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Sandia National Laboratories

Exceptional service in the national interest

Lithoz CeraFab 8500 at Sandia National Laboratories

A Year in Review

D. Cillessen

Presented at the 2021 Ceramitec Conference

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Introduction

Dale Cillessen, P.E.

A Senior Member of the Technical Staff in the Applied Science Technology Maturation Department at Sandia National Laboratories in Albuquerque, NM. Dale is the engineering operational lead of Sandia's metal and ceramic printing facility. His research focuses on developing accurate, repeatable, structurally sound advanced manufactured components.

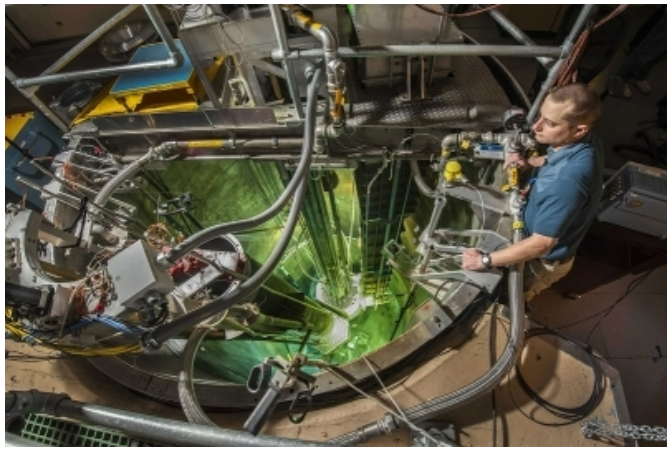
Outline/Agenda

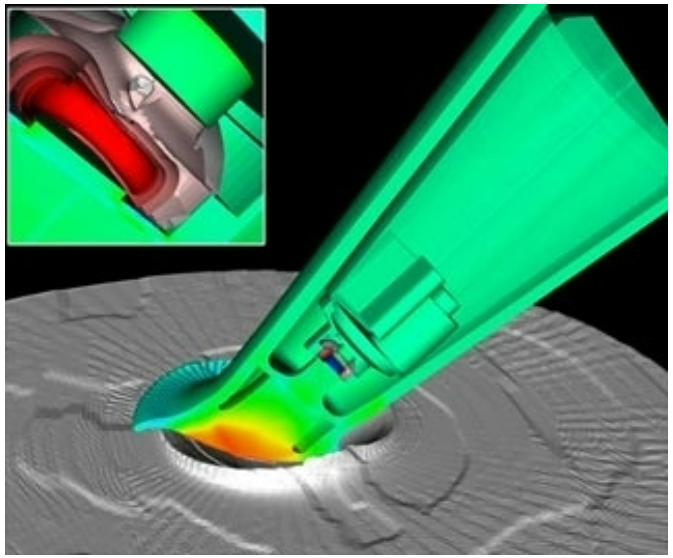
- Who is Sandia National Laboratories
- Motivation
- Building an Internal Customer Base
- Reducing Manufacturing Time
- 2021 Highlighted Projects
- Developing and Characterizing a Glass-Bonded Alumina Ceramic
- Developing an Alumina/Molybdenum DLP compatible Cermet

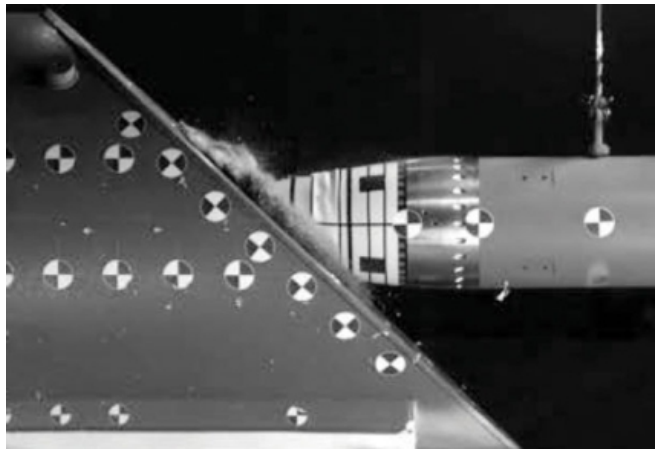
Who is Sandia National Laboratories

Sandia National Laboratories is one of the three National Nuclear Security Administrations research and development laboratories in the United States.

