



CHARGING OF OLIVINE GRAINS IN LOW ENERGY ELECTRON RADIATION

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INTRODUCTION: In the plasma environment of solar system, small particle will be charged negative by collecting free electrons. The movement and accretion of these charged grains will be affected by the action of electronic force, magnetic force, and coulomb force. Except that grains will be charged in space, they also occur on the surface of airless body. On the Moon, lunar dust in shadow region or night side will also be charged negative by collecting free electrons. And it had been verified in Lunar Prospector mission. With accumulation of such charged dust grains, a negative lunar surface potential will be formed. The Electron Reflectometer had detected the night side lunar surface potentials of ~100V in the terrestrial magnetotail lobes and potentials of ~200 V to 1 kV in the plasma sheet. And it is as large as 4 kV during solar energetic particle events [1]. Varieties of local surface potentials might form an electrical field and drive the charged dust grains migrating at the lunar surface. Such movement of charged dust might increase the risk of manned or unmanned lunar surface exploration, and it might also be the main cause of lunar horizon glow formation [2]. To comprehend the movement of charged grains in plasmas environment, charged properties of olivine grains in low energy electron radiation has been investigated as an examples in this study.

FACILITY: Experiments were made in the Simulator of Lunar and Planetary Dusty Environment (SLPDE) at Center for Lunar and Planetary Sciences (CLPS), Institute of Geochemistry, Chinese Academy of Sciences. SLPDE is equipped an electric gun, a UV source, and a vary temperature sample holder in a high vacuum chamber, and a laser doppler measurement system outside the chamber (Fig.1).

- Pressure: ~10⁻⁵ Pa.
- Temperature: RT to ~1000 °C.
- Elwctron energy: 10~500eV.
- UV wavelength: 110~300nm.
- Velocity: 0 to 280 m/s.
- Grain size: 0.5 to 90 μm.

