LABORATORY SIMULATION OF VENUS LIGHTENING FOR ATMOSPHERIC AND SURFICIAL ELECTROCHEMISTRY REACTIONS. Hongkun Qu[1,3], Alian Wang[1], and Elijah Thimsen[2], [1]Dept. of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, [2]McKelvey School of Engineering, Washington University in St. Louis, One Brookings Drive, St. Louis, MO, 63130, USA. [3]Shandong Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, Weihai, Shandong, 264209, China. (hongkun.qu@wustl.edu)

Introduction: Lightning has been thought to be a very important process for planets with atmosphere. Because it might significantly affect the evolution of atmosphere, e.g., fixing nitrogen, and potentially induce atmosphere-surface interactions. Sometime lightning could be regarded as diagnosis of other planetary processes, e.g., volcanism or atmospheric convections. Lightning is also a potential threat to spacecraft during planetary exploration. [1].

On a planet with atmosphere, lightning (or electrostatic discharge, ESD) might occur when dust, ice particles, aerosols, or droplets being electrically charged, separated, and accumulated enough charges (or electrostatic potential) that is beyond the breakdown electrical field threshold (BEFT) of a local atmosphere. Lightning events are detected in the atmospheres of Earth, Jupiter, and Saturn. Lightning on Venus was first reported from mission observations in the 70's [4], with many new ground-based and mission observations (optical and electric) as supporting evidences[3].

Investigations on lightning of extraterrestrial planets would enable us to understand the electrostatic character of their atmosphere, dynamic behavior and the associated chemical cycles. The atmosphere of Venus is complex and extremely different from that of Earth. All available data indicate that sulfur chemistry in Venus atmosphere would play a crucial role. For example, the concentration of SO_2, much higher than that of Earth, varies through the layers of Venus cloud [5], and sulfuric acid is a main component in all layers of Venus cloud and haze [4]. Some of unsolved questions (e.g., the second UV absorber) are believed to be related to sulfur-cycle. Up to now, two well-accepted drivers for sulfur chemistry on Venus are photochemistry within and above the clouds, and thermochemistry at or near the Venus surface [6].

Table 1 Picture of ESD in Air at 28kV driving voltage

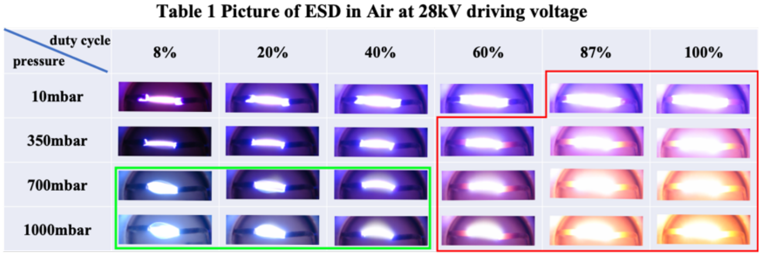
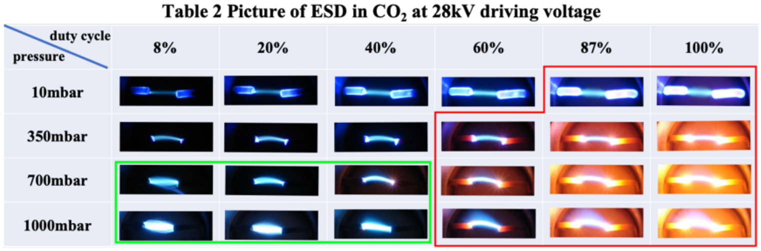


Table 2 Picture of ESD in CO_2 at 28kV driving voltage



However, the mismatch between theoretical modeling and mission observations indicates that there might be other chemical processes occurring on Venus that are previously unaccounted for. ***Electrochemistry driven by ESD, i.e., lightning,*** might be one of these processes.

During ESD process, high speed electrons would be produced and would collide with gas molecules in atmosphere that will be ionized and/or dissociated. Some new species e.g., positive and negative charged ions, and neutral atom with high kinetic energy would appear in plasma driving ***electrochemical reactions*** in atmosphere, and potentially affect Venus surface materials[7].

Further missions to Venus is one of the most effective ways for us to understand many unsolved questions. On the other side, laboratory simulation studies would also help us to unveil some mysteries.

We report here the new results from two sets of simulation experiments on electrostatic discharge (ESD) under conditions relevant to Venus atmosphere.

Experiment Setup: A Venus-ESD-Chamber (VEC) system was employed to conduct the simulation experiments. It contains three functional units: ESD generation, P, T, C control and monitoring, and optical sensing, details in [8]. In the reported experiments, the distance between two electrodes is about 7.874 mm, and we added an adjustable duty cycle control in ESD power supply.

Results and Discussion: We conducted two sets of ESD experiments, in air and in CO_2, with a pressure range of 10 mbar -1bar and a duty cycle range of 8-100%. We took the pictures of plasma for image analysis, measured ESD current and voltage curves to judge the discharge types, and the plasma spectra for phase ID of free radicals.

