DIELECTRIC BREAKDOWN IN THE LUNAR REGOLITH. A. P. Jordan[1], T. J. Stubbs[2], J. K. Wilson[1], N.A. Schwadron[1], H.E. Spence[1], [1]EOS Space Science Center, University of New Hampshire, Durham, NH, [2]NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: The Moon receives a flux of energetic charged particles from the surrounding space environment. In particular, galactic cosmic rays (GCRs) and solar energetic particles (SEPs) deposit their charge below the uppermost layer of the regolith's surface. The lunar regolith is a dielectric and an electrical insulator. Therefore, if incident GCRs and SEPs collect in the regolith on timescales shorter than required to dissipate the buildup of electrical charge, then a significant electric field can be formed within the regolith. If this field becomes strong enough, it can cause dielectric breakdown. In this study we estimate the long-term likelihood of breakdown in the lunar regolith.

Deep dielectric charging: Deep dielectric charging occurs when charged particles are deposited within an electrical insulator. If this charge deposition occurs at a rate faster than the insulator can dissipate the charge buildup, the electric field within the insulator increases. If the electric field becomes great enough, it can initiate dielectric breakdown.

According to avalanche theory, breakdown occurs when the electric field is great enough to accelerate a low-energy, free electron to the ionization energy within a mean free path [1]. This locally ionizes the solid, creating a path to quickly dissipate the charge buildup. If the breakdown occurs near the surface of the dielectric, plasma can be released from the dielectric. The insulator can also undergo chemical and mechanical change, such as localized melting and the release of neutral and ionized constituents [2, 3].

For nearly all solids, the needed field is ~10^7 V/m [4]. This is the macroscopic field of the overall dielectric. Local geometries, however, may enable breakdown to occur at fields of ~10^6 V/m [5]. Based on spacecraft-charging studies, the needed fluence (time-integrated flux) of charged particles to initiate breakdown is about 10^{10}-10^{11} particles/cm^2 [6].

Significant lunar charging events: On the Moon, the most favorable locations for deep dielectric charging are believed to be permanently shadowed regions (PSRs). Their cold temperatures keep the regolith's conductivity at an extremely low value of 10^{-17} S/m, resulting in a charging/discharging timescale of about a lunation (20-30 days). Furthermore, in PSRs, other current sources, e.g. from diverted solar wind plasma, can often be neglected [7], thus enabling us to reasonably assume that the surrounding space environment is an ideal vacuum.

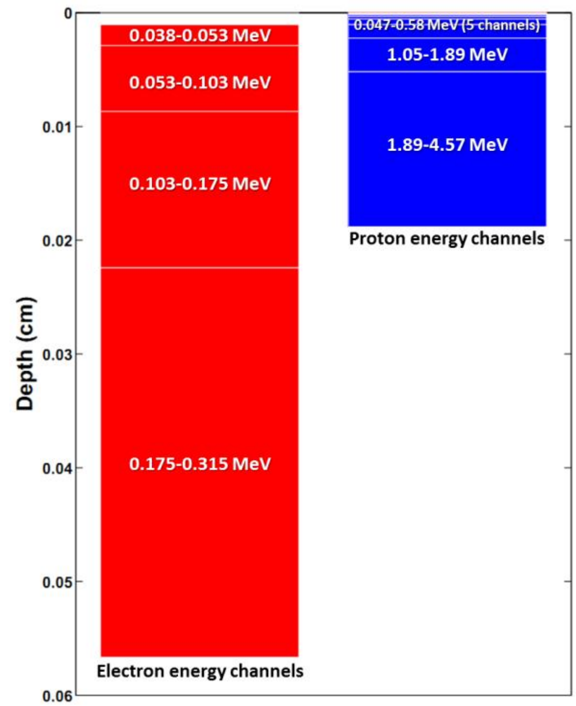

Figure 1: Average regolith penetration depth of electrons (left) and protons (right) in the given energy channels in ACE/EPAM, assuming isotropic incidence.

We have created a model describing the deep dielectric charging of the lunar regolith. We show that typical GCR fluxes can create a subsurface electric field of about 600 V/m. Furthermore, we use SEP electron and proton data from the Electron, Proton, and Alpha Monitor (EPAM) on the Advanced Composition Explorer (ACE) [8] to drive the charging model. Because the electrons penetrate more deeply than the protons (Figure 1), an electric field is set up within the upper millimeter of the regolith. We find that large SEP events, such as the Halloween storms in October 2003, can create a subsurface electric field on the order of 10^7 V/m. This is possibly great enough to create dielectric breakdown within the upper millimeter of regolith.

We also estimate the frequency of SEP events that can initiate dielectric breakdown. To do this, we find their occurrence rate throughout much of the Space Age using work by Feynman et al. [9] and the OMNI data set of energetic protons fluxes [10]. This occurrence rate enables us to better characterize the possible effects of breakdown on the regolith. We also consider typical gardening rates to estimate how many times a given layer of regolith experiences dielectric breakdown.

Conclusion: Our modeling has shown that deep dielectric charging is significant in PSRs. Furthermore, dielectric breakdown is likely to occur in PSRs. Finally, we estimate the occurrence rate of such events and how they influence the evolution of the regolith in these regions of special scientific interest.

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