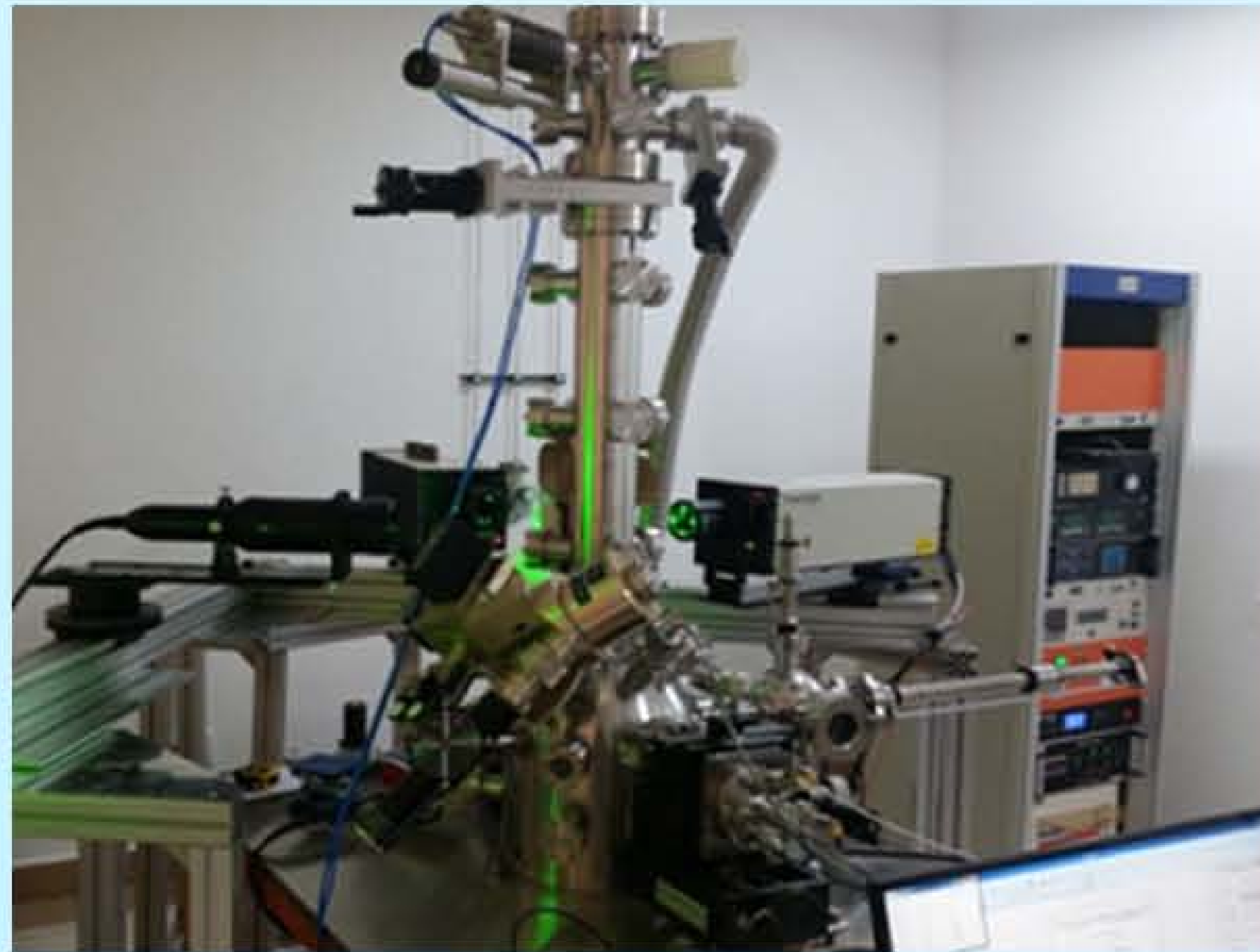


Fig.1. The SLPDE at CLPS.

EXPERIMENT: Experiment was made at room temperature in SLPDE with a pressure of 5.5×10⁻⁵ Pa , an electron energy of 175 eV, and a maximum flow of 500mA. Charged quantity of the grain (Q),

$$Q = \frac{\rho\pi\left(\frac{v^2}{2h}-g\right)D^3}{6E} \quad (1)$$

There, The size (D) and speed (v) of moving charged grains were measured by the laser doppler measurement system. Height of measured point relative to the sample surface (h) is 6mm, density (ρ) of olivine grain is 3.6 g/cm³, E is the intensity of electric field which can be determined by the measured electric potential, and g is the acceleration of gravity.

In this study, olivine is selected as the sample. it has been broken to micron size and dried for more than 3 hours at 105°C before the experiment. The particle size distribution of olivine powder sample was measured by a laser particle size analyzer and the result was shown that all of them are smaller than 80 μm and mean size is about 6μm.

RESULTS AND DISCUSSION

In the experiment, 4192 particles are totally detected and only 44 particles are larger than 12μm in size within 258s measured time. Fig.2 shows the charge quantity of all the grains which are smaller than 12μm in particle size. Most of the grains charged more than 10⁴e and it shows an increases trend with the particle size. The largest grain lifted from sample surface is 25μm and charged about 1.2×10⁷e. And the density of moving charged grains flow pass through the measured areas above samples surface 6mm with an area of 1mm² is about 16 mm⁻²•s⁻¹.

