MSFC-712

LUNAR DUST CHARGING BY SECONDARY ELECTRON EMISSION AND ITS COMPLEX ROLE IN THE LUNAR ENVIRONMENT:

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Introduction: The lunar surface is covered with a thick layer of micron/sub-micron size dust grains formed by billions of years of meteoritic impact. With virtually no atmosphere and exposed to the solar wind plasma and solar electromagnetic radiation, the lunar surface and the dust grains are electrostatically charged. The dominant charging processes include: photoelectric emissions (UV, X-rays), impact of solar wind electrons and ions, and secondary electron emissions (SEE) induced by energetic solar wind electrons. During the Apollo missions, the astronauts found the lunar dust to be extraordinarily high in its adhesive characteristics, sticking to the suits and the mechanical equipment. Electrostatically charged lunar dust is believed to be transported over long distances by the induced electric fields, as indicated by the observed dust streamers and the horizon glow [e.g., 1-3]. The hazardous effects of dust in the lunar environment are recognized to be one of the major issues that must be addressed in planning the forthcoming missions for robotic and human exploration of the Moon. Theoretical studies are being performed along with the development of analytical models and a variety of experimental investigations, to better understand the lunar dust phenomena. [e.g., 4-6].

The lunar dust is believed to be charged negatively on the lunar night-side by interaction with solar wind electrons. However, rigorous theoretical expressions for calculation of SEE yields and the sticking efficiencies of individual micron size dust grains are not yet available, and the information has to be obtained by experiment. On theoretical considerations, however, it is well recognized that SEE yields, similar to the photoelectric yields for small-size grains, would be totally different from the corresponding bulk values [e.g., 7-9]. Some theoretical models for charging of individual small spherical particles have been developed [e.g., 10], and some limited measurements on individual metallic dust grains at keV electron energies have been made [e.g., 11].

In this paper, we present the first measurements of the secondary electron emission yields of individual micron/sub-micron size dust grains selected from sample returns of Apollo 11 and Apollo 17 missions.

Experimental Technique: The measurements presented here were made in an experimental facility based on an Electrodynamic Balance (EDB) briefly described in a companion paper [12]. This technique has been used for measurements of charging of micron size dust grains by photoelectric emissions and by electron beams with energies in the keV range as presented in previous publications [e.g., 13-15]. A charged particle levitated in an EDB is exposed to a mono-energetic electron beam, and the charging/discharging rate of the particle is determined by measuring the quantities in the equation,

$$q(t) = g z_o m / C_o V_{DC}(t), \qquad (1)$$

The particle charge as a function of time is a directly measured quantity on the EDB, determined from the DC voltage V_{DC}, *with* known values of the gravity g, balance constants z_0, C_0, and the mass calculated from the particle diameter and mass density. An electron gun mounted at the top provides a beam of mono-energetic electrons, while a Faraday cup mounted at the bottom with an electrometer gives a measure of the electron flux at the trap center. The charging/discharging rates and the secondary electron yield defined as the electrons ejected from the dust grain per incident electron are thus calculated from the measurements.

Experimental Results on Charging / Discharging of Lunar Dust Grains by Low Energy Electrons: Measurements of charging of dust grains selected from the Apollo 11 and 17 sample returns were made on particles of ~ 0.2 – 8 μm diameters by exposing them to mono-energetic electron beams at energies of ~ 5 – 100 eV. As the particle charges or discharges by interaction with the incident electrons, q(t) is determined in accordance with equation (1). In the following four figures we present measurements based on charging/discharging of some selected particles, focusing on the basic nature of the charging processes as a function of the particle size, the electron energy, and the incident electron beam current.

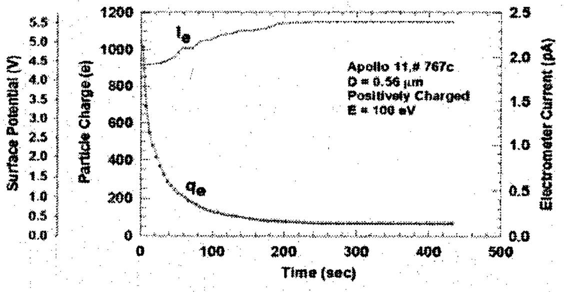

Figure1a. A positively charged discharged to an equilibrium potential by exposure to a 100 eV electron beam.

