ELECTROSTATIC DISCHARGE (ESD) EXPERIMENTS AT CONTROLLED TEMPERATURE, RELEVANT TO MARS & EUROPA.

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Introduction: The electrification of atmospheric species (aerosol and ice particle) and dust particles is very likely a ubiquitous process operating on many planetary bodies. A local electric field (E-field) will form when charged particles (or droplets) being separated by atmospheric processes, such as thunderstorm on Earth, dust storm on Mars, and air turbulence on Venus, Jupiter, Saturn. Electrostatic discharge (ESD) can happen when the strength of accumulated E-filed growing beyond the breakdown electric field threshold (BEFT) of a planet, which is ~ 3Mv/m on Earth [1,2], 25-34 kV/m on Mars [3,4], and can be > $3x10^2$ Mv/m on Venus [5].

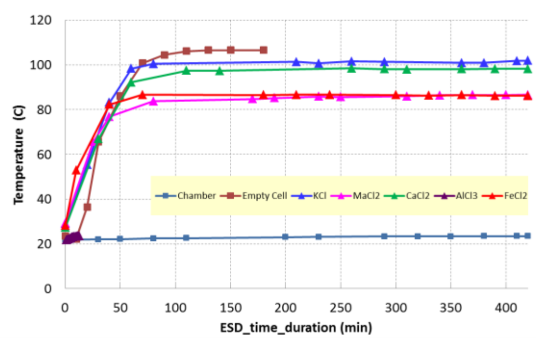
An ESD event will generate large quantity of high-speed-electrons [6,7], namely electron avalanche, which could collide with the molecules in the atmosphere of a planet, such as N_2, O_2, CO_2, and H_2O on Earth, mainly CO_2 on Mars, and CO_2 and N_2 on Venus. This type of collisions will cause the molecular ionization and/or dissociation [8], resulting positive and negative charged ions, plus neutral molecules or atoms at excited states [9,10,11]. These charged or excited atomic and molecular species with inherited kinetic energy will stimulate the ***multiphase redox plasma chemistry***, or simply ***electrochemistry*** in planet atmosphere, and at planetary surface.

Supported by NASA Solar System Working program, we have been conducting simulating ESD experiment in a Mars chamber. Our goal is to investigate the electrochemistry as induced by ESD process under Mars atmospheric conditions on martian surface minerals, especially, the Cl-, S-, and Fe-systems.

During these ESD experiments, we observed (1) the instantaneous transformation of chloride (NaCl) to chlorate ($NaClO_3$) and perchlorate ($NaClO_4$), with a yield to be 10^3 times that of UVC (at per electron and per photon basis) in laboratory [9]; (2) the instantaneous Cl-release in form of Cl atom at first excitation state, Cl_I, from common Na, K, Ca, Mg, Fe, Al-chlorides [11]; (3) the fast amorphization of hydrous Mg, Fe-sulfates and chlorides [12]; (4) the destruction of a biomarker mixed with a Mg-chloride [13].

The ESD experiments for (1) and (2) sets of simulation were conducted in ambient laboratory temperature range. ESD process generates heat that raises the actual T of sample cell. Because the selected starting phases were all ***anhydrous chlorides***, with melting temperatures in the range of 193 °C ($AlCl_3$) to 801°C (NaCl), while the measured temperature of sample cell for those anhydrous chlorides were < 110° C (Figure 1), thus the slightly raised T would not affect the reactions appreciably.

Figure 1. Temperatures of sample (anhydrous chlorides) cells during ESD



Because some of the hydrous sulfates and hydrous chlorides have the melting temperature below 100°C [14]. The survivability of ordinary biomarkers at high temperature is very low. Therefore If we want to investigate only the chemical effect of ESD in the systems relevant to Mars or to Europa (radiated by energetic electrons), we will have to control the experiments (3) and (4) at lower temperature.

Experimental design and modified set-up: A trade-off in the experimental design will be: either to use as low as possible T in order to simulate a system on Mars or on Europa, or to use a mid-to-low T in order to have a reasonable reaction rate thus to be able to observe the phase changes in a reasonable timeframe in laboratory and then to employ the extrapolation for much lower temperature as we did before [15]. On the basis of this consideration, we set a goal to control the sample cell temperature at < 30°C for both ESD experimental sets (3) and (4).

The used Mars chamber, PEACh [16], has a T setting/feedback/control system using LN_2 as coolant, which could cool down the cold plate in PEACh (Figure 2) to -100°C. Now, we added a set of four thermocouples with T reading into PEACh (Figure 2). The first thermocouple is inserted directly beneath the lower electrode (electrically isolated by a thin layer of SiO_2). Its reading is considered very approach the actual T of the sample cell inside of lower-electrode, especially for long duration ESD process, e.g., 7 hours. The 3rd thermocouple is attached to the cold plate, independent from its T-setting/feedback/control system from PEACh. The 2nd and 4th thermocouples are used to measure the ambient Ts (thin CO_2 and wall) in PEACh.

