# Triboelectric Charging of Dust and Its Relation to Organic Degradation on Mars

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***Abstract*—Since the mid-1970s, when the Viking landers' experiments showed no evidence of organic material on Mars, researchers have been trying to find the reason for Mars's sterile surface. Evidence indicates that activity in the Martian atmosphere may be at fault. One possibility is that glow discharges in the atmosphere may be degrading any organic material which does reach the surface of Mars. Through simulating the Martian environment, we are investigating triboelectric charging of dust particles suspended in the planet's atmosphere, resultant glow discharges caused by these charged particles, and the effects that they have on organic material.**

## I. Introduction

Although Mars has a steady influx of organic material due to meteoric impacts [1], [2], no evidence of organic material was found by the Viking landers' experiments [3]. This indicates that any organic matter deposited on the planet must be destroyed at a rate higher than that of its input.

While the Viking landers did not detect any biological activity on Mars, their experiments indicated that the regolith was, in fact, chemically active [4]. As such, scientists have theorized that the main source of organic degradation is the existence of an oxidant in the Martian regolith or atmosphere.

One possible cause is that glow discharge in the Martian atmosphere is destroying the organics which are present. Glow discharge is an electrical breakdown in the atmosphere which generates a plasma glow. Exposure to such plasma is also used as a method of sterilization in industry.

In order for such an electrical discharge to take place, the breakdown voltage must be reached. As such, another important aspect of this study was the determination of the Paschen breakdown curve under Martian conditions. The Paschen breakdown curve shows the electrical potential at which breakdown occurs as a function of gas pressure and distance.

The main focus of our current research is to determine the effect of triboelectric charging within the atmosphere on Mars. Frequent dust storms and dust devils at the surface of Mars may cause dust particles to become triboelectrically charged. By simulating dust devils under Martian conditions, we are able to investigate the likelihood that such triboelectric charging results in glow discharge and what effect, if any, such dust storms have on organics.

## II. Research and Experimentation

### *A. Paschen Curve for Martian Atmosphere*

A Paschen Curve is a graph illustrating electrical breakdown voltage in a gas as a function of the product of pressure and distance. Such a breakdown occurs as a result of collisions between free electrons and molecules in the gas. When a collision occurs, the electron transfers energy to the gas molecule which then excites more electrons. This process occurs in a chain-reaction, called a Townsend avalanche, until a conductive path through the gas is formed [5] .

The actual voltage at which breakdown occurs is dependent on both pressure and the mean free path distance within the gas. The breakdown voltage is lower for lower pressures because, as pressure decreases, the mean free path length increases, which allows the electrons to gain more energy between collisions and, in turn, accelerate the Townsend avalanche process [6].

Typically, electrical breakdown occurs in the form of a localized spark. However, in low pressure gas, electrical breakdown takes the form of a glow discharge instead [6]. This is because gas at low pressure also has a low number density of particles, and a larger overall volume of gas is needed in order to have a sufficient number of particles for breakdown to occur.

The Paschen Curve for the Martian atmosphere was determined through a series of experiments in a vacuum chamber where the Martian atmospheric pressure and composition were simulated. The chamber was evacuated and re-filled with gas to the appropriate pressure. The atmospheric conditions on the surface of Mars range from a pressure of 5.6 to 7.9 torr and a temperature of 130 to 290 K. This experiment was conducted at the ambient laboratory temperature of 293 K, so the pressure in the chamber was adjusted to 5.7 to 17.8 torr in order to more closely match the atmospheric density at the surface of Mars [6]. Experiments were conducted using both carbon dioxide, the primary component of the Martian atmosphere, and a mixture of gases which more closely mimic the components of the atmosphere on Mars. The composition of the Mars gas mixture is as follows: 95.500% $CO_2$, 2.700% $N_2$, 1.600% Ar, 0.130% $O_2$, 0.070% CO.