The primary mission is to develop, engineer and test the non-nuclear component of nuclear weapons.







Motivation

At Sandia National Laboratories Advanced Manufacturing Enables Rapid Product Realization.

The pursuit for Advanced Manufacturing capabilities has pushed SNL to investigate internal developmental opportunities.

Ceramic Additive Manufacturing reduces development time, opens design opportunities, and provides rapid exploration of custom materials.

Growing an Internal Customer Base

Motivation for the acquisition of the Lithoz CeraFab 8500 was based on the technology's applicability for two to three components spanning over two SNL organizations.

The component design was established and tested. However, both organizations had a strong desire to improve and create new designs.

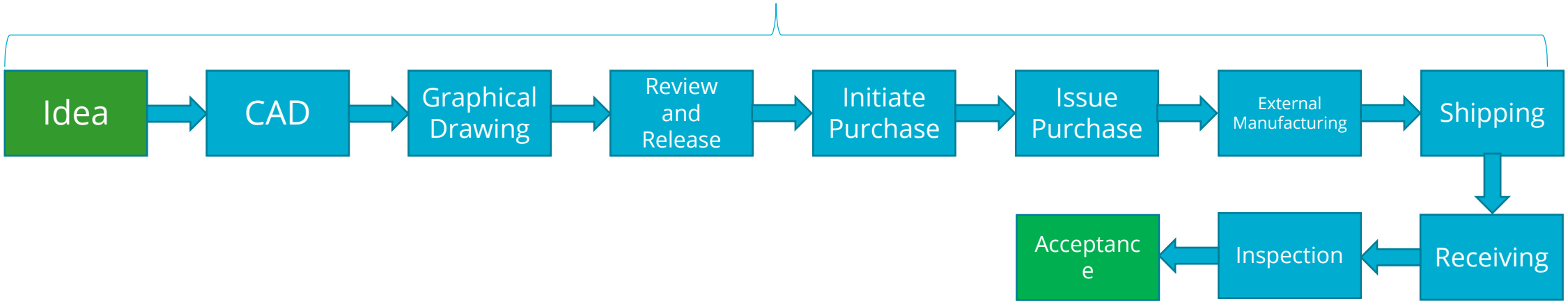
In late 2020, an internal proposal coupling next generation designs and ceramic additive was submitted. This three year proposal was awarded and began in 2021!

In the past year, our internal customer network has grown to over 15 customers.

Reducing Requirements and Removing the Procurement Burden

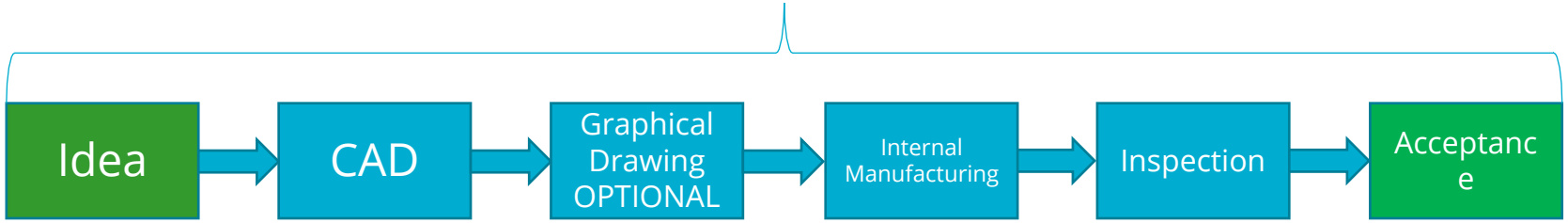
Traditional Manufacturing Process at SNL

Expected duration 4 – 6 months!