Sample cell T < 30°C for ESD study of biomarker: Figure 3 shows the temperatures maintained by our new system during a set of the ESD processes on the mixture of $MgCl_2$ and a biomarker, *palmitic acid*. These experiments were run with five time-durations of 15 min, 1 hour, 2 hours, 3 hours, and 7 hours. The results on survivability of palmitic acid is reported in [13]. Figure 3 shows that we successfully controlled the sample cell temperature below 30 °C during the longest ESD process, 7hours (red diamond spots). In addition, the temperatures for 15 min, 1 hour, 2 hours, and 3 hours ESD (dark blue, light blue, green, and orange diamond spots) follow a very similar trend of change, almost overlapping with the T of 7h-ESD. The system gets to equilibrium after a short period (about 60 minutes), to be stabled at 28.02 ±0.27°C. The ΔT between the measured T_3 of cold plate and T_1 of the sample cell (MgCl2+palmitic) is about 36°C.

Adjustable T for ESD study of hydrous salts: Figure 4 shows the temperature of sample cells when running ESD on $FeCl_2.4H_2O$ whose melting temperature is 105 °C [14]. Different setting temperatures (T_{set}) for the PEACh-Cold-Plate were used: -15°C for 7h-ESD and -10°C for ESD-3h. First, we noticed that when using $FeCl_2.4H_2O$ as sample, the sample cell T reaches equilibrium in a much short period (~ 20 minutes). Secondly, the ΔT between measured T_3 of cold plate and T_1 of the sample cell, with $FeCl_2.4H_2O$ as sample, is much larger, about 49-50°C. Thirdly, this ΔT is almost no change with the setting T of PEACh-Cold-Plate system, i.e., average ΔT=49°C for T_{set}= -15°C and average ΔT=50°C for T_{set}= -10°C

Figure 2. Modified T control and readings in PEACh

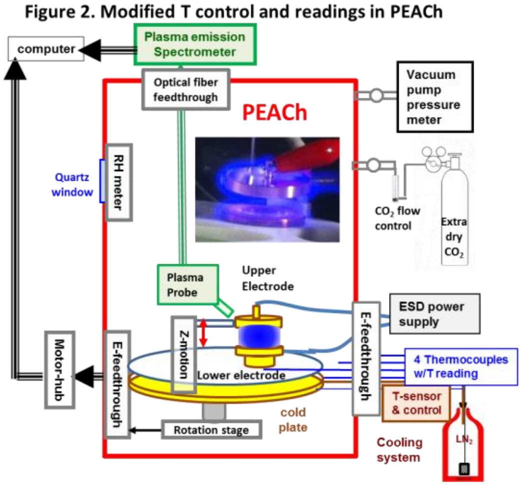


Figure 3. T of sample cells during ESD on $MgCl_2$ + Palmitic

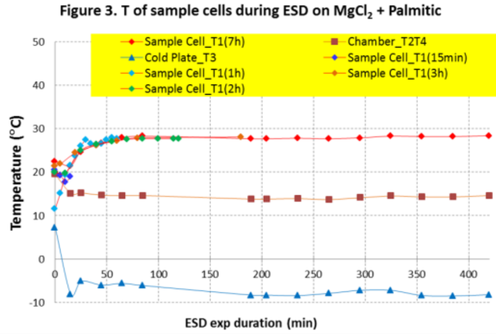
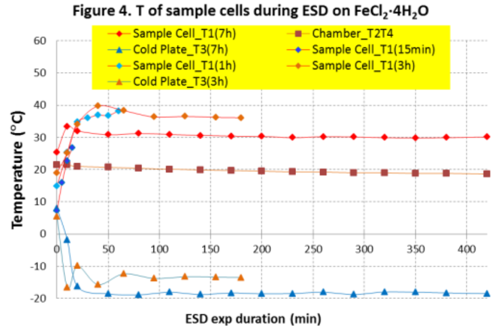


Figure 4. T of sample cells during ESD on $FeCl_2 \cdot 4H_2O$



Conclusion: Through these experiments, we gained two sets of knowledges, (a) the ΔT and the rate of reaching T equilibrium are functions of the sample properties used in ESD, even for the samples that belong to the same chemistry group, i.e., chlorides; (b) the modified T setting/controlling system in PEACh has a traceable performance.

On the basis of these knowledge, we have conducted experiment sets (3) and (4), reported in [12] and [13]. Furthermore, we will be able to design and to conduct the ESD experiments of a salt (mixed with or without biomarkers) at controllable temperatures, and to extrapolate the results to much lower temperatures that are relevant to Mars and to Europa, when it becomes impractical to do the simulations in laboratory.

Acknowledgments: NASA SSW-80NSSC17K0776, and ICEE-2 NNH18ZDA001N

References: [1] Winn et al., *JGR*, *V79*, 1761, 1974; [2] Zhai et al., *JGR*, *V111*, E06016, 2006;[3] Farrell et al., *Icarus*, *V254*, 333, 2015; [4] Yan et al., *48th LPSC#2413*, 2017; [5] Qu et al., *this volume*, 2020; [6] Delory et al., *Astrobiology*, *V6*, 451, 2006; [7] Atreya et al., *Astrobiology*, *V6*, 439, 2006; [8] Jackson et al., *JGR*, *V115*, E05006, 2010; [9] Wu et al., *EPSL*, *V504*, 94, 2018; [10] Bak et al., *EPSL*, *V473*, 113, 2017; [11] Wang et al., *9th Mars Conference #6117*; [12] Wang et al., *this volume*, 2020a; [13] Wang et al., *this volume*, 2020b;[14] Lide, *Handbook of Chemistry and Physics*, 82 th edition; [15] Wang et al., *Icarus*, 2019, [16] Sobron and Wang, *JRS*, 2012;