Microwave Structure Construction Capability Year 1 Accomplishments

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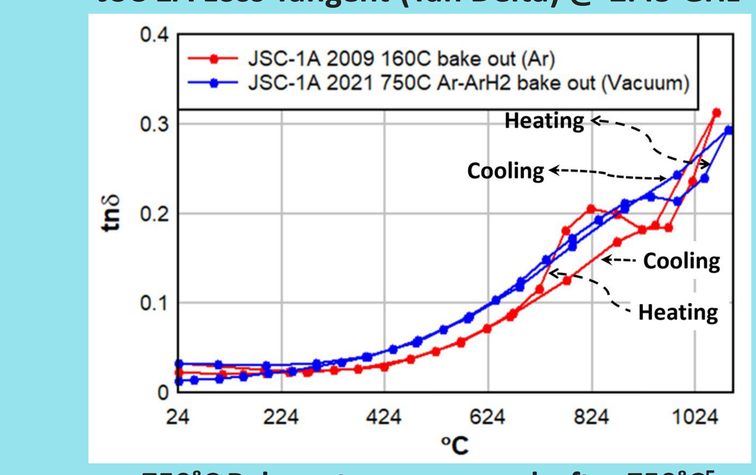
Introduction

The Microwave Structure Construction Capability (MSCC) element, part of the Moon to Mars Planetary Autonomous Construction Project (MMPACT) was initiated in 2020. MSCC is responsible for creating horizontal and vertical infrastructure on the moon using microwave energy. Microwave sintering is being pursued since it is the only heating method to volumetrically heat the regolith. Advances were achieved in materials characterization and understanding, microwave sintering in vacuum with a lunar-like applicator and sample bed, microwave design and analyses, and conceptual design.

Simulant Characterization

JSC 1A Loss Tangent (Tan Delta) @ 2.45 GHz



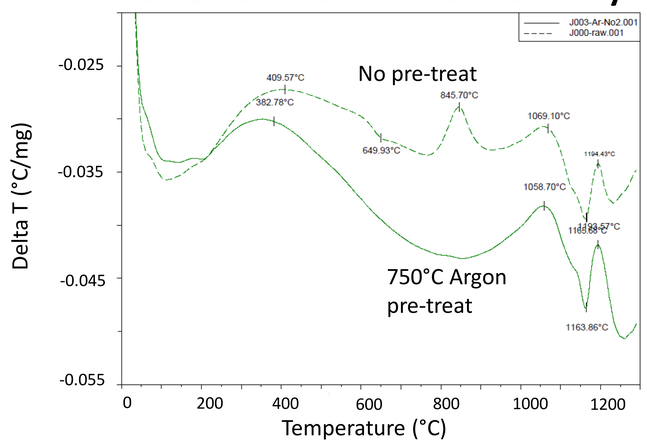
Increased density leads to better microwave coupling, but not a driver at room temperature[3]

JSC 1A Loss Tangent (Tan Delta) @ 2.45 GHz

750˚C Bake out removes peak after 750˚C[5]

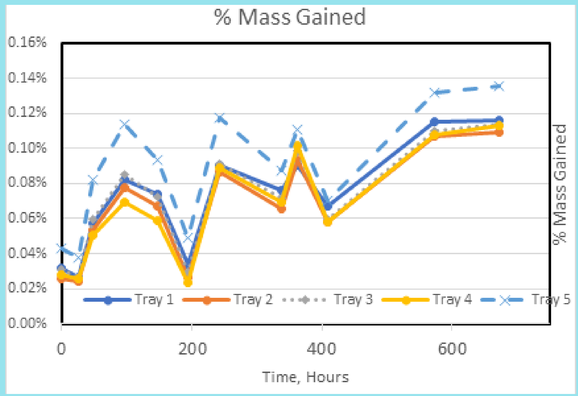
Simulant Characterization

JSC 1A Differential Thermal Analysis



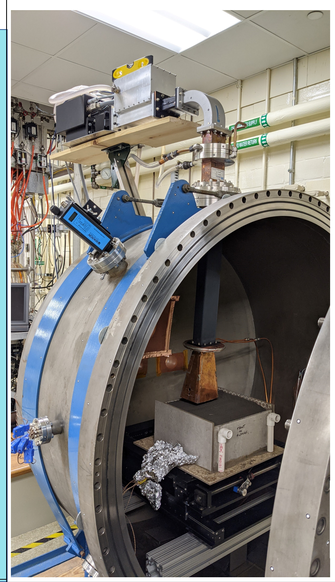
750C Bake out removes 845˚C peak[5]

JSC 1A Mass gained after 200˚C bake out



About 100hrs to gain 50% of original mass loss[6]

Microwave Sintering



Lunar- like applicator & sample bed sintering at ~10^{-4} Torr (small scale sintering takes advantage of reflections from container walls)[1]

