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Laboratory investigations of electrical effects in a simulated Martian atmosphere

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Abstract

Electrical discharges are expected to occur on Mars, by analogy with the high electric fields generated in terrestrial dust devils, which should break down the low-pressure Martian atmosphere. Previous laboratory work has supported this by reporting electrical discharges from Mars analogue environments. We have reproduced one such experiment, and found that many of the results obtained can be reproduced by triboelectric charging of the walls of the vessel used, with no dust or sand present.

1. Introduction

Electrical discharges are widely expected to exist in Martian dust storms, but have not yet been conclusively observed. The basis for this is a combination of measurements of terrestrial dust charging, and laboratory experiments in low-pressure CO_2 atmospheres. On Earth, dust charging has been measured in dust devils [1], volcanic plumes [2] and in Saharan dust aloft [3]. The Paschen curve indicates that electrical breakdown will take place at ~20 kV/m at the Martian surface (10mbar CO_2) in comparison with ~3 MV/m on Earth, therefore electrical discharges are expected in Martian dust devils.

Corona ("glow") discharges and sparks have been observed visually and electrically in dried sand or Martian analogue dust in low-pressure CO_2 after agitation of the dust sample [4,5,6]. Discharges were assumed to be caused by triboelectric charging within the dust. Our initial motivation to repeat the lab measurements was to measure the radio spectrum of the discharges, and use it to constrain a search for Martian lightning emissions in spacecraft data.

2. Experimental apparatus

The experiment was based on [5] and used a cylindrical Perspex tank ~1m long of diameter 0.25m. The top of the tank contained a funnel sealed by a plunger, which is accessible from outside the tank. The funnel was filled with 500g dry JSC Mars-1 Martian regolith simulant, and the tank was evacuated and filled with 7-9 mbar CO_2. The plunger was then released, allowing dust to fall to the bottom of the tank through another inverted funnel. The top metal plate was electrically grounded, and the voltage on a screened collecting electrode at the bottom of the tank was measured with a high-impedance voltage follower. The tank was mounted on a support frame so that after each dust drop it could be rotated to reload the funnel, Figure 1.

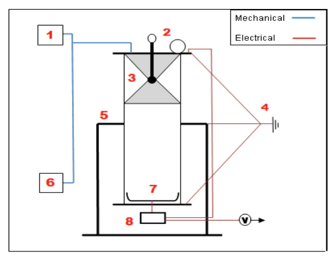

Figure 1: Diagram of the apparatus. 1) CO_2 inlet; 2) Pressure gauge; 3) Polythene funnels, with plunger to keep the dust in the upper funnel; 4) Upper plate, lower plate and frame are all grounded; 5) Frame allows the tank to be rotated in order to return the dust to the upper funnel; 6) Roughing pump; 7) Collecting electrode (isolated from lower plate) 8) Voltage follower

In [5] electrical discharges were only observed when the Martian analogue dust was mixed with glass microbeads, so our experiments used both dust alone, and dust mixed with microbeads.

3. Results

Repeatable results were obtained when the voltage at the collector plate was measured during dust drops, Figure 2.

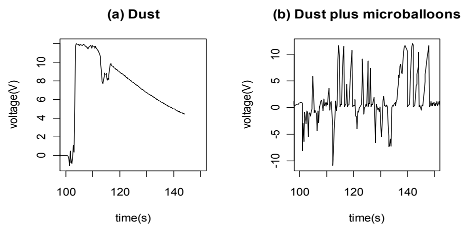

Figure 2 Typical dust drop results at 9mbar (a) ~490g dust only, representative of 12 out of 13 drops (b) ~250g dust with ~230g microballoons, representative of 8 out of 9 drops.

Figure 2(a) shows a similar shape to the results in [6], which were interpreted as discharges. However, we found that these results could be reproduced by rubbing a nylon cloth against the side of the empty tank. This suggests that wall effects are larger than any dust charging signals for the dust only case.

4. Discussion

The triboelectric series determines the direction of charge transfer between different materials. Nylon is higher in the series than acrylic, and will transfer electrons to the acrylic walls. The collecting electrode then experiences a change in electric field, which we detect, due to the changing vertical component of the charge on the inside walls. (Subsidiary experiments with a field mill instrument showed that a substantial electric field was generated on the opposite side of a flat acrylic sheet when rubbed with a nylon cloth). The voltage decay seen in Figure 2(a) is likely to be due to the leakage of charge away from the walls into the air, and estimates of the air conductivity obtained from the decay rate support this. The transients could be readily simulated by events outside the tank. Our results with dust shown in Figure 2(a) are therefore likely to have been generated by triboelectric effects between the Mars simulant dust and the acrylic walls of the tank, with a contribution from local electrostatic charging on the outside of the tank.

Glass is located close to nylon in the triboelectric series and therefore charge transfer during glass-dust interactions are expected to be similar to nylon-dust triboelectrification. The Martian analogue dust has a workfunction of 5.6 eV [7] and is located close to the bottom of the triboelectric series, whereas glass and nylon are near the top. Mixing the Mars simulant with glass microballoons ensures maximum charge transfer between the two materials, and their varying densities will enhance charge separation as they fall through the tube, providing good (though unrealistic) conditions for electric discharges [6]. Estimates suggest that the presence of glass microballoons reduces the field strength needed to generate discharges in our tank by 20%. The results in Figure 2(b) could not be reproduced by deliberately tribocharging the tank walls, and may have been caused by micro-discharges from local regions of charge separation within the tank.

Early experiments [4,5] used glass flasks containing dried sand, in which discharges were observed when the sand was shaken. Triboelectric charging between the sand and the flask walls could have contributed to the high electric fields generated. The applicability of laboratory experiments to support the existence of electrical discharges in the Martian atmosphere seems limited until local tribocharging effects can be eliminated.

References

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