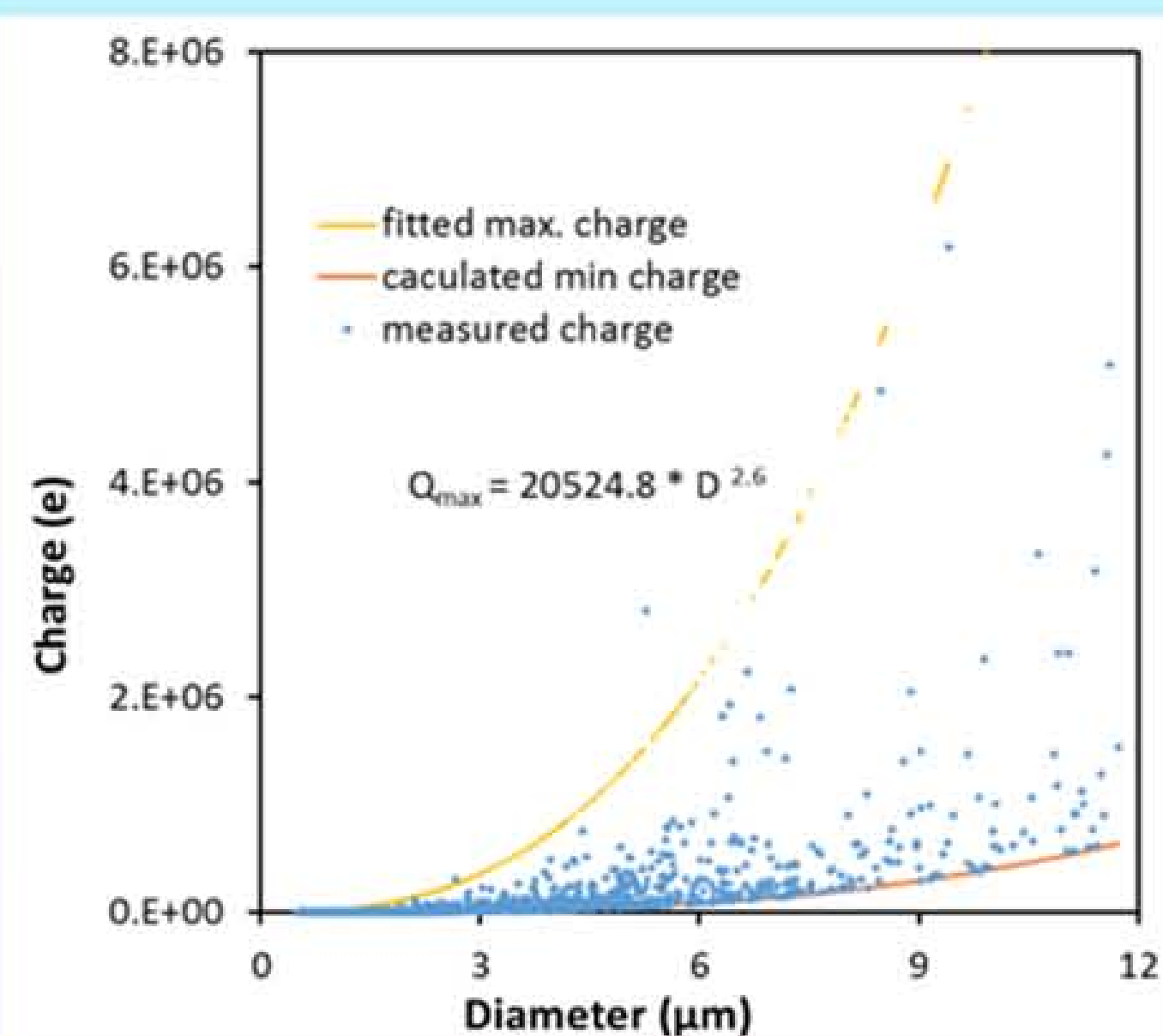


Fig.2. charged quantity of different size grains in the experiments.