Parallel plate electrodes were used to generate a uniform electric field. For this experiment, the electrodes chosen were 10 cm in diameter and were modeled after Schonhuber's design [7]. This particular design was chosen because it best met the needs of having rounded edges to prevent field distortion, while still maintaining the necessary small gap distance for use with low pressure gas. The parallel plates were shielded with glass and insulated to prevent back-arcing.

The method chosen for inducing electrical breakdown also followed that described by Schonhuber [7]. Essentially, a voltage was applied to the parallel plate electrodes, and the system was monitored for signs of breakdown using an oscilloscope. If no breakdown had occurred after five seconds, the voltage was increased by 5, 10, or 20 V. This process was repeated until a breakdown was detected. For this experiment, electrode separation distances of 5, 7.5, and 10 mm were used.

Figures 1 and 2 show the Paschen curves obtained for the Martian atmosphere. Results were similar between the Mars gas mixture and pure carbon dioxide gas experiments, as would be expected. These results show that, under Martian conditions, voltages necessary for breakdown could easily be reached within the atmosphere.

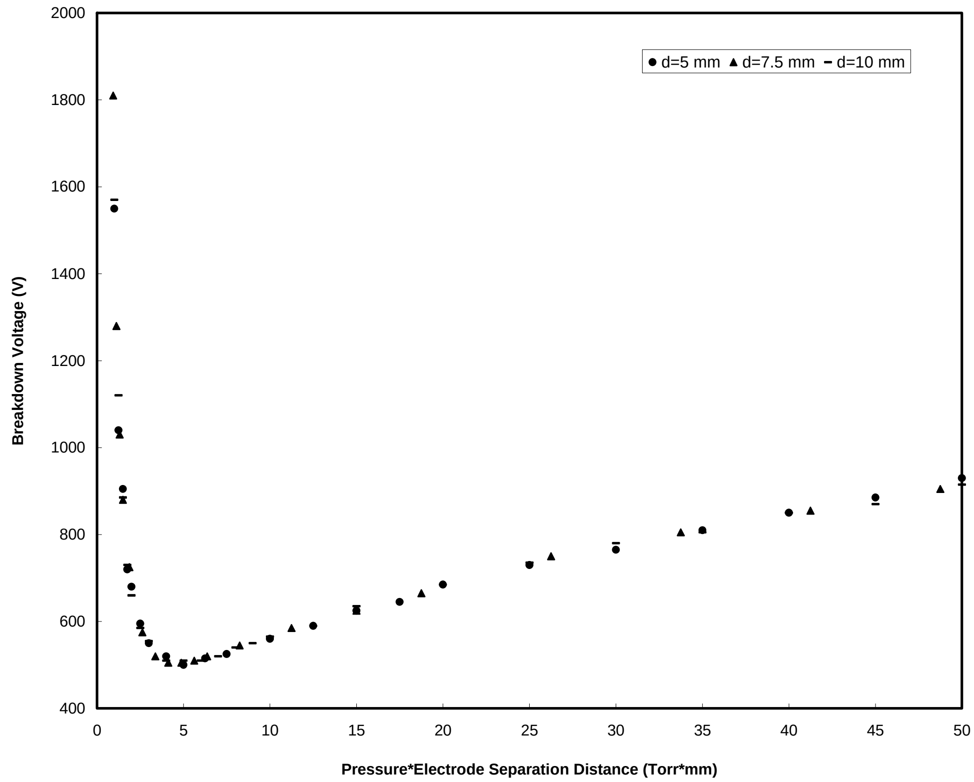


Fig. 1. Paschen Curve illustrating breakdown voltages in carbon dioxide gas at low pressures

