Contact Electrification studies of Muscovite Mica using Surface Amplitude Modulated (AM) Surface Potential Microscopy (KFM)

Jose M. Esmeria Jr.[1, 2], Romeric Pobre [1]

[1]*Physics Department, De La Salle University, 2410 Taft Avenue, Manila 1004 Philippines*
[2] *Reliability Engineering Department, TDK Philippines Corp. 119 East Science Ave., SEPZ, Laguna Technopark, Bińan, 4026, Laguna, Philippines*

[2]*Corresponding Author: jose_esmeria@dlsu.edu.ph*

Abstract: Surface potential images of muscovite mica were taken using Amplitude Modulated Kelvin Force Microscopy (AM-KFM). Using this method, both topographic height and potential maps of the mica surface were taken simultaneously. The mica samples were rubbed by clean room type cotton q tip to generate contact electrification or CE. Carpet like formations on the surface with average potential of ±36mV was observed for the first time, and the charges dissipated after 3600 seconds through a grounded conductive surface.

Key Words: Triboelectricity; contact electrification;

1. INTRODUCTION

Contact electrification (CE) or tribo electrification is well known phenomena were two materials (similar or different) are separated *after contact* generates opposite charge surfaces. CE study is important in the industry for the protection of electronic devices, photocopiers, and safety from fuel explosions. However, CE is still poorly understood [1][2]. The common method of measuring CE was using electric field meter to measure its field strength [3]. Materials were then characterized based on their charge affinity and were arranged through triboelectric series [4]. However, in the last 20 years, saw the advent of very sensitive and accurate Atomic Force Microscope (AFM) [5], which made it possible to analyse surfaces after CE at nanoscale level. Electrical functions incorporated in commercial AFM made it possible to analyse surface potential maps. Baytekin et.al [6], made a significant result using polymer surfaces after triboelectrification showed a mosaic charge distribution of both positive and negative charges in both surfaces through the use of Kelvin Force Microscopy (KFM) or Surface Potential Microscope (SPM). AFM/KFM simple schematic is shown in Fig. 1a. Fig.1 b to c shows the SPM function for generating potential images. The tip taps on the surface to create a topographic height images, these images are then stored and the tip lifts to a scan height and scans the surface potential difference. The stored *height* image and *the potential plot* are both *interleaved* to produce potential maps. This method is usually referred as Amplitude Modulated (AM)–KFM or simply AM-K

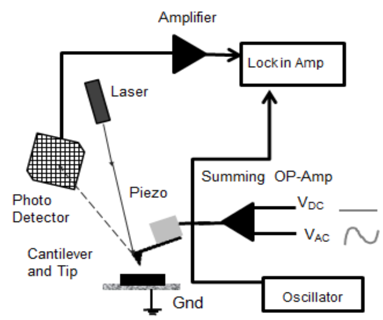

Fig. 1a

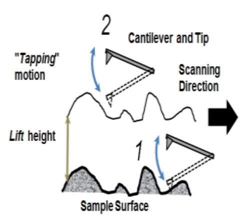

Fig. 1b

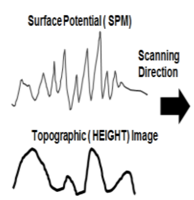

Fig. 1c

KFM is based on the capacitor model between tip and sample. Equation (1) shows the relationship of the capacitance and the force F on the tip [7].

$$F = -\frac{1}{2}\frac{dC}{dz}(\Delta V)^2 \qquad (1)$$

Where, ΔV is the potential difference between tip and sample, and $dC/_{dz}$ is the capacitance gradient between the tip and the sample separated by distance z. The potential difference ΔV is the sum of the AC and DC driving voltage to the tip. The contact potential difference V_{CD} is defined as: $V_{CD} = (\varphi_{tip} - \varphi_{sample}/(-q)$ where φ_{tip} and φ_{sample} are the work function of the tip and sample respectively, and q is the electronic charge. Muscovite mica was chosen as sample for performing contact electrification in this experiment. Muscovite mica which has a chemical formula: $(KAl_2\ (SI_3Al)\ O_{10}(OH)_2$ has gain interest in the areas of engineering and sciences because of its flat uniform surface, its insulating and thermal properties. This makes it an excellent substrate material for active solar cells [8]. Significant studies on surface charge characteristics after CE using mechanical rotating charger at macroscopic level. However, there is no known study so far of CE for muscovite mica using surface potential microscope techniques at nanoscale level [9]. This CE work would hope to be significant in designing nan-triboelectric generators [10], for micro energy

2. METHODOLOGY

The AFM used in the experiment is a Bruker ICON1 with SPM (AM-KFM) options with resolution is 0.02nm. The tips used were CoCr coated MESP Silicon with nominal tip radius of 20nm. The tips were biased at 1V DC and AC voltage drive voltage was 500mV. Scan rate was 1Hz with scan size of 1 x 1 μm. The sample was placed on a SUS304 stainless steel disk (3 x 30mm). Muscovite mica samples were commercially available high grade V1 disk (12mm x 0.15mm) from SPI supplies [10]. Measurements were done at room temp of 22±5°C with a Relative Humidity (RH) of 55 ±5%, and were carried out at atmospheric pressure. The cotton q tip is an industrial clean room type HUBY 340 [11]. CE is accomplished by rubbing the q tip on the surface of the Mica approximately 5x times.