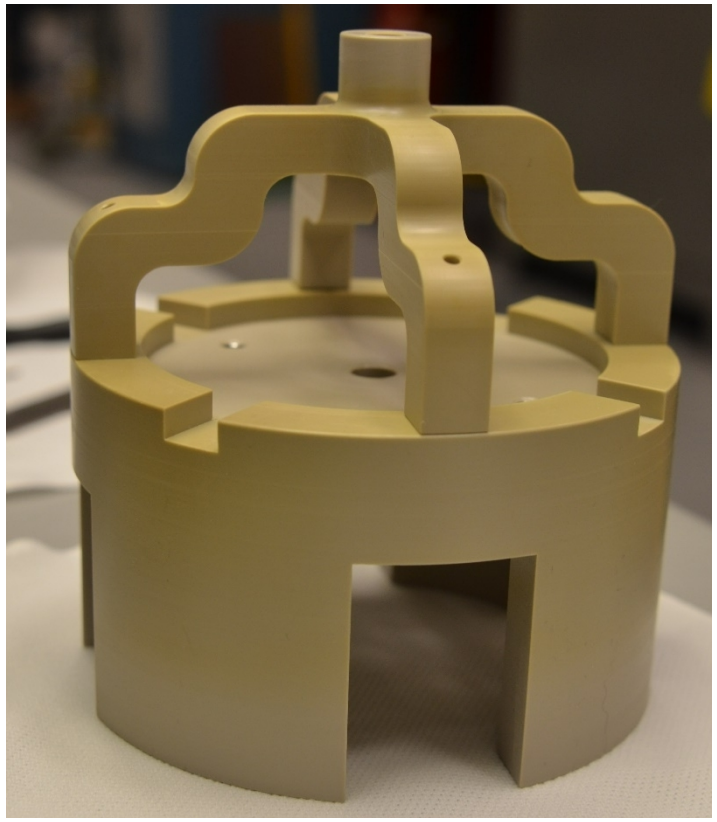
Ceramic Additive Manufacturing Process Internal to SNL

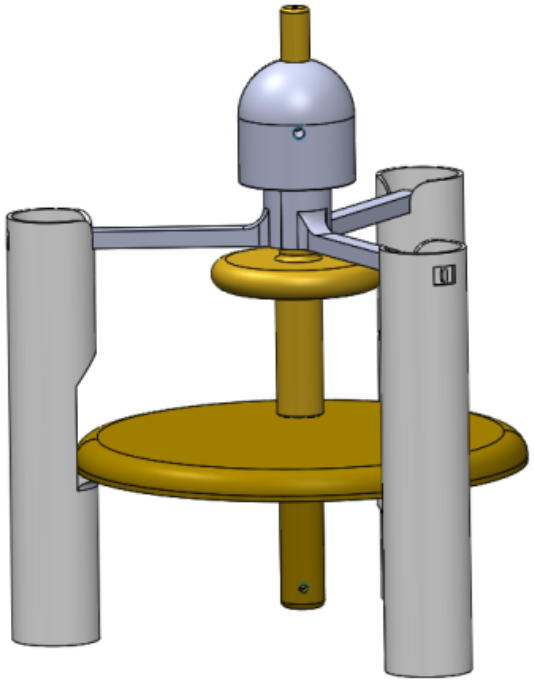
Tested Duration < 2 weeks!