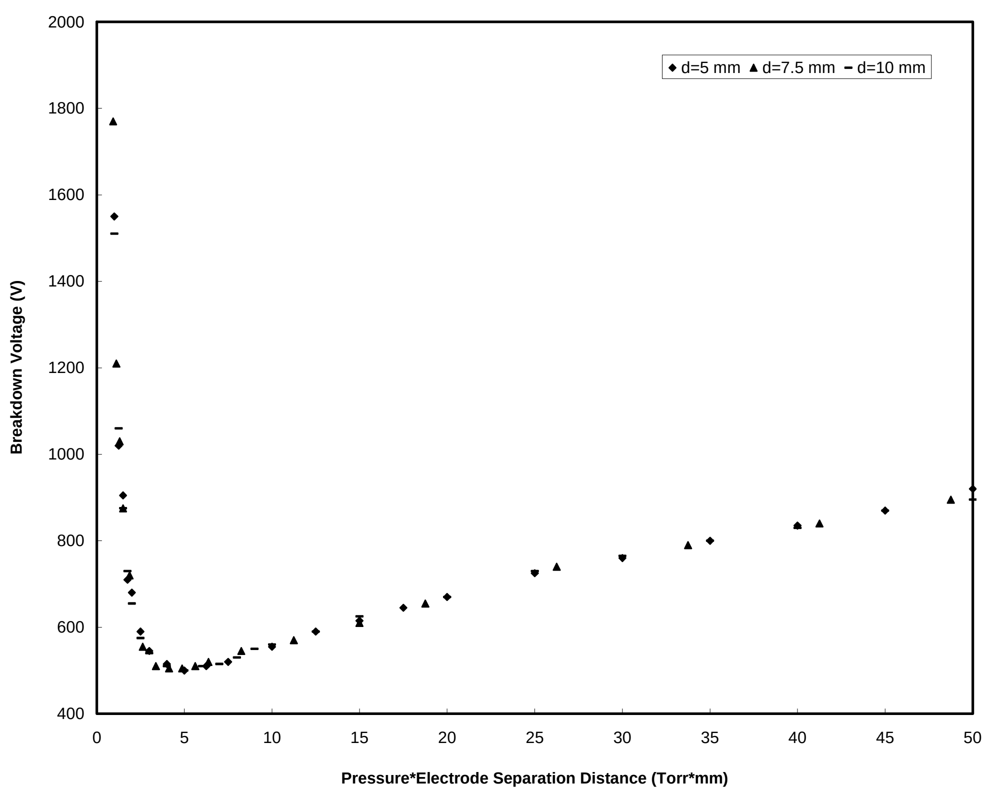


Fig. 2. Paschen Curve illustrating breakdown voltages in Mars gas mixture at low pressures

### *B. Plasma Degradation*

On Mars, glow discharge is the most likely form of electrical breakdown to occur because the pressure of the planet's atmosphere near the surface is low. When a glow discharge breakdown occurs, plasma is formed. In industry, exposure to plasma is often used as a method of sterilizing surfaces and equipment. Likewise, the regolith covering the surface of Mars could lack organic components as a result of exposure to plasma generation near the planet's surface. In fact, Ballou et al used radio frequency glow discharge to accelerate reactions between soil and oxygen present in the atmosphere. They also found that such glow discharges emit ultraviolet radiation [8].

In order to find the effect of exposure to glow discharge on organic material on Mars, glass slides containing thin films of organic material were placed in a chamber between a pair of electrodes. The electrodes were polished brass, parallel plate electrodes separated by a gap of 2 to 3 mm with 700 V applied across them. The plasma generated between the electrodes was measured to have a spectrum ranging from 190 to 1000 nm. A portion of its spectrum is illustrated in Figure 3. Prior to testing, the chamber was evacuated and re-filled with the same Mars gas mixture described earlier. The organic material chosen was that which is most commonly found on meteors, as organic material is believed to be deposited on Mars by frequent meteoric impacts [1], [2]. It included: naphthalene, phenanthrene, benzly ether, and coronene.