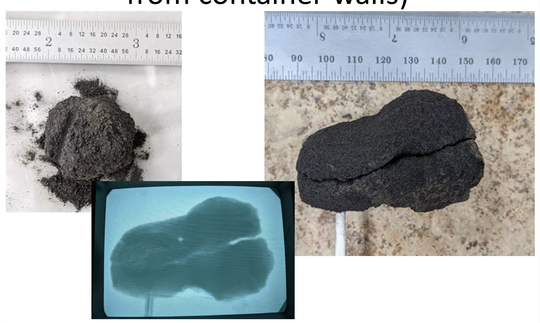
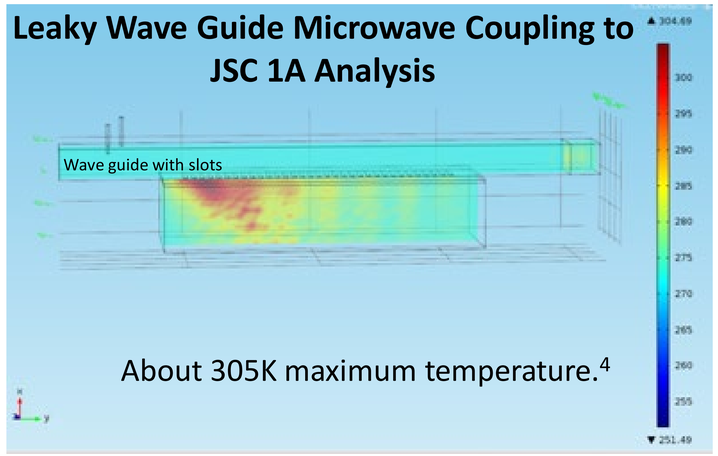


Photo and X-ray images of dense, sintered JSC 1A specimen obtained in TVAC[1,2]

Applicator Modeling

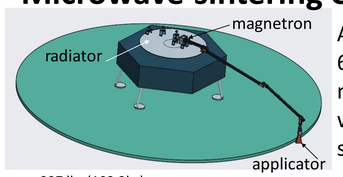
Leaky Wave Guide Microwave Coupling to JSC 1A Analysis



About 305K maximum temperature.[4]

Concept Design

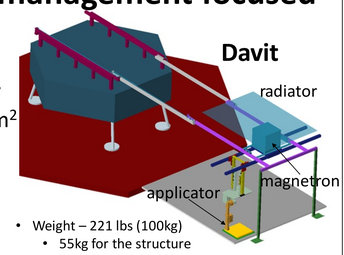
Microwave sintering & thermal management focused



Assumptions: 6kW power to magnetron, 3kw waste heat, 1.5m^2 sintering area

- 227 lbs (103.2kg)
- Both the stowed and extended configurations stress results are under the materials limit stress.
- Operational speed and acceleration when in the extended configuration may need to be limited to prevent excessive lateral deflections.[1,2]

Minimum Margins of Safety and Max Deflections			
	Ultimate	Yield	Deflection (mm)
Stowed Configuration	3.75	4.28	0.81
Extended Configuration	0.35	0.5	5.84 (vertical) / 554.73 (lateral)



- Weight – 221 lbs (100kg)
  - 55kg for the structure
  - 45kg for the microwave and instrumentation on end of arm
- Max Stress – 163 MPa (Slightly Negative Margin)
- Max Deflection –5.7 cm[1,2]

MSCC Publications

- M.R. Effinger et al, "Microwave Sintering Lunar Landing Pad & Horizontal Infrastructure," Moon Village Architecture Working Group Workshop, December 14, 2020.
- M.R. Effinger et al, "Microwave Sintering: Initial Scale-Up for Lunar Landing & Launch Pad Construction," 2021 Joint Planetary & Terrestrial Mining Sciences Symposium & Space Resources Roundtable, Jun 8-11, 2021
- D. Rickman et al, "Basis of Creating a Microwave-Based Construction System for the Moon," 2021 Joint Planetary and Terrestrial Mining Sciences Symposium and Space Resources Roundtable, Jun 8-11, 2021.
- R.W. Bruce et al, "Preliminary Considerations for Microwave Consolidation/Sintering of Lunar Regolith Simulant," 55th Annual Symposium – International Microwave Power Institute (IMPI), Jun 28th-Jul 1st, 2021.
- H. Shulman et al, "Exploration of Scalable Methods to Fabricate Synthetic Lunar Minerals for Engineered Regolith Simulants," LSSW Fundamental and Applied Lunar Surface Research in Physical Sciences, August 18–19, 2021.
- G. Voecks et al, "Understanding Pretreatment Processes of Lunar Simulant to Assist in Defining Material Characterization," LSSW Fundamental and Applied Lunar Surface Research in Physical Sciences, August 18–19, 2021.
- R.P. Wilkerson et al, "Characterizing the effects of thermal profile and gas environment on the heat treatment of JSC-1A lunar simulant using combined thermogravimetry and mass spectroscopy," LSSW Fundamental & Applied Lunar Surface Research in Physical Sciences, August 18–19, 2021.