Ultra High Vacuum Test Fixture

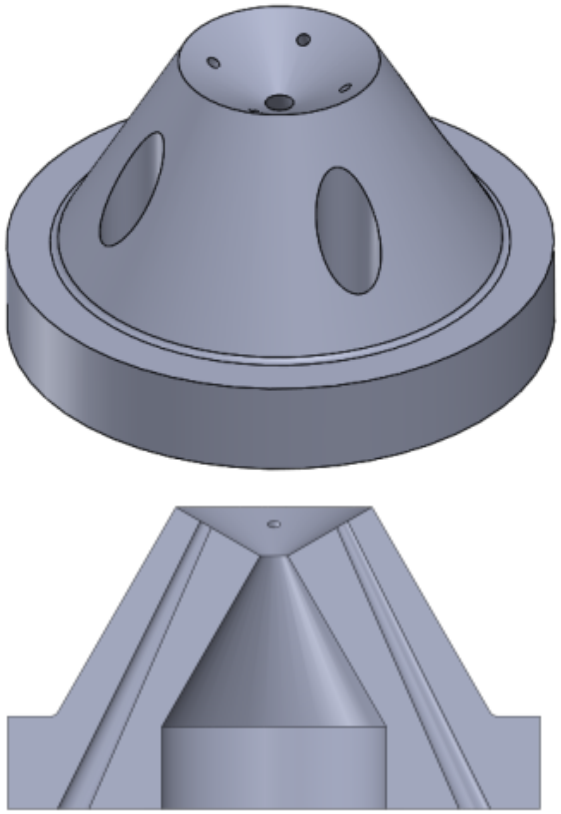
Early in 2021, an internal customer identified the traditional polymer (FDM) test fixture was the cause of outgassing internal to the vacuum chamber and limited the testing environment temperature.



