SENSORS TO CHARACTERIZE THE PROPERTIES OF THE MARTIAN REGOLITH.

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Introduction: The scientific goals of current and past Mars surface exploration missions include a desire to determine the physical and chemical state of the regolith, its mineralogy and surface distribution, and whether solid volatiles, such as water ice or solid carbon dioxide, are present in the regolith. Certain mineral constituents and solid volatiles in the regolith are considered to be potentially valuable resources that could replenish mission consumables that would not need to be transported from Earth, thereby reducing the overall cost of a mission [1]. In practice, excavators would collect and deliver raw regolith to an in-situ resource utilization (ISRU) reactor system that would process the regolith and extract the desired byproducts, such as water, oxygen, and pure metals. These materials could then be used to produce propellants, structural materials, and even the sintered "waste" material from the ISRU reactor might be used to construct landing pads. In order to process regolith efficiently it is necessary to be able to survey the local terrain to determine the nature of the surrounding regolith.

We have developed an early prototype of an electrostatic sensor system that could be built into a future rover wheel that is capable of differentiating minerals in the Martian regolith [2-4]. The electrostatic sensor system will also be capable of differentiating between dry and moist regolith and between coarse and fine soils.

Triboelectric Charging and Soil Differenciation: Contact electrification or triboelectrification is the process by which materials are brought into contact and then exchange electrostatic charge, thus becoming charged upon separation. The triboelectric properties of particulate materials have been shown to be functions of the bulk mineralogical composition, condition of the surfaces (radiation damage, oxidation, ions, adsorbed substances, contamination, and impurities), particle size and shape, state of electrostatic charge prior to contact, force of contact, and environmental conditions such as temperature, pressure, atmospheric composition, and humidity [5]. Despite the number of variables affecting triboelectric charging, a variety of studies have shown that different minerals can be differentiated based on their triboelectric behavior and placed in a triboelectric series [6-8]. This triboelectric series places materials in order of how they respond electrostatically when rubbed with one another. For example, fiberglass will charge positive against most materials and therefore is near the positive end of the series while Teflon, which charges negatively when rubbed against most materials, will appear near the, negative end of the series. Even though some experimenters derive slightly different triboelectric series, there is a general consensus among the placement of common materials, including minerals.

Instrument Description: The current array prototype consists of a series of triboelectric and electric field sensors built into a small wheel for laboratory testing. A proposed flight configuration will incorporate this sensor array into a rover wheel. The sensors will be attached just beneath the rover wheel in such a way that each sensor will be exposed to the Martian regolith either by direct contact with the regolith (Fig.1). This configuration is in line with other Jet Propulsion Laboratory considerations for the inclusion of near-surface sensors on rover wheels [4]. The wheel-mounted sensor array will have low mass, power, and volume requirements and will perform continuous measurements that would not impact other operations.

There will be two basic types of sensors. A triboelectric sensor to measure the amount of electrical charge that develops on a polymer through frictional contact as the rover wheel rolls over the Martian regolith and an electric field sensor to measure the regolith surface charge density as the rover wheel rolls over the Martian surface. The electric field sensor can be mounted directly on the rover and will also be able to measure atmospheric electric fields.

Figure 1 shows the rover wheel with the proposed locations for the sensor modules. The five sensors would utilize a different insulator material backed by independent miniature electrometers.

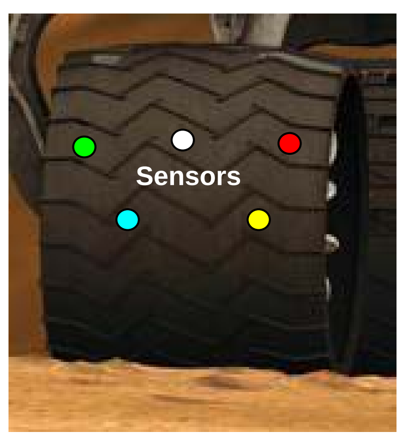

Figure 1. The proposed sensor array shown on the Curiosity wheel.

Preliminary Results: Experiments with a prototype sensor array mounted on a rectangular box were performed in a carbon dioxide atmosphere at 9 mbars of pressure. Five TRIBO sensors capped with fiberglass, Teflon, Lexan, polyethylene, and Lucite were placed in contact for 3 seconds with the granular material. Fig. 2 shows the cumulative charge developed on each one of the five polymers when in contact with dry coarse JSC Mars-1 simulant, dry coarse sand, a 50-50 mixture of simulant and sand, a 2 mm layer of fine simulant over coarse simulant, fine dust over sand, fine simulant, as well as moist and dry simulant.

