Permittivity Testing of Lunar Regolith Simulants Using Small Sample Sizes

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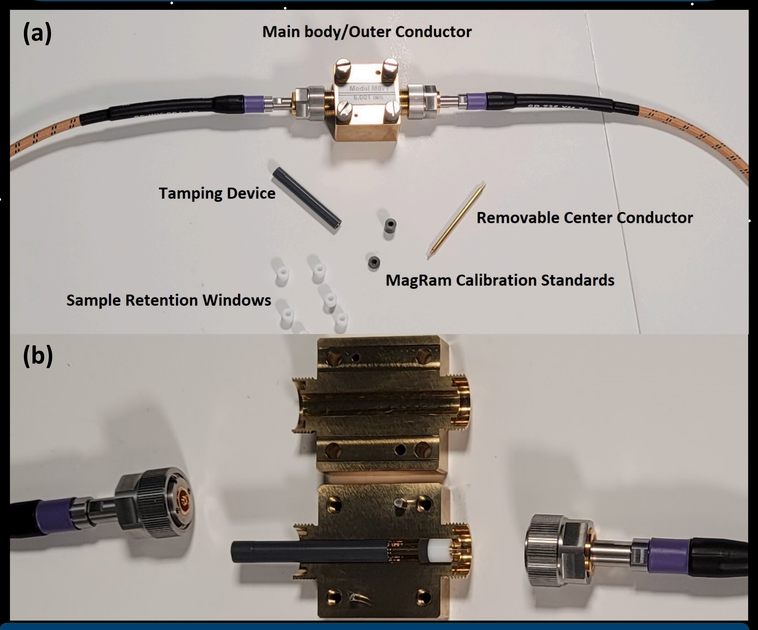
RADIANCE TECHNOLOGIES

Introduction:

- Proper dielectric characterization of both lunar regolith and simulants is essential to evaluating and developing hardware and processes that will sinter regolith on the Moon
- The existing body of work characterizing the dielectric properties of regolith was conducted from 1972-1978 [1] [2] [3] [4] [5] and is of limited usefulness
- Due to the logistical complexities of testing Apollo lunar regolith samples on Earth, a custom, advanced permittivity testbed is required to collect appropriate dielectric data

Concept:

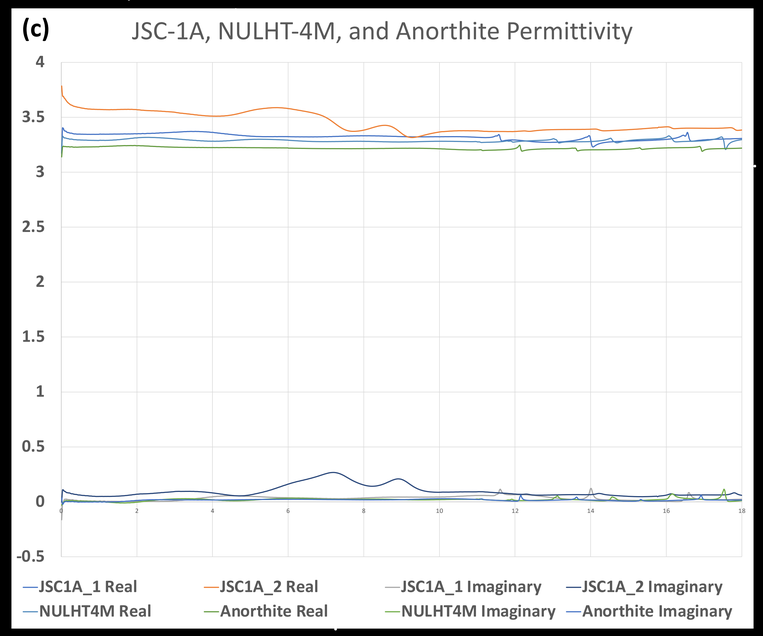
- The coaxial permittivity testing device is examined as an electrical 2-port network using a Vector Network Analyzer to measure the four scattering parameters
- Simulants are non-magnetic, permeability is assumed μ_r^* = 1, and complex permittivity and loss tangent are calculated from measured S-parameters



(a) Closed coaxial testbed and accessories **(b)** Open coaxial testbed with conductor, retention window, and tamping rod in place

Design:

- The testbed was designed to satisfy several objectives to allow testing of Apollo regolith samples:
  - Minimize sample size, due to the low regolith availability
  - Testing must be nondestructive and the sample completely recoverable
  - Operate within 0.5-15 GHz, with a resolution of at least 20 MHz
  - Operate in a vacuum
  - Allow for variable packing rate
- Final design consists of a body that bisects into two equal parts, with a removable center conductor
- 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 1/2 cm^3 of material



(c) Complex permittivity measurements of three simulants being assessed by MMPACT for use as an analog for lunar regolith in sintering experiments

Performance:

- 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]
- This system is intended to be used at a constant temperature of 25°C ± 15°C; varying temperature will invalidate the calibration
- The system is compatible with varied atmospheres, including argon, nitrogen, and vacuum
- Procedure:
  - 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 calculated
  - 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

Future Work:

- Determine calibration schedule and necessary variable monitoring for multi-sample runs
- Process development to eliminate ringing and resonances in the device

References:

[1] Strangway P. G. and Olhoeft G. (1974) Earth and Planetary Science Letters, 24, 394-404. [2] Olhoeft G. et al. (1974) Journal of Geophysical Research, vol. 79 no. 11, 1599-1604. [3] Olhoeft G. et al. (1973) Fourth Lunar Science Conference. [4] Strangway D. W. et al. (1972) Earth and Plane-tary Science Letters, 16, 275-281. [5] Chung D. W. (1972) Third Lunar Science Conference. [6] Barmatz M. et al. (2011) JPL