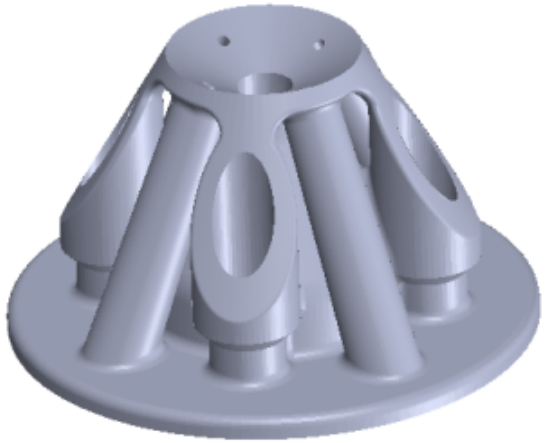


Thermal Resistant Nozzle

As Designed

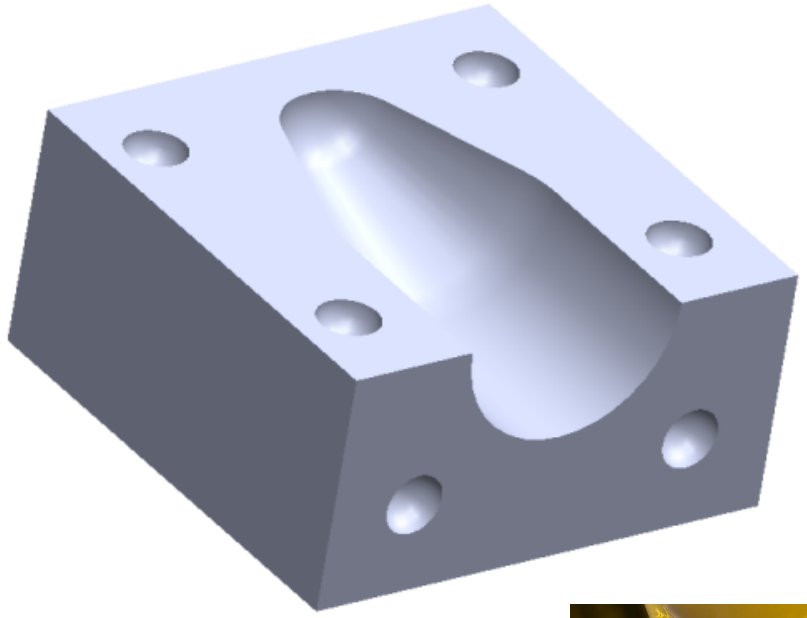


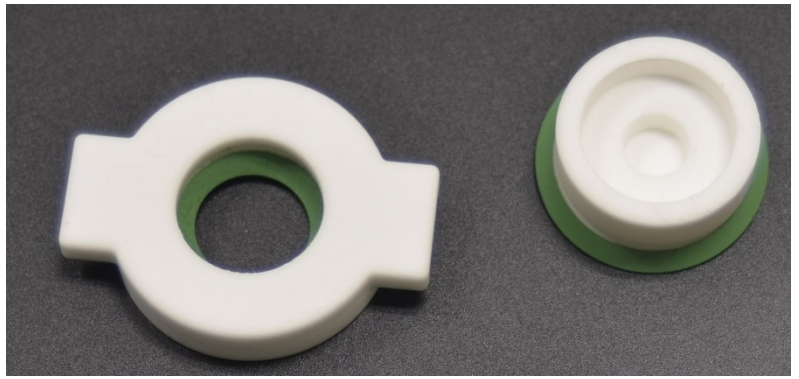
Ceramic AM Design

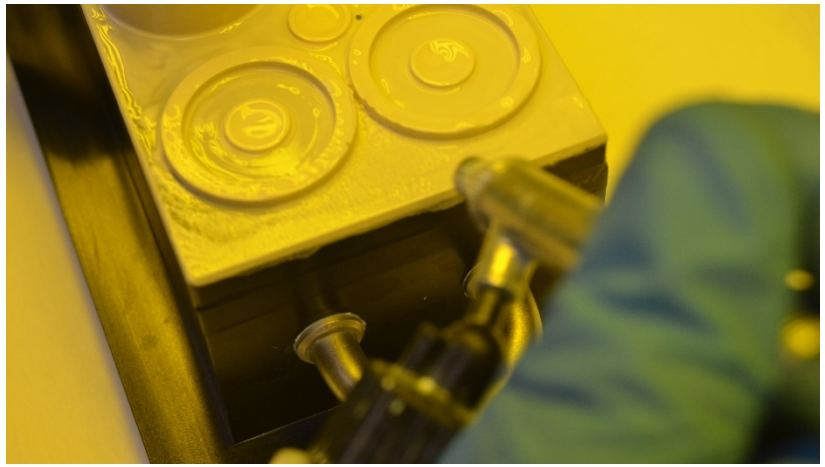


Manufactured Ceramic AM

Fixtures and Processing





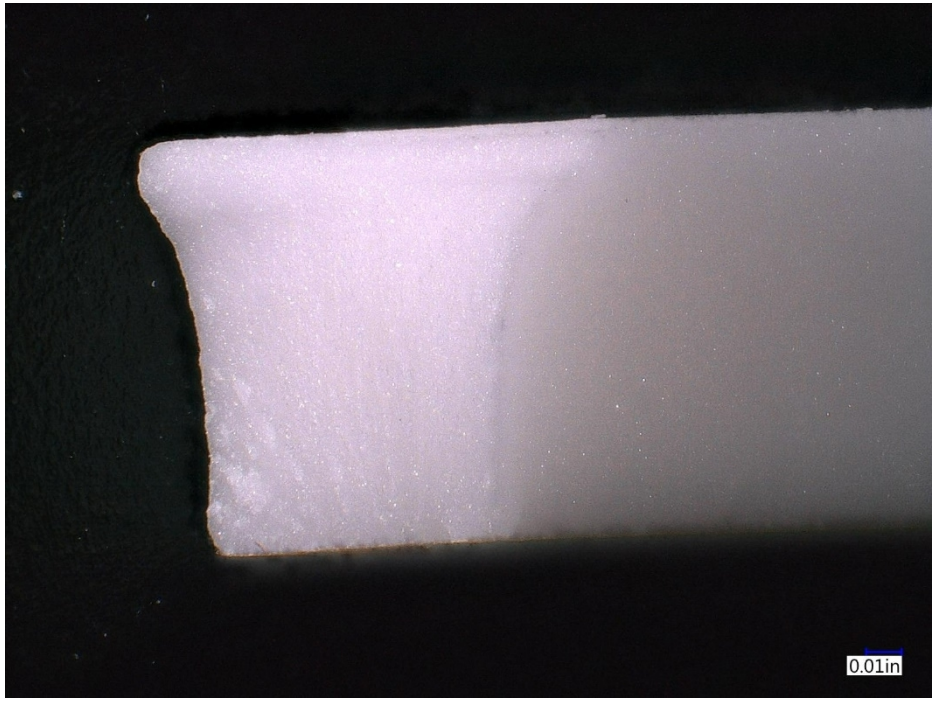


Developing and Characterizing a Glass-Bonded Alumina

In the mid 90's Sandia developed a Glass-Bonded Alumina ceramic. The glass-bonded material is 94% Al_2O_3, 1.5% MgO, 1.2% CaO, and 3% SiO_2 . The addition of Silica allows for processing at lower temperatures compared to pure Al_2O_3.

