to a variety of charging environments. A balance of currents due to plasma bombardment, photoemission, electron and ion emission and collection, and secondary electron emission determines the surface's charge. In the inner solar system, especially around 1 AU, photoelectron emission is the dominant charging process on sunlit surfaces due to the intense solar UV radiation. This results in a positive surface potential, with a cloud of photoelectrons immediately above the surface, which is the photoelectron sheath. Conversely, the unlit side of the body will charge negatively due the collection of the fast-moving solar wind electrons [1]. The interaction of charged dust grains with these positively and negatively charged surfaces, and within the photoelectron and plasma sheaths may explain the occurrence of dust lofting, levitation and transport above the lunar surface.

The Moon's plasma sheath is characterized by a photoelectron density of approximately 60 cm^{-3} and a Debye length on the order of 1 m [2]; however, both the density and size of the sheath fluctuates according to the variation in UV flux with the solar cycle [3]. Laboratory measurements of the photoelectron yield from lunar soil samples under solar-like illumination produces emission currents of about 5 $\mu A/m^2$ [4]. During a solar maximum, emission currents will increase to around 16 $\mu A/m^2$ due to an enhanced solar UV photon flux, and solar flares will result in emission currents on the order of 40 $\mu A/m^2$ [3].

Experimental Setup: Experiments are conducted in a 0.6 m^3, 60-cm diameter vacuum chamber (Figure 1). A 50-cm diameter aluminum table is covered by thin sheets of zirconium metal. Zr is chosen because it has a relatively low work function, W = 4.05 eV, and a high photoelectric yield [5]. In order to study the photoelectron sheath above an insulating material, we use CeO_2, both in powdered and solid disk form. CeO_2 has been used in other dusty plasma experiments [6] and it is a good photoemitter. It is used in our setup to obtain measurements above a surface with vastly different material properties than the Zr metal. For the powder experiments, an approximately 7x10 cm patch of CeO_2 powder is placed on the Zr surface. A 6” solid disk of CeO_2 is placed in the same location on the surface for comparison experiments.

In order to simulate the lunar surface environment in the laboratory, we use xenon excimer lamps (Osram Xeradex) that emit ~8 W of ultraviolet (UV) radiation in a narrow band centered at 172 nm (7.21 eV). This generates a sheath with significant space charge and a shielding distance of approximately 7 cm, and a density $n_e \approx 4x10^4$ cm^{-3} above the Zr surface.

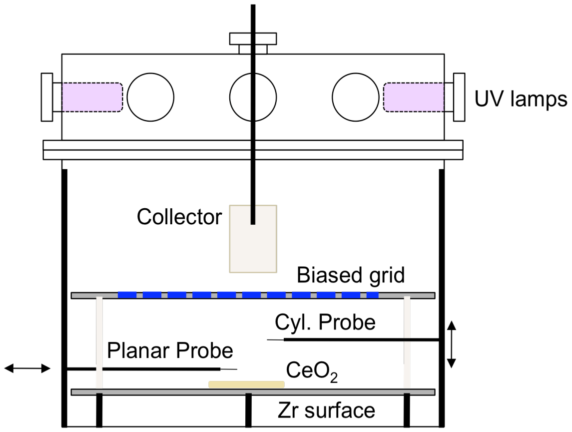

Figure 1. Experimental setup for UV photoemission studies with various surfaces, in vacuum.

We measure the electron densities and temperatures of the photoelectron plasma with two types of Langmuir probes. A cylindrical probe is constructed from a 0.5mm tungsten wire, approximately 4 cm in length, at the end of an insulating glass tube. A single-sided planar probe is constructed from a 1-cm diameter disk of tantalum foil at the end of a glass tube, with a ceramic coating on one side of the foil to make it an insulator. An emissive probe is also used to measure local potentials within the plasma as another measure of the electric field above the surface. The emissive probe is constructed of an emitting 0.025mm thick tungsten filament, about 5 mm in length, at the end of a ceramic tube. The cylindrical and emissive probes are attached to linear rails that allow for vertical motion (perpendicular to the surface) inside the chamber. The single-sided probe is positioned about 5 mm above the surface and moves parallel to the surface. Probe motion and data collection are controlled through a LabView program interface.

Because of the high energy of the UV photons, the signal we measure above the Zr surface is contaminated by electrons produced from the walls of the chamber. In order to reduce these electrons, we place a nickel grid above the Zr plate that can be biased negatively to repel the electrons emitted from the walls. To further reduce contamination in the measurement space, a piece of metal hangs vertically in the space above the grid in the chamber – this “collector” is bi