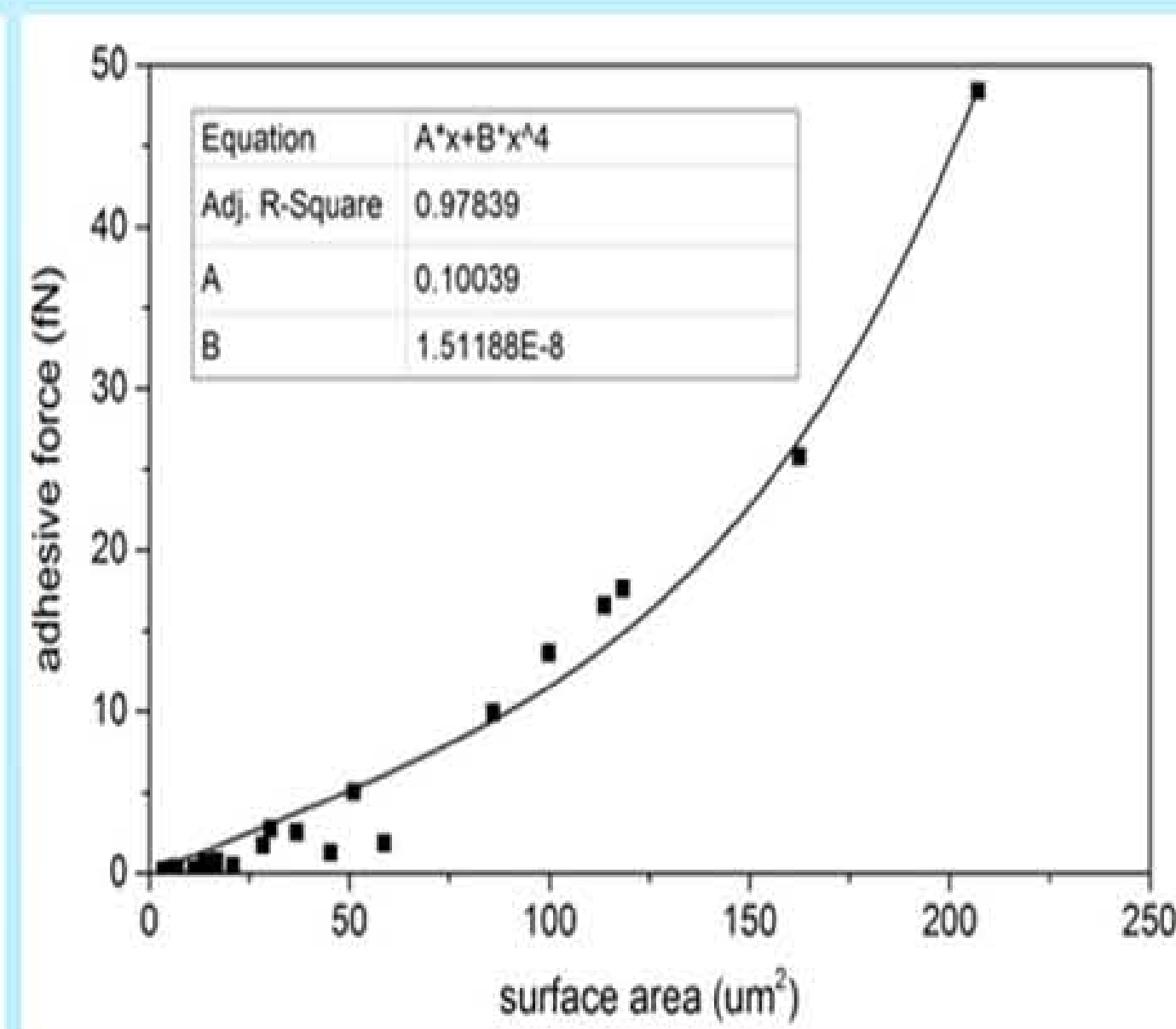


Fig.3 adhesive force change with surface area of grain.