In 2018, Lithoz America successfully manufactured test components using SNL's base ceramic material combined with Lithoz photosensitive resin.

Preparing for "production", Lithoz America conducted various studies to increase the production quantity from ~200 gram to > 1kg batch.



Mechanical Testing SNL's Glass-Bonded Material

Tensile (flexural bend)

Density

Coefficient Thermal Expansion

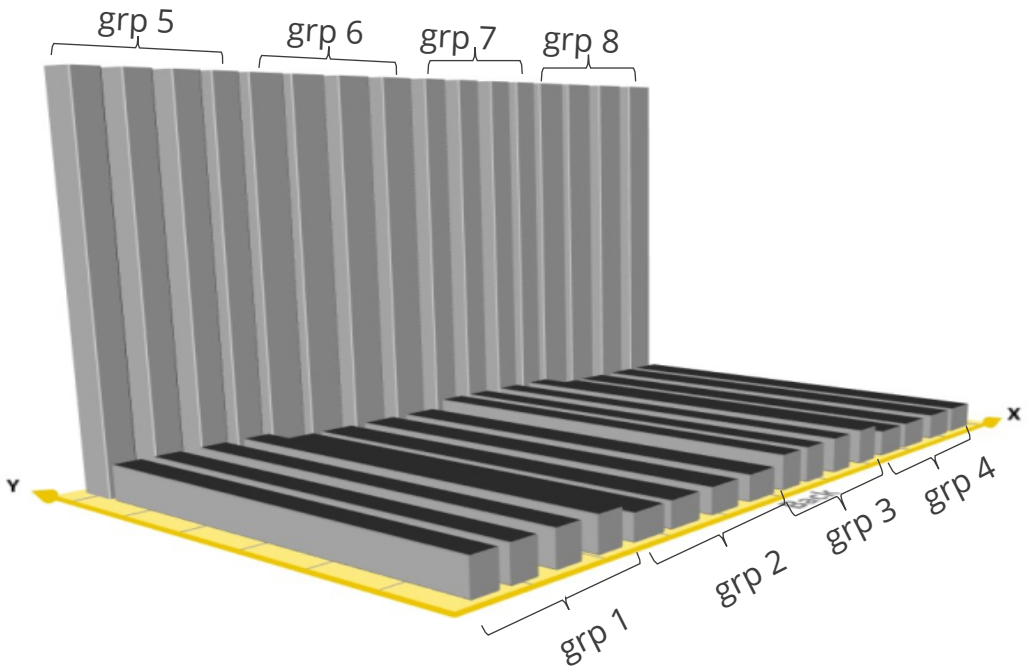
