MEASUREMENTS ON CHARGING OF APOLLO 11 AND 17 LUNAR DUST GRAINS BY LOW ENERGY ELECTRONS.

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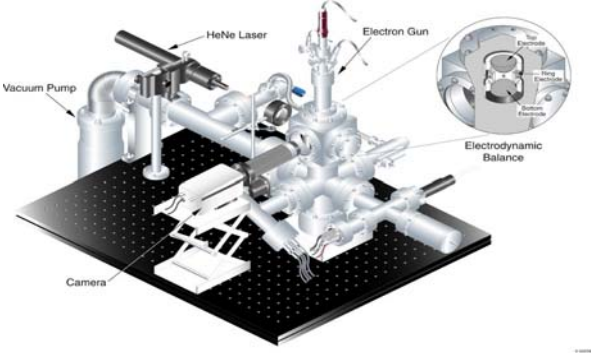
Introduction: Obeservetions made during Apollo missions as well as theoretical models indicate that the Moon's surface and lunar dust grains are electrostatically charged. It is belived that the lunar dust is charged positively during the lunar day by UV photoelectric emissions, and negatively by the solar wind electrons during the lunar night [e.g., 1-2]. Since the high adhesive characteristics and toxic nature of lunar dust may have severe impact on human habitat as well as operations a nd lifetime of a variety of equipment, it is of great importance to investigate the physical and optical properties of lunar dust to develope appropriate mitigating strategies. Results obtained from laboratory measurements on the charging of individual lunar dust grains by UV photoelectric emissions are presented in previous publications [3-4]. In this paper, we present the measurement technique and some of the preliminary results on charging of both, positively and negatively charged Apollo 11 and Apollo 17 lunar dust grains by low energy electrons(5-100eV) to study the charging of lunar dust by the solar wind electrons. Additional results and disussion are given in a companion paper [5].

Experiemetnal Facility and Measurement Technique: The measurements were made on a laboratory facility based on an electrodynamic balnce (EDB). The experimental apparatus consists of: particle generator, EDB electrodes, DC and AC voltage power supplies, vacuum system, electron gun, and the monitoring equipment. Schematic of the experimental apparatus is shown in Fig. 1.



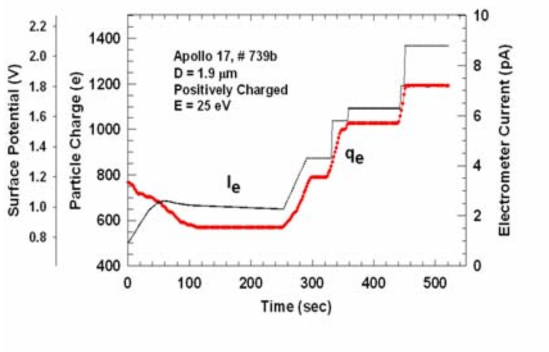
The particle generator employing a pressure pulse technique is used for charging the particles [6-7]. The balance itself consists of spherically shaped DC top and bottom electrode and a ring AC electrode with apertures made to allow optical access to the trapped particle. The trap is held in a vacuum chamber. The particle is visually monitored by imaging the scattered light from a 5 mW-HeNe laser with a standard CCTV camera using a zoom microscope lens. The particles are trapped in the balance at atmospheric pressure.The inductively charged droplets coming out of the particle generator, settle into the electrodynamic balance volume by passing through an apperature on its top electrode. Once the particle is stabaly trapped and the particle generator is removed, the electron gun is at the top of the chamber. The system is evacuated to pressures of ~ 1-5 torr at which the particle diameter is determined by the "spring point" method [e.g. 8]. The particle diameter has to be determined separately because the direct measurements on the EDB provide the charge to mass ratio only. This technique is based on slowely varying the electrical parameters of the trap to a point near an unstable regime when the particle begins to oscillate. The is then evacuated to pressures of ~ 10^{-5} torr, and the trapped particle is exposed to an electron beam from the electron guns (Kimball Physics ELG-5/E and FRA-2X1-2) capable of providing monoenergetic electon beams in the 5-30000eV energy range. The electron beam current is measured by a faraday cup located below the bottom electrode of the trap . As the particle charge changes, the particle is manually balanced against gravity by adjusting V_{dc}. The change in particle charge is then determined as a function of time in accordance with equation

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

With measurements of V_{DC}, the mass m is calculated using the effective particle diameter determined by the "sprig point" technique and lunar dust grain density $\rho = 1.8$ gcm^{-3}, the particle charge *q(t)* is calculated from equation (1) as a function of time. Regimes. With this measurement technique one electron change in particle charge can be detected in certain regimes.

