USE OF ATMOSPHERIC GLOW DISCHARGE PLASMA TO MODIFY SPACEPORT MATERIALS.

S. Trigwell[1], A.C. Schuerger[2], C.R. Buhler[1], and C.I. Calle[3]; [1]ASRC Aerospace, ASRC-20, Kennedy Space Center, FL 32899, TrigwS@kscems.ksc.nasa.gov; [2]University of Florida, Bldg. M6-1025, Space Life Sciences Lab., Kennedy Space Center, FL 32899, acshuerger@my.ifas.ufl.edu; [3]Electrostatics and Surface Physics Lab, NASA Kennedy Space Center, FL 32899, Carlos.I.Calle@nasa.gov

Introduction: Numerous materials used in spaceport operations require stringent evaluation before they can be utilized. It is critical for insulative polymeric materials that any surface charge be dissipated as rapidly as possible to avoid Electrostatic Discharges (ESD) that could present a danger. All materials must pass the Kennedy Space Center (KSC) standard electrostatic test [1]; however several materials that are considered favorable for Space Shuttle and International Space Station use have failed.

Moreover, to minimize contamination of Mars spacecraft, spacecraft are assembled under cleanroom conditions and specific cleaning and sterilizing procedures are required for all materials. However, surface characteristics of these materials may allow microbes to survive by protecting them from sterilization and cleaning techniques.

In this study, an Atmospheric Pressure Glow Discharge Plasma (APGD) [2] was used to modify the surface of several materials. This allowed the materials surface to be modified in terms of hydrophilicity, roughness, and conductivity without affecting the bulk properties. The objectives of this study were to alter the surface properties of polymers for improved electrostatic dissipation characteristics, and to determine whether the consequent surface modification on spaceport materials enhanced or diminished microbial survival.

Methods for Plasma Treatment: Six materials were used altogether in this study; aluminum 6061, PTFE, polycarbonate, Saf-T-Vu (a PVC material used in solid rocket booster joint enclosures for segment mating operations), Rastex (a PTFE woven cloth used in orbiter radiator protective covers), and Herculite 20 (used in launch service processing). Coupons of each material were ultrasonically cleaned for 10 minutes successively in acetone, methanol, and iso-propanol, and finally rinsed in DI water. The coupons were allowed to air dry in a positive pressure sterile hood until used.

The plasma treatment procedure (Figure 1) was optimized on Saf-T-Vu (failed KSC test), Herculite 20 white (borderline KSC test), and Rastex (did not dissipate charge) with different gases (O_2, air, O_2+H_2O, and He+O_2) at 47 +/- 3% RH and at 72 °F. He+O_2 produced the most significant effect, determined by monitoring the increase in the O:C ratio on the surface by X-ray photoelectron spectroscopy (XPS) and by contact angle measurements. The Al6061, PTFE, and polycarbonate were treated by the optimized protocol for the inclusion in the bacteria testing.

Methods for Recovery of Microorganisms: All six materials were treated as above and then transferred to a microbiological lab to evaluate how spores of the bacterium, *Bacillus subtilis* HA101, would adhere to the treated materials. Spores of *B. subtilis* were applied to the treated upper surfaces of each coupon at the rate of ≈1.5 x 10^6 viable spores per coupon. Two tests were conducted. First, in order to estimate how "sticky" the materials were after plasma treatment, spores were applied to coupons, allowed to air dry at 25°C for 24 hrs, and then processed with an enhanced Most Probable Number (MPN) assay [3,4] with a minimum detection limit of 10 spores per coupon. Second, in order to determine if the plasma-treated materials inhibited the survival of spores over time, a new set of plasma-treated coupons were doped with spores of *B. subtilis* and then placed within incubation chambers maintained at 30°C and 100% relative humidity for 7 days. After incubation, the MPN assays were used to estimate the numbers of viable spores still adhering to the coupons after treatment.

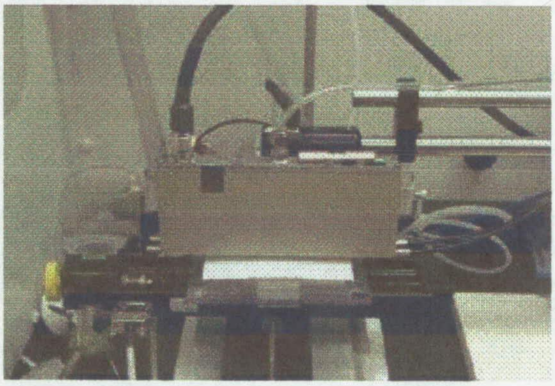

Figure 1. He+O_2 plasma head shown treating PTFE sheet

Results: Figure 2 shows the results of He+O_2 on Saf-T-Vu. Results on PTFE material (Rastex) after APGD with He+O_2 showed a decrease in the amount of surface voltage, but the material still failed the test. Samples of Rastex and Herculite 20 white were submitted to AST Products Inc. where a chemical treatment (Hydrolast©) was applied after plasma treatment that "locks in" the surface modification. Subsequent tribocharging data for the two materials are shown in Figure 3.