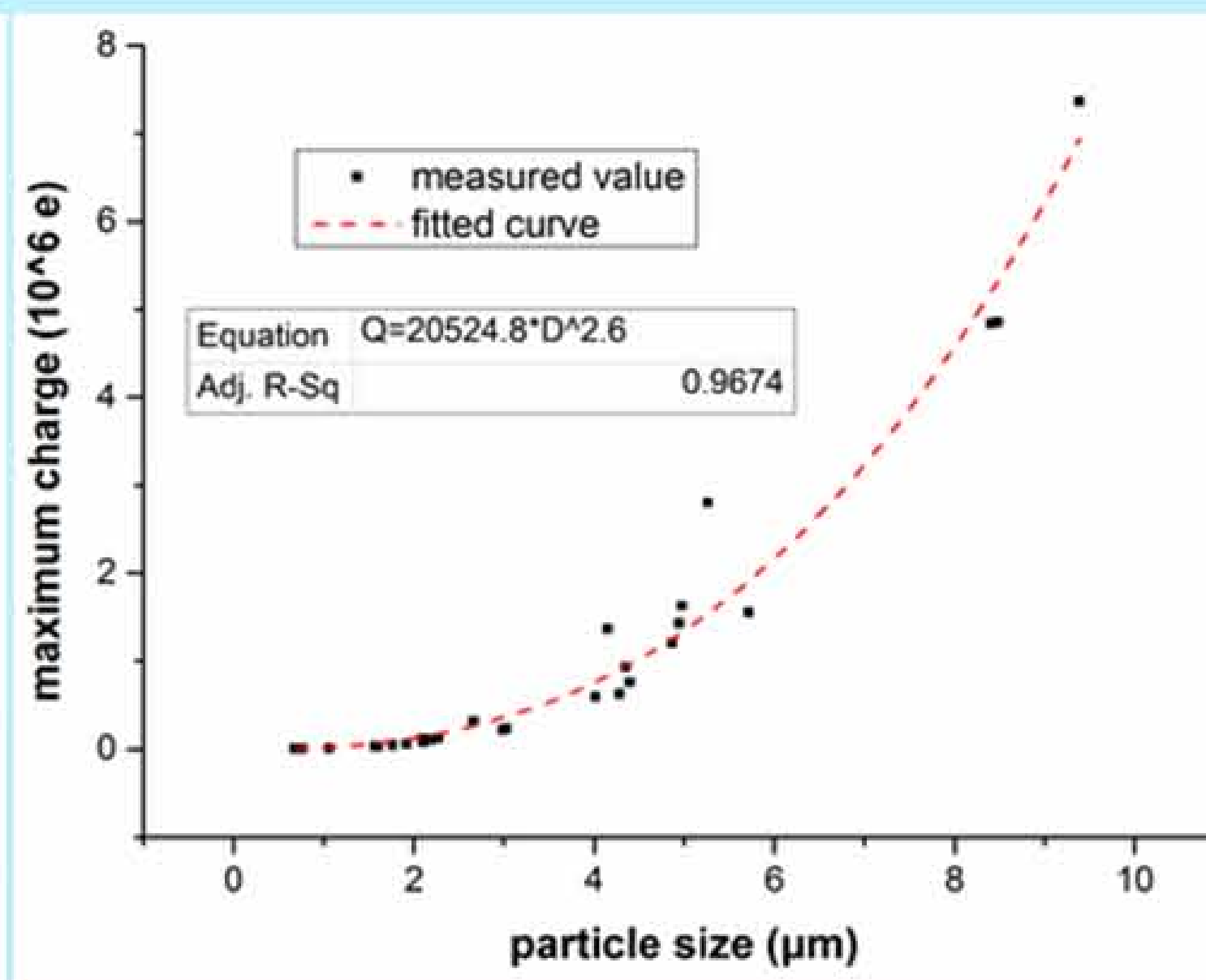


Fig.4. maximum charge change with particle size.