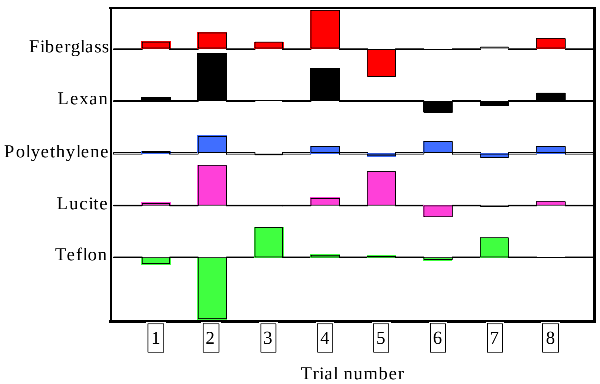

Figure 2. Results of eight experiments performed at 9 mbars with CO_2. Shown is the relative cumulative charge deposited onto Fiberglass, Lexan, Polyethylene, Lucite, and Teflon. Conditions for the experiments are: 1 dry, coarse JSC Mars-1 Martian regolith simulant; 2 dry coarse sand; 3 a dry 50/50 mixture by volume of simulant and sand; 4 dry, coarse JSC Mars-1 simulant coated with 5 μm simulant dust to a depth of 2 mm; 5 dry coarse sand coated with 5 μm simulant dust; 6 dry, fine simulant alone; 7 moist and 8 dry JSC Mars-1 Martian regolith simulant.

These results show that differences in soil texture, size, and shape can be detected with the prototype sensor array. It is also possible to distinguish between moist and dry simulant.

A second prototype sensor array was built on an aluminum wheel 12.7 cm in diameter with four sensors capped with Lucite, Teflon, figerglass, and Lexan. Fig. 3 shows preliminary data with this prototype in dry air at 9% relative humidity and at atmospheric pressure. The prototype wheel was rolled along a 60 cm tray containing JSC Mars-1 simulant. The fours insulators acquired different electrostatic charges when in contact with this simulant. The sharp peaks observed in the graph are due to the initial contact with the soil. Repeated contacts show an increase in the charge between simulant and insulator. Several runs were taken prior to the one generating the data presented here. The insulators and simulant were exposed to an ionizer to neutralize their surface charges before this run but no cleaning was performed. Thus, this procedure is fairly close to an actual procedure that could be used on a flight instrument. Atmospheric ions would neutralize the insulator during long periods of rover inactivity.

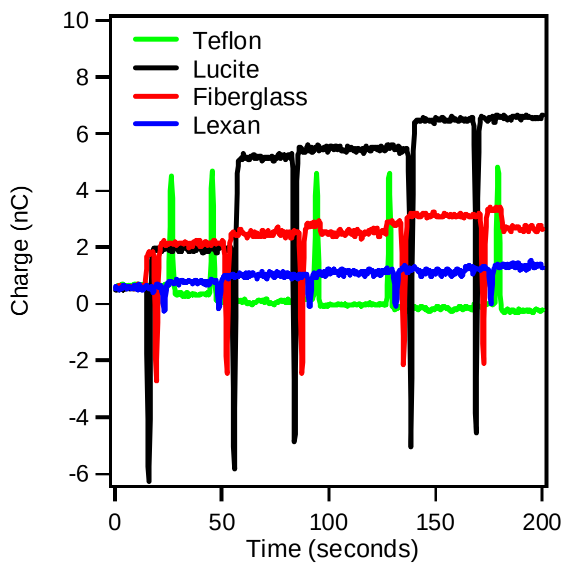

Figure 3. Charge generated on the four polymers capping the electrometer sensors on the prototype sensor array on a wheel.

Conclusions: Our preliminary data indicates the feasibility that an electrometer sensor array mounted on a rover wheel could be able to differentiate minerals in the Martian regolith and distinguish between dry and moist as well as fine and coarse regolith. To achieve that goal, extensive laboratory tesing under Martian simulated conditions must be performed to develop a comprehensive library of the electrostatic responses of a large set of polymers to the minerals known to exist on Mars.

References:

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