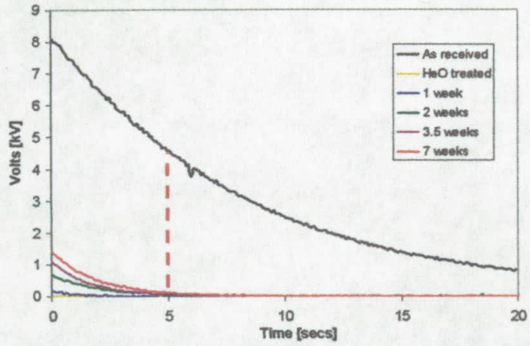

Figure 2. Effect of He+O_2 APGD on Saf-T-Vu. For the as-received material, the surface voltage after tribocharging failed to reach < 350 V after 5 seconds as per the standard. Post APGD treatment, and after seven weeks, the material passes the standard test

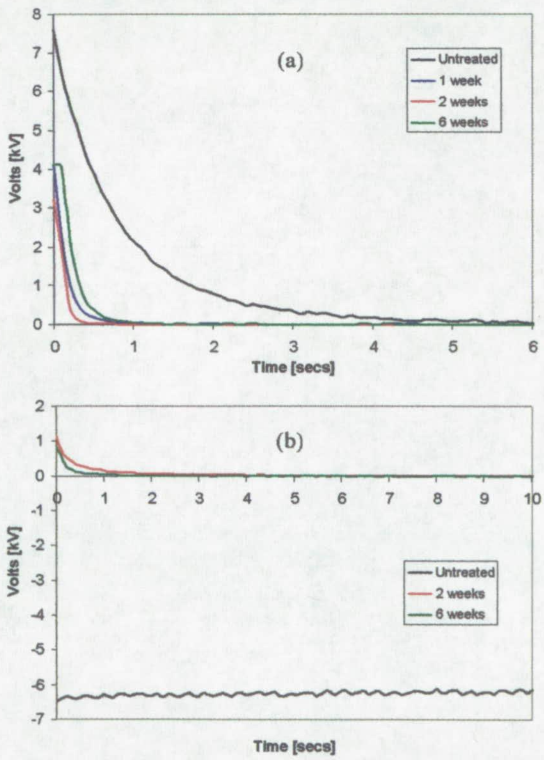

Figure 3. (a) Herculite 20 white material easily passes the test. (b) Rastex also passes the test 6 weeks after APGD and Hydrolast© treatment.

Surface contact angle measurements for Saf-T-Vu decreased from 104° to 35° after APGD treatment showing increased hydrophilicity. Monitoring the aging showed no recovery with a measured contact angle of 30° after 3 weeks.

Results of the microbiological assays indicated that the material Al6061 was the stickiest of the six materials tested, but that it (Al6061) and the other five materials were unaffected after plasma treatment for the level of inherent stickiness to spores of *B. subtilis* compared to no-plasma treated controls. However, in the second assay, incubation in a 100% RH environment resulted in a clear decrease in recovered spores for the materials Al6061, polycarbonate, and Saf-T-Vu when compared to the non-plasma treated controls. In addition, there was a slight (but statistically significant) increase in the spores recovered from the plasma-treated coupons, PTFE, Herculite, and Rastex compared to non-plasma treated controls.

Conclusions: Exposure to He+O_2 APGD plasma and subsequent chemical treatment significantly improved the electrostatic dissipation of polymeric materials and rendered them compliant with the KSC standard electrostatic test. The results were still valid up to 7 weeks after treatment. Long-term monitoring is ongoing.

The results of the spore testing indicate that plasma treatment can both inhibit and enhance the recovery of adhered spores after exposure to saturated ambient environments of up to 100% RH. Thus, the plasma treatment does alter the surface properties of several spacecraft materials making them either slightly more, or slightly less, sticky to spores of *Bacillus subtilis* when compared to non-plasma treated coupons.

References: [1] Finchum A. (1998) Standard Test Method for Evaluating Triboelectric Charge Generation and Decay, KSC Test Standard MMA-1985-98, Rev. 3; [2] Trigwell et al., (2005) *Proc. ESA Annual Meeting*, Alberta, Canada, 46-54; [3] Schuerger et al., (2003) *Icarus.*, 165, 253-276; [4] Schuerger et al., (2006) *Icarus.*, (in press for Feb. issue).