Preparation and Characterization of Highly Insulating Granular Samples for Electron Yield Measurement

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Introduction

Dust in space is of particular concern for space exploration. Because particle electrostatic adhesion is amplified by space-environment induced charging, it can attach to instrumentation and physically damage equipment.

To address this issue, a better understanding of dust's electrostatic properties is imperative. Relevant physical properties and phenomena include individual dust grain charging, dust mitigation, particle adhesion and removal, coating technologies for dust charge dissipation, particle aggregation, and dust dynamics and transport mechanisms

This experiment focuses primarily on the preparation and characterization of highly insulating granular samples for the eventual purpose electron yield data collection. Particles of varying size, shape, and composition are used to create a multilayered sample that can will be able to withstand vacuum conditions.

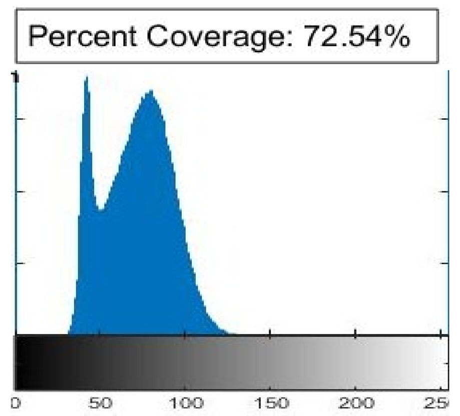
Fig 1. (Right) A close-up view of an astronaut's boot print in the lunar soil, during the Apollo 11 extravehicular activity (EVA) on the Moon. *Credits: NASA* [1], (Left) model A7L spacesuit worn on the lunar surface by Apollo 12 LMP Alan Bean [2].

The Experiment

The actual process of sample preparation is as follows:

- Particulates suspended in liquid using sonification
- Droplet placed above the graphite Carbon adhesive tape substrate
- Gravimetric Deposition of particles adheres them to tape and liquid evaporates
- Particles pressed into soft tape substrate
- Loose dust is blown off with dry nitrogen jet (~60PSI)

Fig 3. analyzing program created the histogram to the right. The first peak corresponds to the darker, substrate pixels and the second peak corresponds to the lighter, alumina pixels.

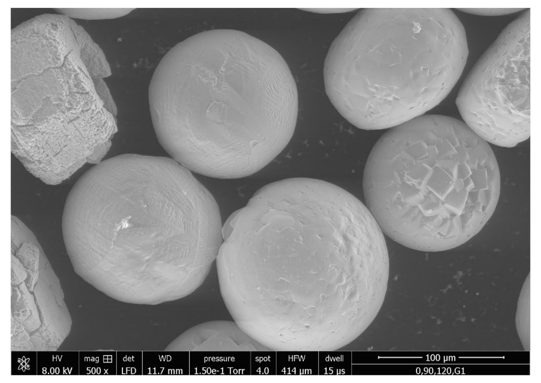


This preparation method has already proven versatile enough to consistently produce a range of coverages on a sample, including multilayer.

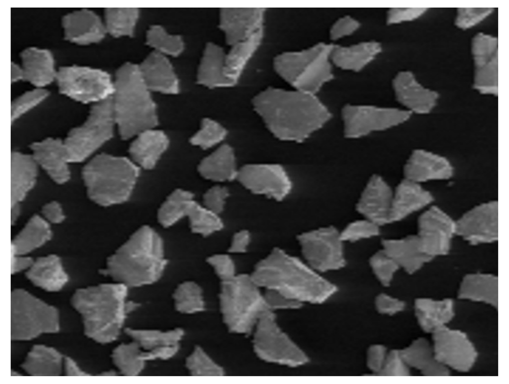
Determining particle shape and the coverage and uniformity of samples is critical.