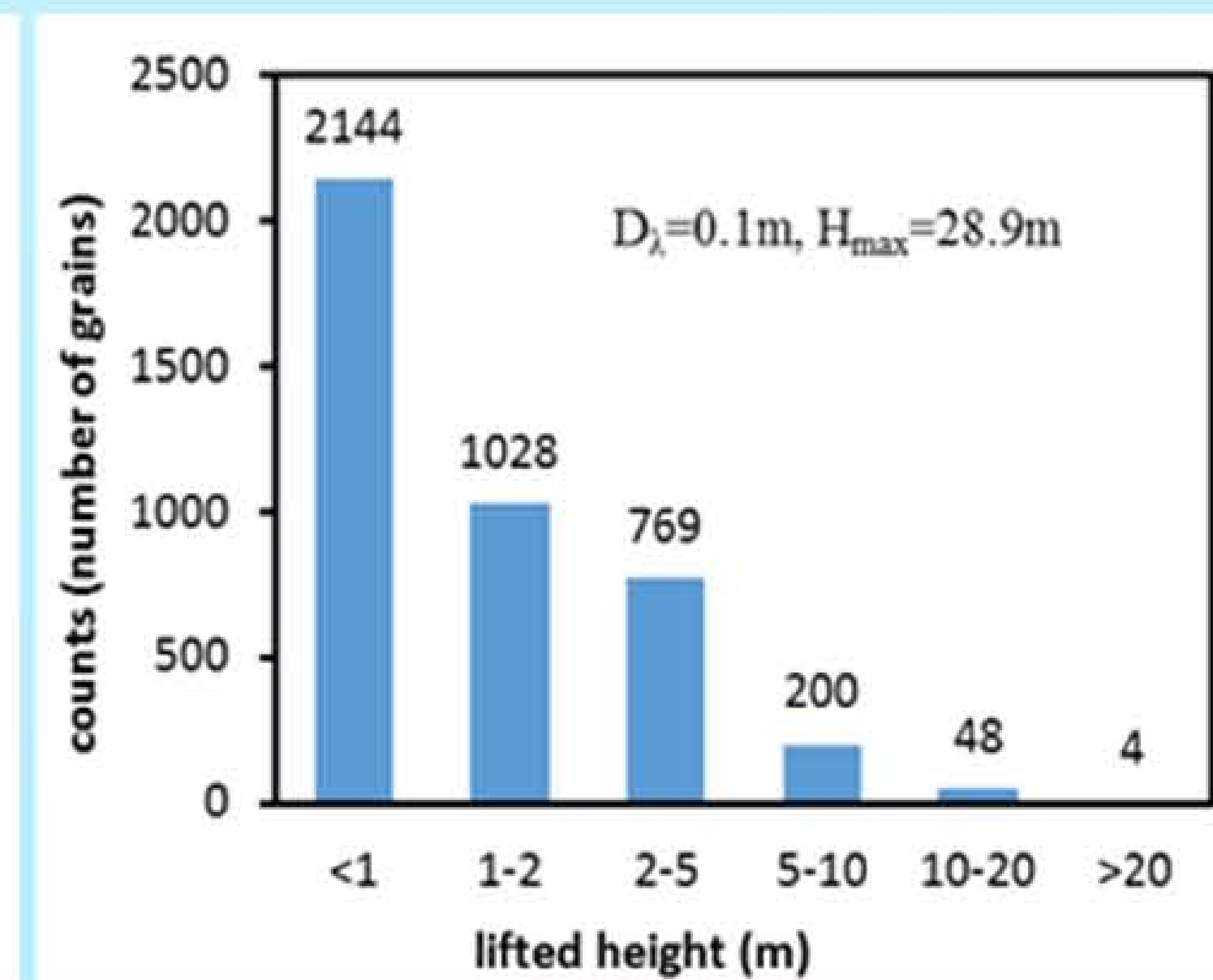


Fig.5. count of grains in different lift height with D_λ=0.1m and charged Q_m

Minimum charge and adhesive force: In Fig.2, the bottom line shows the minimum charged value (Q_c) of grain when the electric field force just overcomes the gravity. Compared to these values, there are still some differences in measured values (Q_m) which close to bottom line. To analyze these differences, a charged coefficient (α) is defined as following,

$$\alpha = Q_m / Q_c$$

All the data meet α ≤ 1.005 are selected to analyze the characters of lifted grains which just overcome the gravity. It is shown that Q_m is always a little larger than Q_c. In fact, the grain lifts from sample surface need to overcome the adhesive force except the gravity. That is, the electric field force cause by Q_m-Q_c equals approximate to the adhesive force. With these data, the relationship between adhesive force and surface area is plotted in Fig.3. The adhesive force of micron grains is about several to tens fNs and it increases with surface area.

References: [1] Halekas, J. S. et al. (2008), J. Geophys. Res., 113, doi:10.1029/2008JA 013194. [2] O'Brien, B. J. and Hollick, M. (2015) Planetary and Space Science, 119, 194-199.

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Maximum charge and maximum lifted height: with α > 20, some maximum charged grains are selected and plotted in Fig.4. It shows that the maximum charged quantity increases with the diameter of grain and electric quantity is about 10⁶ e for the grain in micron scale. With these data, a function between maximum charged and diameter could be fitted as following,

$$Q_{max} = 20524.8 * D^{2.6}$$

With the maximum charge quantity, the grains could lift to the maximum height of 28.9m in case of the Debye height (D_λ) is 0.1m. With the same case, the maximum lift height of most grains charged with the measured value is just several meters (Fig.5).

CONCLUSIONS: With the SLPDE at CLPS, characters of olivine grains charged in low energy electron radiation are analyzed. The results show that the maximum charged quantity is about 10⁶ e and the adhesive force is several to tens fNs for grains in micron scale. And the maximum lift height of most grains charged with the measured value is just several meters.