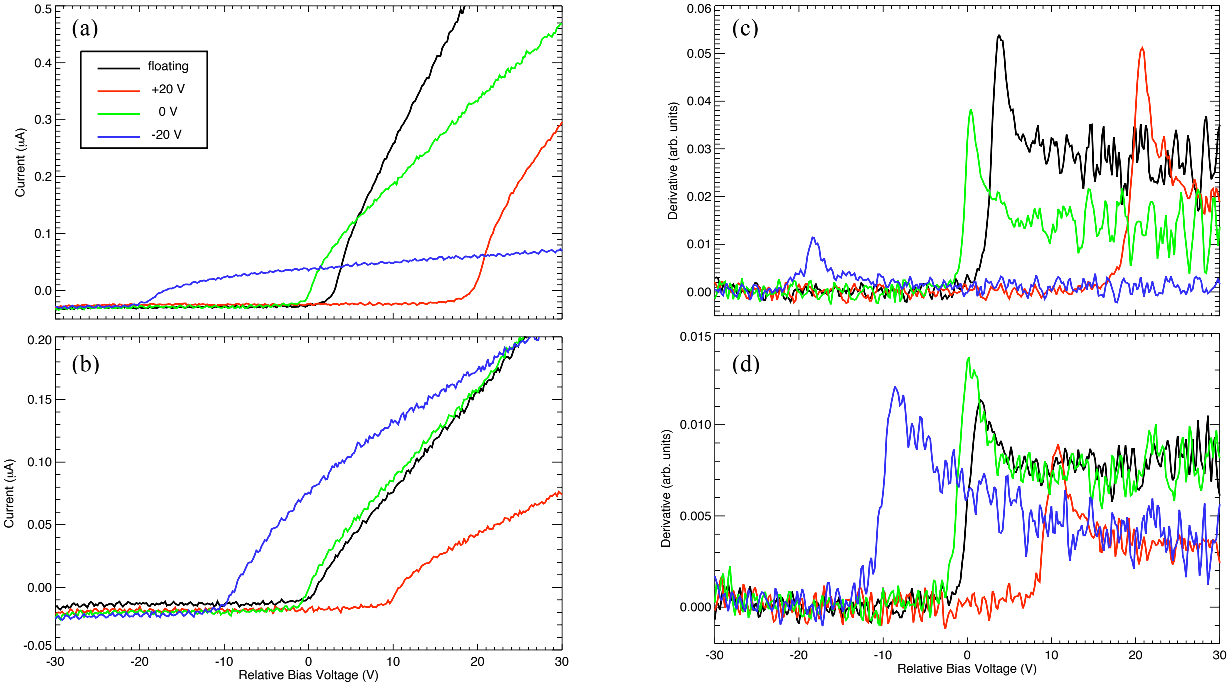

Figure 2. Cylindrical Langmuir probe sweeps above the photoemitting (a) Zr and (b) CeO_2 surface, and the sweep derivatives ((c) and (d), respectively). In all cases, the underlying Zr surface was biased as shown in (a), and the sweeps were taken with the probe ~4 mm above the surface.

ased very positively to collect both wall electrons and electrons produced by photoemission from the grid.

Sheath Measurements: Using the cylindrical Langmuir probe, we measured the photoelectron sheath above a biased or floating Zr plate when the grid was biased to -20 V [7]. Above the floating surface, the measured sheath had an electron density $n_e \approx 4 \times 10^4$ cm^{-3}, an electron temperature $T_e \approx 1.4$ eV, and a resulting Debye length $\lambda_d \approx 7$ cm. Our setup allows the emitting surface to reach a floating potential several volts more positive than the surroundings or the biased grid. Because the Debye length is on the order of 7 cm, we are able to characterize the changes vertically within the sheath.

While metallic surfaces are relevant to spacecraft, dusty, insulating surfaces are more relevant to lunar surface conditions. For measurements above the CeO_2 surfaces, we use both the cylindrical Langmuir probe and the planar Langmuir probe. We begin by comparing these measurements to those taken above the Zr surface. Cylindrical Langmuir probe sweeps taken ~4 mm above the Zr surface and the powdered CeO_2 surface are shown in Figure 2(a) and (b), respectively. The blue lines in Figure 2 represent the sweeps taken when the Zr surface is biased to -20 V; in this situation, the electrons are almost entirely moving upward away from the surface. Figure 2(b) indicates that the CeO_2 may actually be emitting more than the Zr surface. Further analysis will be presented.

For a probe above a photoemitting *conducting* surface, we expect that the measured plasma potential (as determined by the peak in the first derivative of the IV trace) follows the surface bias, within a few volts [7], as seen in Figure 2(c). For the sweeps above the insulator, however, the peaks in the first derivative are shifted due to the more complex surface processes (Figure 2(d)). These results will be further explored, and compared with measurements taken above a solid CeO_2 disk.

References: [1] Manka, R. H. (1973) *Photon and Particle Interaction with Surfaces in Space*, ed. R. J. L. Grard, 347. [2] Colwell, J. E. *et al.* (2007) *Rev. Geophys.*, 45, RG2006. [3] Sternovsky, Z., et al., 2008. *JGR*, 103, A10104. [4] Willis, R. F. *et al.*, 1973) *Photon and Particle Interaction with Surfaces in Space*, ed. R. J. L. Grard, 389. [5] Michaelson, H. B. (1977) *J. Appl. Phys.*, 48, 4729-4733. [6] Fortov, V. E., *et al.* (1998) *J. Exp. and Theor. Phys.*, 87, 1087-1097. [7] Dove, A., *et al.* (2012) *Physics of Plasmas, in review.*