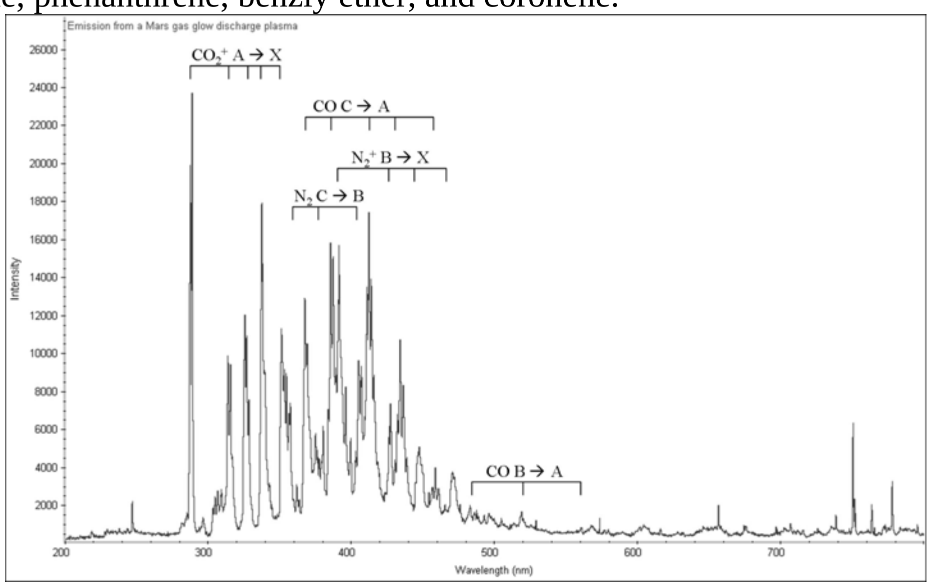


Fig. 3. Emission spectrum taken from glow discharge generated in simulated Martian environment

The organic films were exposed to the plasma generated between the electrodes for up to thirty minutes. After exposure, the organics were derivatized using N,O-Bis-(trimethylsilyl) Acetamide, or BSA. This process converts the compounds to ones which allow for better analysis using GC/MS.

Analysis of the exposed organics was performed using GC/MS, Fourier-transform infrared spectroscopy, and visual inspection. Visual inspection showed that the organic films had been altered by their exposure to the glow discharge. One film had turned brown in color, while another developed a waxy texture [9]. GC/MS analysis, as well as Fourier-transform infrared spectroscopy showed that some chemical changes resulting in the degradation of organics had taken place during exposure to Mars gas glow discharge plasma [9]. These results indicate that organics on the Martian surface could be degraded as a result of glow discharge present in the planet's lower atmosphere.

### *C. Triboelectric Charging of Martian Dust*

A likely source of charging within the Martian atmosphere necessary to reach the breakdown voltages and result in the generation of glow discharge is triboelectric charging of dust at the planet's surface. Triboelectric charging is the electrostatic charging of particles as a result of inter-particle contact and separation. On the surface of Mars, this interaction between dust particles frequently occurs as a result of dust storms and dust devils. Dust devils are very powerful whirlwinds which occur on the planet's surface. They are highly frequent, particularly in certain regions and during specific seasons [10].

In previous studies, Mills [11] and Oyama [12] have both suggested that the triboelectric charging of dust on Mars generates oxygen plasma which is known to be a very powerful oxidant. In Mills's experiment, sand was placed into a flask filled with low pressure air. As the flask was rotated, glow, twinkling, and ribbon-like discharges were visible [11].

We repeated the Mills experiment using JSC-1 Martian soil simulant and Mars gas mixture. A small amount of Martian soil simulant was placed in the bottom of a 500 mL flask. The flask was then capped, evacuated, and re-filled with Mars gas mixture to a pressure of 7 torr. The flask was vigorously shaken to simulate a dust devil while in a darkened room. A glow within the flask was observed while the dust was being shaken.

In order to better quantify the simulated dust devil activity, a new test was developed. In this experiment, test material doped with organics, either glass beads or Martian soil simulant, is placed in a beaker and rapidly stirred by a glass rod with attached stirring blade attached to a small motor. The entire apparatus is placed within a chamber which is evacuated and re-filled with Mars gas mixture to a pressure of 5 to 7 torr. The chamber is covered to prevent light intrusion and a fiber optic is positioned above the flask to detect any glow present. A control sample of identical material to the test material is also placed within the chamber, but is not stirred.