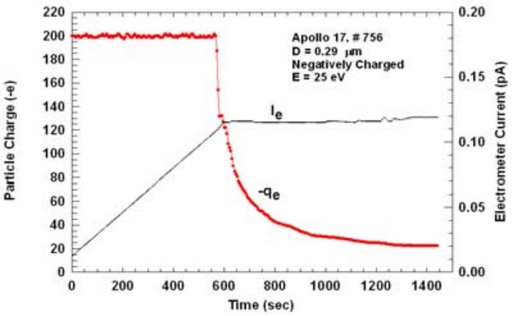
Experimental Results: The measurements were made on positively and negatively charged Apollo 11 and 17 lunar dust grains of ~ 0.2–8 μm diameters by exposing them to electron beams at energies of ~ 5 – 100 eV. Some of the selected experimental data are presented in Figs 2-5. Fig.2 shows the charge and surface potential as a function of time of a 1.9um positively dust grain from Apollo 17 mission when exposed to a monoenergetic electron beam of 25eV. For the fist 100s, as the incident electron current continuously increases and the particle discharges as a result of electrons sticking to the particle. When the current reaches the value of 2.4pA, an equilibrium potential is reached with the incident electron current on the particle becoming equal to the secondary electron emission current SEE. At about 250s from the beginning of the experiment, the incident electron current gradually increases to 4.6pA in ~60s and the particle charge increases to an equilibrium value due to the SEE. At the incident electron current of 4.6pA the dust grain reaches a higher equilibrium state. The same process is repeated a couple of more times as shown in the figure.

Fig.2



In Fig.3 discharging of a negatively charged 0.29um Apollo 17 grain as a result of the SEE from the particle by 25eV electron beam impact on them, with a corresponding electron current is presented.

Fig.3



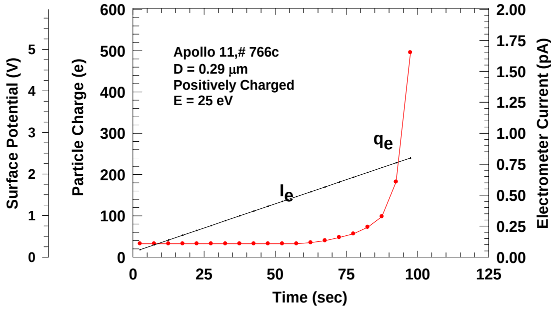
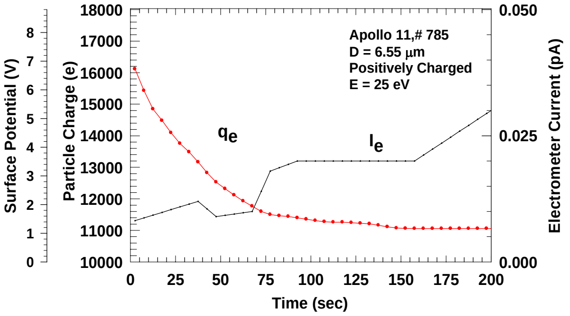


Fig.4

Fig.5



In Fig.4 the charging of a positively charged 0.29um diameter Apollo 11 grain as a result of 25eV electron beam impact is shown. The obtained data for this particle indicate that, as result of the SEE, the charge increases from 32 to 495e positive charges, as the flux of the electron beam hitting the particle is increasing. In Fig.5 the discharging of a positively charged 6.55um diameter Apollo 11 grain as a result of 25eV electron beam impact is presented. In this case the data indicate that as result of the electrons sticking to the particle, the particle charge decreases from about 16000e down to about 11000e positive charges.

Conclusions: **(1)** The experimental technique employing an EDB is very useful for studying charging processes and many other phenomena on an individual dust grain. **(2)** With this method the change in particle charge can be detected with accuracy as high as one electron in certain regimes **(3)** The discharging, charging and different charge equilibrium states of positively charged Apollo 11 and 17 dust grains while being exposed to the electron beams in the 25-100eV energy range demonstrate the two competitive charging processes when the particle exposed to an electron beam, namely: the SEE and electrons sticking to the particle. The data indicate that the negatively charged Apollo 11 and 17 grains discharge to some equilibrium value when exposed to 5-100eV electron beams. More detailed analysis with additional measurements will be discussed in subsequent publications.

References: [1]Stubbs, T. J. et al.(2006) *Adv. Space Res.*, 37(1), 59-66. [2] Horanyi, M., et al.(1998) *J. Geoph. Res.*,103, 8575 8580. [3] Abbas, M. M. et.al.(2006) *ApJ*, 645.No.1, July 1, 2006.[4] Abbas, M. M. et.al.(2007) *Planet. Space Sci*, 55, 953-965. [5] Abbas M. M. et al (2008) 39th LPSC [6] Spann, J. F. (1984) PhD. Dissertation, Dept. of Physics, University of Arkansas, Fayetteville, Arkansas.[7] Venturini, C. C. (1998) *Physics of Dusty Plasmas: Seventh Workshop*, ed. M. Horányi et al., AIP Conf. Proceedings #446 [8] Davis, E.J. (1985) *Langmuir*, **1**, 379-387 .