- Scanning Electron Microscopy (SEM) images needed sub-µm resolution (Figure 2)
- Characterization of full ~20mm diameter sample are required a composite montage of 20-50 SEM images (Figure 4)
- Coverage determined using custom image analysis software to produce histograms of light (particulate) and dark (adhesive substrate) pixel count (Figure 3).
- The accuracy of this calculated coverage value is about ± 5%
- Comparison of coverage analysis for multiple regions of sample confirmed uniformity of coverage near samples center

One challenges associated with SEM imaging of particulates ~0.1 µm and below is that, while a clear image can be obtained, creating a composite of the entire sample surface is just too time consuming to be practical. In these cases, lower resolution image is used to create the composite.



~100 microns



~60 microns

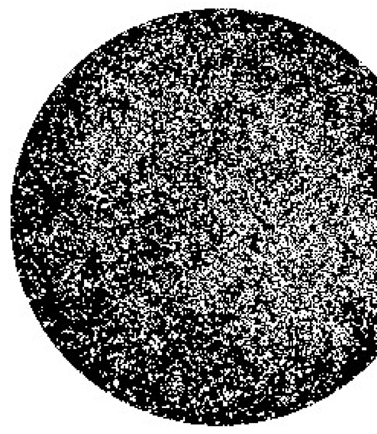


Fig 2. An example of a SEM image, (left and center) and the composite formed from the sum of several overlapping SEM images (right).

EY Measurements

The amount of sample charges due to incident space electrons fluxes incident on the lunar surface is determined by measuring the electron yield (EY) curve (Figure 5) of the sample (# electrons out/# electrons in) as a function of electron energy.

In EY experiments the primary electron beam is directed at a sample and any backscatter or secondary emission is recorded (a diagram of this process is seen in Figure 4).

Electron yield measurements of the dust samples are taken and then compared to the EY results of a bulk samples of the particulate and substrate materials. Results are expected to be different, though still correspond to each other, due to the very different surface structure of the samples.

In the context of dust, measuring the EY of individual particles has many experimental complexities associated with data collection, such as lofting (when particles charge up, electrostatically repel each other and launch into the air).

The fractional coverage of the particulates on the substrate is analyzed with an electron yield "patch model" [1] (see Figure 4(C) practically applied to something like Figure 3(A)). The reduction of the electron yield due to the sample surface roughness is modeled by a roughness coefficient model [2] (see Figures 4(B) and 4(C)). EY measurements are further complicated as charge accumulates on non-conductive surfaces from beam exposure, significantly affecting the subsequent EY measurements [3].

where particles are then able to adhere to nearby surfaces. As a result of this, very few experimental results are recorded in scholarly literature [4, 5].