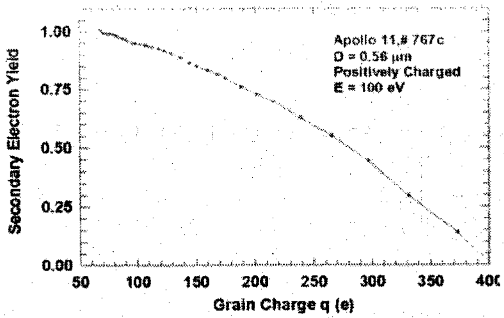

Figure 1b. The calculated SEE yield for the particle in Fig. 1a. The yield increases from an initial value of zero to a maximum yield of ~ 1 at equilibrium.

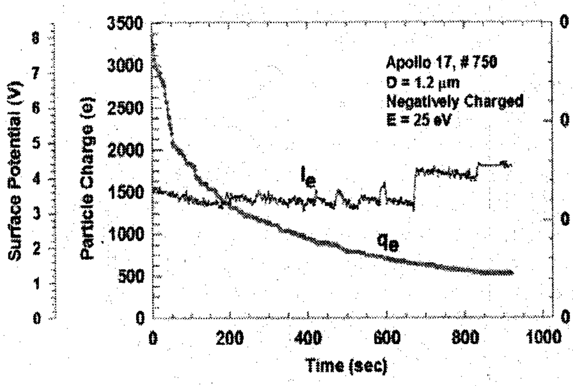

Figure 2a. A negatively charged particle exposed to a 25 eV electron beam discharges from an initial charge of ~ 3400e to a final value of ~ 500e.

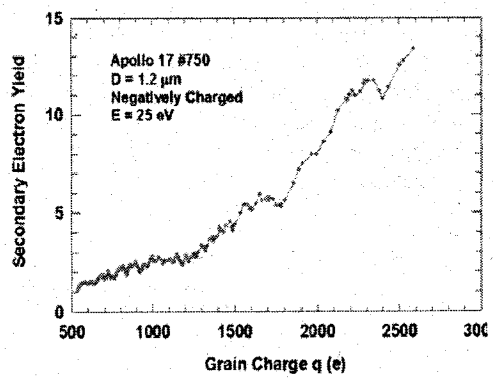

Figure 2b. The calculated SEE yield for the particle in Fig. 2a. The yield deceases from an initial value of ~ 14 to a final value of ~ 1 at equilibrium.

Conclusions on complex nature of secondary electron emissions (SEE):

(1) Positively charged particles larger than a few microns in size, discharge at a rapid rate when exposed to 25 -100 eV electron beams, reaching equilibrium potentials with a balance between sticking electrons and SEE.

(2) Submicron size positively charged particles at low surface potentials generally charge more positively when exposed to 25 eV electron beams, indicating the SEE process dominating the primary electron sticking, with yields larger than one.

(3) The SEE yields for small positively charged particles (< 0.3μm) at relatively low energies of ~ 25 eV are generally found to be larger than at 100 eV. A small positively charged dust grain charges to higher potentials in the former case and discharges in the latter.

(4) Negatively charged particles exposed to 5-100 eV electron beams generally discharge to equilibrium potentials

(5) Equilibrium charges and surface potentials of dust grains in the lunar environment are expected to be a function of the grain size and the incident electron energy and density, with the equilibrium potentials depending on the initial grain charge or potential.

(6) The complex nature of the SEE process implies that both negative and positive dust grains may exist in the same lunar environment depending upon their past history of charging.

Acknowledgements: This work was supported by the MSFC-IRAD and the NESC-Mechanical Systems Lunar Dust Assessment programs. The Apollo lunar dust samples employed in the measurements were kindly provided by NASA-Johnson Space Center. We thank Drs. D. Gallagher and R. Sheldon for helpful discussions.

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