Permittivity Testing of Lunar Regolith Simulants Using Small Sample Sizes. Q. H. Otte[1] and A. J. King[1], [1]Radiance Technologies, 310 Bob Heath Dr., Huntsville, AL 35806. (Contact: Quinn.Otte@radiancetechnologies.com)

Introduction: Proper characterization of both lunar regolith and simulants in terms of their dielectric properties is essential to evaluating and developing hardware and processes that will succeed in sintering regolith on the moon. There is an existing body of work characterizing the dielectric properties of regolith, conducted from 1972-1978 [1] [2] [3] [4] [5]. Several features of this existing data make it insufficient for sintering process research. Many studies suffer from lower sample rates and do not examine permittivity variation over frequency ranges, instead focusing on a handful of discrete frequencies which are below the frequency range useful for sintering. Furthermore, due to the logistical complexities of testing Apollor lunar regolith samples here on earth, a custom, advanced permittivity testbed is required to collect appropriate dielectric data.

Concept: The coaxial perittivity testing device is examined as an electrical 2-port network. The procedure uses a 2-port vector network analyzer (VNA) to measure forward and reflected power to and from each end of the device, obtaining the four scattering parameters (S-parameters) of the network. Since the simulants are non-magnetic, permeability is assumed $\mu_r^* = 1$, and complex permittivity is calculated from measured S-parameters. From the complex permittivity, loss tangent can be calculated. The test software utilizes time-domain gating and multi-step calibration to filter non-specimen effects on the signal.

Design: The testbed was designed to satisfy several objectives to allow testing of Apollo regoloth samples. Traditional measurement techniques, such as focused-beam or TEM cell measurements, all fail to comply with one or more of these design parameters. First, sample size must be minimized, due to the low regolith availability. Additionally, the testing must be nondestructive and the sample completely recoverable, *i.e.* the device must be easily cleaned. The device must operate within $0.5 - 15$ GHz to span the range of potential sintering frequencies. Data must be gathered with a resolution of at least 20 MHz. The device must function in a vacuum, due to regolith handling and storage requirements. Finally, a variable and measureable packing rate of the sample material must be accounted for.

The final design consists of a body that bisects into two equal parts, with a removeable center conductor. The coaxial terminals on each end of the device are APC7 standard. A Teflon plug keeps the center conductor in place during assembly and retains the sample during testing. The cavity is 7 mm in diameter, requiring less than $\frac{1}{2} cm^3$ of material.

Performance: The system is calibrated using a Maury 2650CK30 calibration kit and the empty, assembled device. The device is held in a test tube stand, with the cavity oriented vertically and the Teflon window at the bottom. A weighed aliquot of material is added into the cavity from the top of the device, and the packing density can be obtained by measuring the height of the sample via tamping rod insertion depth. Mating surfaces for the cables are cleaned using lint-free swabs. Then the cables are connected and measurements are taken. Data is collected using Copper Mountain's C1420 VNA and S4VNA software and processed using a custom software developed by Compass Technology Group specifically for this device.

This system is intended to be used at a constant temperature of $25°\,\mathrm{C} \pm 15°\,\mathrm{C}$. Varying temperature will invalidate the calibration. It is compatible with varied atmospheres, including argon, nitrogen, and vacuum.

The device has been used to measure the complex permittivity of the simulants JSC-1A, NU-LHT-4M, and synthetic anorthite. In the case on JSC-1A, measured values of real permittivity matched existing published data [6]. No existing published data is available for the other simulant materials.

Future Work: Further process development to allow gloved handling in a vacuum box is necessary. Alternative window materials may be tested to simplify calibration procedures. Once the device is validated in vacuum using simulant, a proposal for Apollo regolith sample testing will be initiated.

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