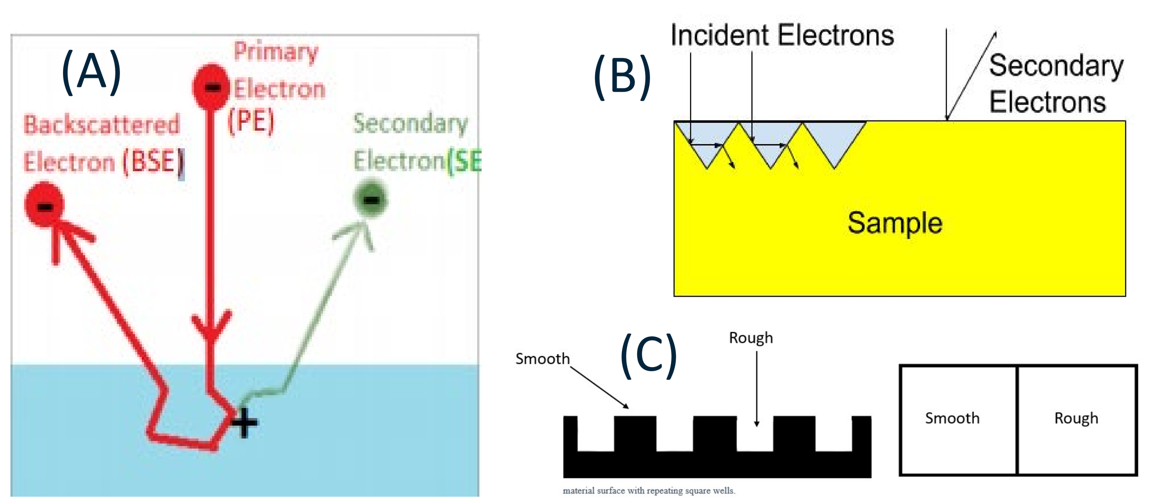


Fig 4. (A) Diagram showing incident primary electrons, emitted backscattered electrons and secondary electrons (B) how roughness influences electron emission (C) the sum of rough and smooth sections are used in the patch model for Electron Yield.

Results and Conclusions

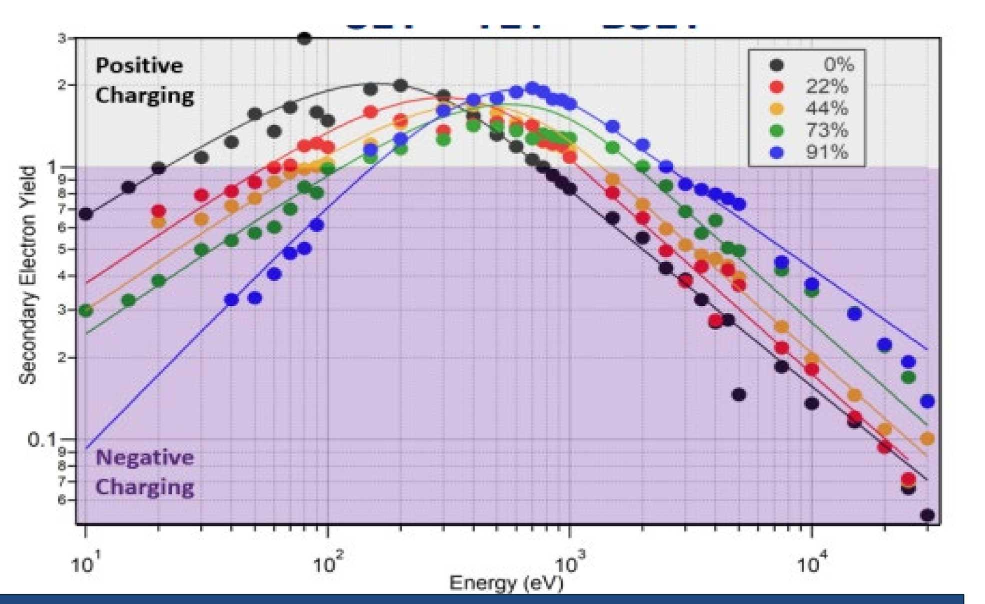
Preliminary EY measurements have been take for highly insulating Al_2O_3 particulates on conducting graphite C substrates for different coverages and particulate sizes and shapes.

- Results confirm that the sample preparation method described here works well [6].
- EY curves vary significantly with coverage, evolving systematically from C substrates EY to bulk Al_2O_3 EY (Figure 5).
- Particulate EY curves at full coverages have similar energy dependence to bulk Al_2O_3 but with EY magnitude suppressed, up to 10x, by roughness [3].
- EY of single layer coverages of 100 nm particulates differs little from C substrate EY as incident electrons can penetrate the thin 100nm particles.

The successful method for preparation of highly insulating particles for EY measurements will be extended to:

- Study additional Al_2O_3 particle sizes ranging from 0.1-120 µm, varying shapes and aspect ratios, and coverages from bare substrates to multilayers
- Different particulate materials including SiO_2 and cubic particles of MgO and NaCl.
- Lunar and Martian simulants
- Highly angular Lunar dust with primary compositions of Al_2O_3 and SiO_2 and exotic surface coatings and inclusions.

Fig 5. (A graph of the secondary electron yield of a ~60 µm angular aluminum oxide sample, this image compactly shows the gradual difference in EY measurements based on varying coverage



Acknowledgements

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