Microwave Structure Construction Capability for the Moon. M. R. Effinger, NASA Marshall Space Flight Center (MSFC), Huntsville, AL (Contact: Michael.R.Effinger@nasa.gov)

Introduction: Infrastructure on the Moon utilizing in-situ resources is necessary for a permanent base. To consolidate the lunar regolith into infrastructure, a heating source to achieve a glass-ceramic. The most efficient means to volumetrically heat regolith is with microwave energy. The Microwave Structure Construction Capability (MSCC) element within Moon to Mars Planetary Autonomous Construction Technology project is developing technology and conops to build infrastructure with microwave energy [1, 2].

Overview: MSCC is pursing paving and brickmaking processes for infrastructure formation. For the paving method, the microwave system would move across the regolith and sinter the regolith in place. In order to do this, there is site preparation necessary. Rocks would need to be removed from the construction area. The site would then be leveled and compressed. Bearing strength, dielectric, and angle of repose testing would occur. Microwave sintering would commence at that time. Placing additional material on top of the sintered material would occur after the first layer is complete. The load sustaining capability, coarse porosity, & geometry would be characterized with instrumentation for the final product.

Multiple organizations are working to develop microwave sintering. Small scale microwave sintering is being done at NASA Jet Propulsion Laboratory. Large scale microwave sintering is being done at Alfred University and MSFC. Full-scale testing will be done at MSFC in a 20ft diameter vacuum chamber. Large-scale and full-scale testing will generate plates with horizontal and vertical fused joints for characterization. That characterization will feed modeling for performance and life prediction for resulting infrastructure. Non-destructive and destructive evaluation will occur. Critical flaw size determination will also be done.

MSCC is evaluating multiple hardware configurations. Microwaves can be generated from two different sources: magnetron and solid state. Solid state is baseline for Mars. MSCC is evaluating different applicators, the location where microwaves exit from the hardware and are transmitted into the regolith or simulant. Horns, leaky wave guide, and wave guide array are current options being pursued. Other options are being considered for the future to increase system performance and efficiency, product quality, and reduce risk.

In order to be flexible to the composition and dielectric properties of various locations on the Moon, MSCC is planning to characterize major regolith constituents to estimate microwave sintering protocols with models.

High temperature bakeout procedures for simulants are being developed to mitigate non-lunar behavior of the simulants and ensure more accurate microwave sintering. New highlands simulants are being developed [3].

Extensive simulant testing is being done to support all this development including, but not limited to: Differential Thermal Analysis (DTA), Differential Scanning Calorimeter, and Thermal Gravimetric Analysis (TGA) in vacuum and inert, particle size, particle shape, and surface area testing, Raman spectrometry, optical and electron microscopy, cathodoluminescence imaging, mass spectrometry with respect to temperature in vacuum and inert, chemical analysis, etc.

Furnace sintering tests are being conducted to better define the sintering window that will feed into the microwave sintering testing and protocol development.

References:

[1] R. G. Clinton, et al. ASCEND 2021.

[2] M.R Effinger, et. al. Lunar Surface Innovation Consortium Fall Meeting, November 4, 2021.

[3] Doug Rickman, Holly Shulman, Matthew Creedon, & Mike Effinger. 53rd Lunar and Planetary Science Conference, March 7-11, 2022.