3. RESULTS AND DISCUSSION:

Fig. 2a shows the Mica sheet height images, the topographic images showed the surface profile with resolution of 0.2 nm. The same surface after CE using cotton tip was scanned using SPM.

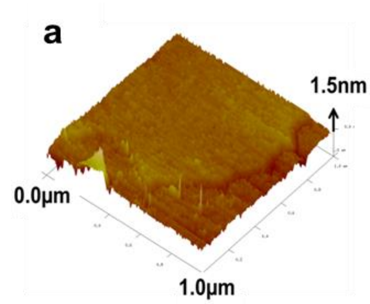

Fig.2a. Height image of Mica surface showing surface profile.

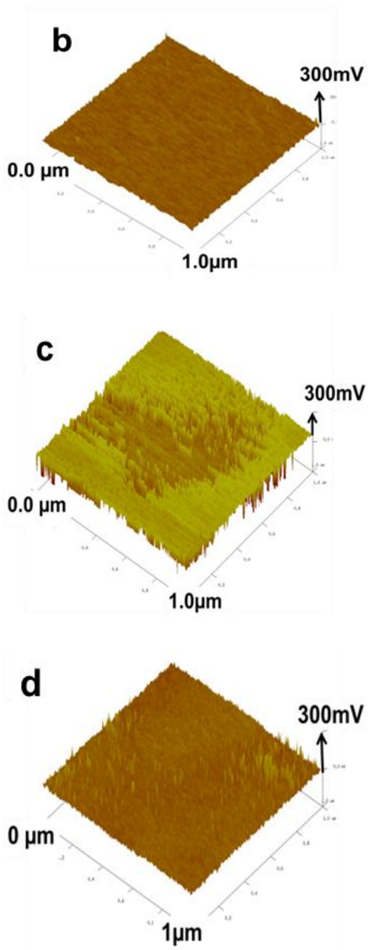

Fig.2b. the same surface before CE using SPM imaging, surface shows flat profile. No uneven features shown in the *height* images are observed at SPM image. Fig. 2c charge surface which is "carpet like" appeared after CE. The charge formations dissipated through grounded surface after 3600 seconds

The carpet like images showed the potential map on the surface after CE. The roughness value of the surface, computed through the AFM software was around ±36mV [12]. The surfaces after CE consist of *positive* (bright color) and *negative* (dark color) spikes. This potential map resembles a *mosaic pattern* of both positive and negative charges and is similar to the previous CE studies using polymer samples [6]. The surface charges freely dissipated to ground after 3600 seconds and the same location was re scanned. The surface potential formations dissipated and showed a planar surface with some remaining spikes formations.

4. CONCLUSIONS

Potential maps on the surface mica which appeared as *carpet like* formations, resembles a *mosaic* surface of positive (+) and negative (-) charges were observed for the first-time nanoscale level. The surface returned to it planar pattern after 3600seconds when the charge freely dissipated through conductive grounded fixture.

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6. REFERENCES

Baytekin, H. T., Patashinski, A. Z., Branicki, M., Baytekin, B., Soh, S., & Grzybowski, B. A. (2011). The Mosaic of Surface Charge in Contact Electrification. Science, 333(6040),

Chubb, J. (2002). New approaches for electrostatic testing of materials. Journal of Electrostatics, 54(3-4), 233-244.

Cotton swabs for industrial use | Sanyo. (n.d.). Retrieved from https://www.sa-n-yo.co.jp/en/kougyou/

De Poel, W., Pintea, S., Drnec, J., Carla, F., Felici, R., Mulder, P., … Vlieg, E. (2014). Muscovite mica: Flatter than a pancake. Surface Science, 619, 19-24.

Diaz, A., & Felix-Navarro, R. (2004). A semi-quantitative tribo-electric series for polymeric materials: the influence of chemical structure and properties. Journal of Electrostatics, 62(4), 277-290.

Gady, B., Reifenberger, R., & Rimai, D. S. (1998). Contact electrification studies using atomic force microscope techniques. Journal of Applied Physics, 84(1), 319-322.

Hashimoto, Y., & Sakakibara, T. (2000). Surface States of Mica and Contact Charging. Japanese Journal of Applied Physics, 39(Part 1, No. 1), 231-235.

Instruction Manual, Bruker Dimension ICON, 004-1023-000, Rev E, Chapter 18 "Electric Techniques", page 392-401. (n.d.).

Instruction Manual, Bruker Dimension ICON, 004-1023-000, Rev E, Chapter 18 "Electric Techniques", page 392-401. . (n.d.).

Lacks, D. J., & Mohan Sankaran, R. (2011). Contact electrification of insulating materials. Journal of Physics D: Applied Physics, 44(45), 453001.

Melitz, W., Shen, J., Kummel, A. C., & Lee, S. (2011). Kelvin probe force microscopy and its application. Surface Science Reports, 66(1), 1-27.

Muscovite Mica Substrates: SPI Supplies. (n.d.). Retrieved from http://www.2spi.com/category/mica-substrates/substrates/

Wang, Z. L. (2014). Triboelectric nanogenerators as new energy technology and self-powered sensors – Principles, problems and perspectives. Faraday Discuss, 176, 447-458.

Williams, M. W. (2012). Triboelectric charging of insulating polymers–some new perspectives. AIP Advances, 2(1),