Spectral measurements are taken frequently through the fiber optic, with the intention of detecting a glow discharge and measuring its spectrum. In addition, after several hours of spinning, the test material and control are chemically processed and analyzed to determine the effects of the simulated dust devil on the organics within the system.

The initial testing was conducted on 2 mm outer diameter glass beads which had been coated with 200 mg of benzyl ether and phenanthrene. For this particular test, the chamber was left uncovered but was located in a darkened room. During the spinning process, glow discharge was visually detected, but was not detected with the spectrometer [9]. The sample was spun for a total of three hours.

Analysis of that particular sample after testing was conducted in three layers, as it was likely that more triboelectric charging and, therefore, glow discharge, occurred at the top of the sample than at the bottom [9]. GC/MS analysis and Fourier-transform infrared spectroscopy were performed on the sample. Both indicated that organic degradation did occur within the sample and, as expected, that more organics had been removed from beads in the upper layer than from those in the lower layer [9]. Figure 4 shows the amounts of benzyl ether and phenanthrene within each of the three layers after spinning. In addition, visual inspection of the beads showed that they had developed a brown tint, similar to that of the organic films exposed to glow discharge in previous testing [9]. These results indicate that glow discharge did, in fact, occur as a result of the beads' spinning, and that the glow discharge present degraded the organics within the sample.

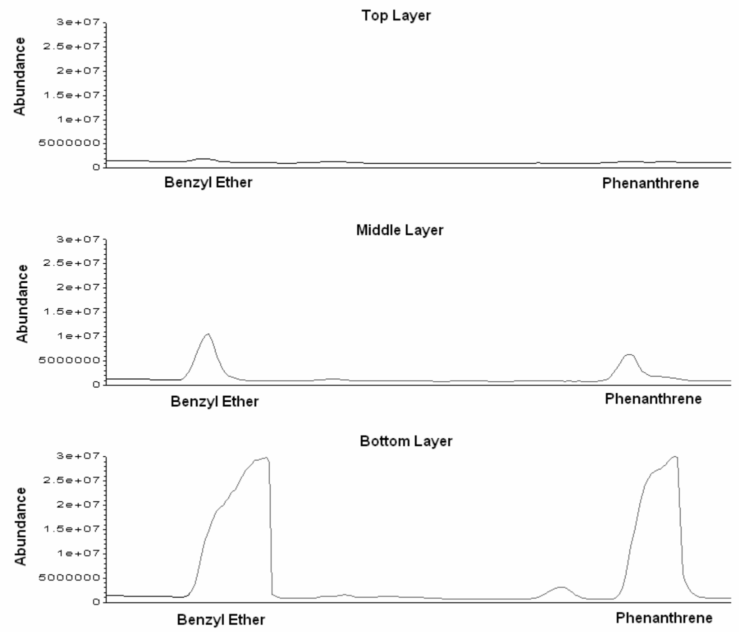


Fig. 4. GC/MS data illustrating amounts of benzyl ether and phenanthrene remaining in three layers of the sample after three hours of spinning

At the time this paper was written, testing on triboelectric charge, glow discharge, and their effects on organic material are on-going. Analysis of much of the experimentation performed thus far using both glass beads and Martian soil simulant is incomplete. In addition, further attempts to quantify the glow discharge generated will be made in the upcoming months.

## III. CONCLUSION

These studies indicate that glow discharge is possible in the Martian atmosphere, given the relatively low voltages which must be reached in order for electrical breakdown to occur under Martian conditions, and that such breakdowns will take the form of glow discharge. Furthermore, they show that glow discharge plasma generated in a simulated Martian environment does lead to organic degradation. While further experimentation and analysis is needed, triboelectric charging generated by dust devil and dust storms on the surface of Mars may result in the presence of glow discharge and, in turn, the degradation of any organics present on the Martian surface.

## ACKNOWLEDGEMENT

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