Table 1 and 2 show the pictures of ESD plasma in air and in CO_2 taken by a Nikon camera with fixed exposure conditions, using a driving voltage of 28 kV for all. Following the increase of duty cycle, the brightness of plasma increases monotonically, because more energy was coupled into the discharge. Marked by the red polygons in Table 1&2, the electrodes were heated to a very high temperature at high duty cycle due to a high rate of electron collisions. At a same pressure and duty cycle, the plasmas in CO_2 are thinner than that in air, because CO_2 is more difficult to be ionized and dissociated. Marked by the green rectangles in Table 1 &2, we observed a transition from filamentary to homogeneous discharge following an increasing duty cycle.

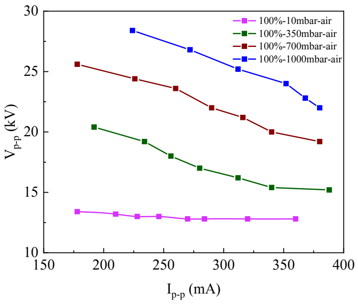


Fig. 1 The ESD current as a function of voltage under different pressures of air at 100% duty cycle

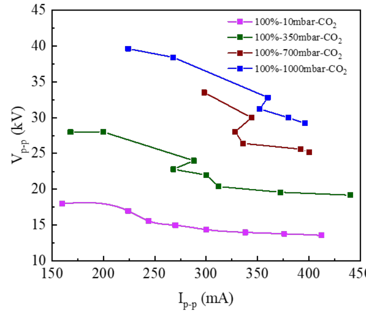


Fig. 2 The ESD current as a function of voltage under different pressures of CO_2 at 100% duty cycle.

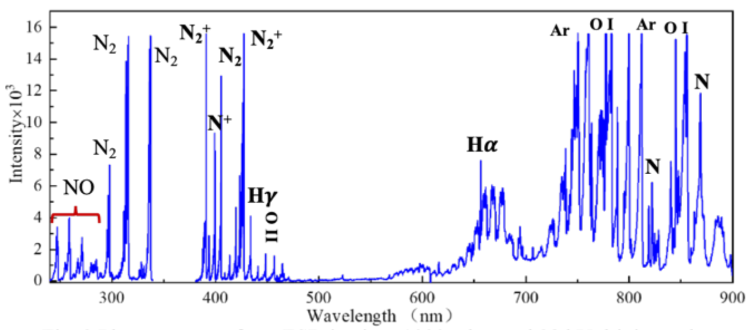


Fig. 3 Plasma spectra from ESD in air at 1000 mbar and 28 kV driving voltage

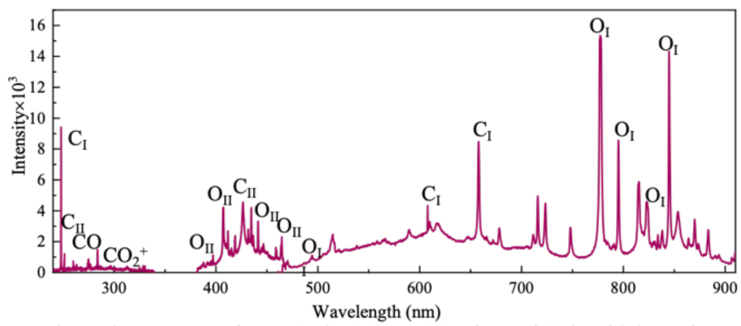


Fig. 4 Plasma spectra from ESD in CO_2 at 1000 mbar and 28 kV driving voltage

The ESD current as a function of voltage under different pressures of air and of CO_2 with 100% duty cycle are showing in Fig. 1 and 2. We observed a V_{p-p} increase with the increase of pressure. It is because when pressure increases, the number density of molecules between two electrodes increases and the mean-free-path of electron decreases sharply. In order to obtain enough kinetic energy to initiate the discharge, an electron would need a stronger E-field to accelerate. Another observation is that V_{p-p} decrease as I_{p-p} increase (Fig. 1, 2), which is a typical characteristics of arc discharge (i.e., lightning). The abnormal "zig-zag" observed in Fig. 2 at 350, 700, and 1000 mbar is caused by the transition from filamentary to homogeneous discharge.

Fig. 3 and 4 are plasma emission spectra from ESD in air and in CO_2 at 1000mbar and 28 kV driving voltage. From ESD in air, we observed the plasma lines of NO, N_2, N_2^+, N^+, O_I, O_{II}, Ar, H_α, and H_γ. From ESD in CO_2, we observed emission lines of C_I, C_{II}, CO_2^+, CO, O_I, and O_{II}.

Further Work: For next step, we will conduct ESD in SO_2 gas and in gaseous mixtures to study the ESD produced ionic and molecular species.

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