Porosity via CT

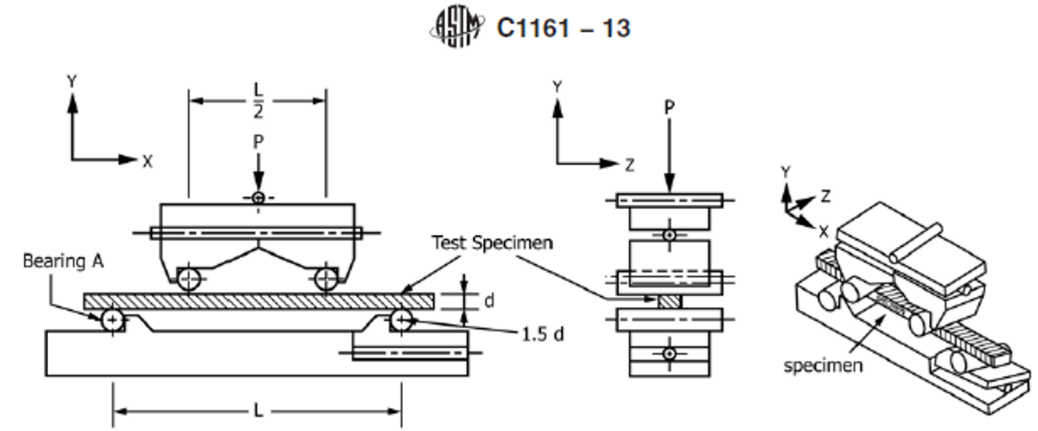
Hermetic Capability

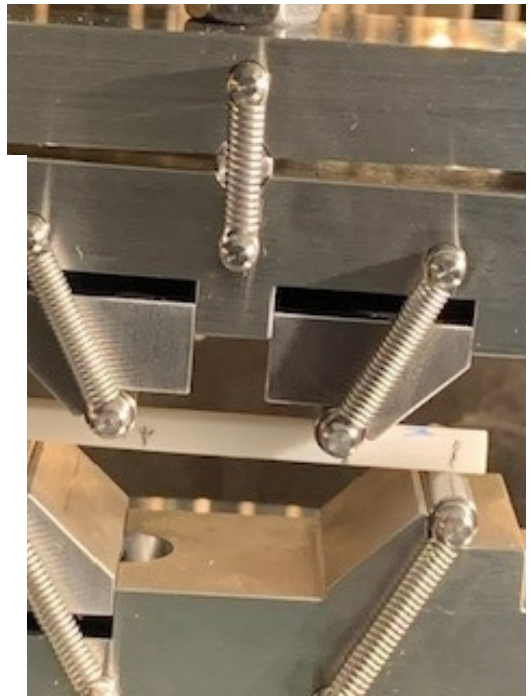
Flexural Bend Testing

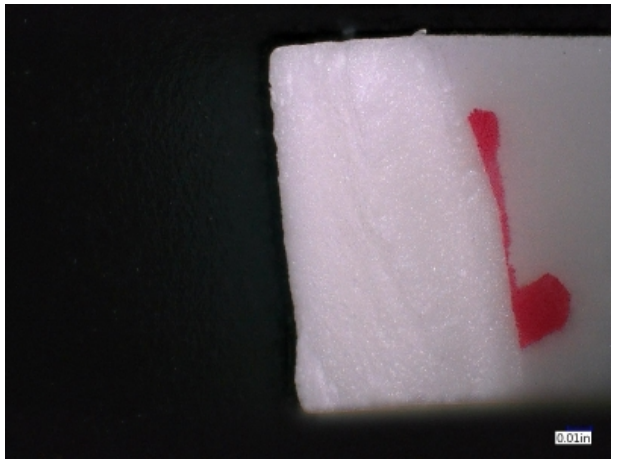
To quantify the strength of ceramics the ASTM C1161-13 four-point bend test were performed.

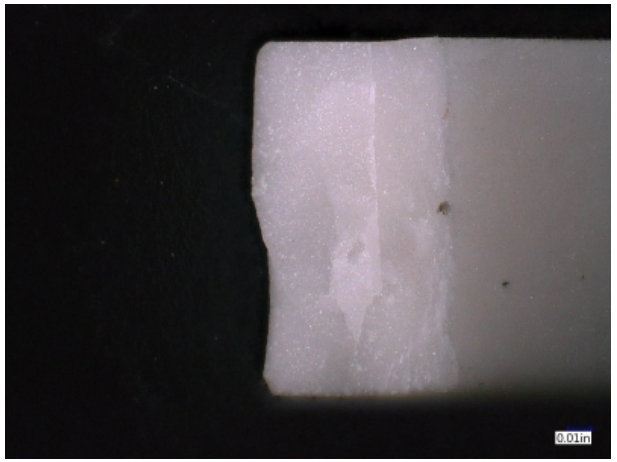
For statistical evaluation 128 samples were evaluated with 4 different print orientations.

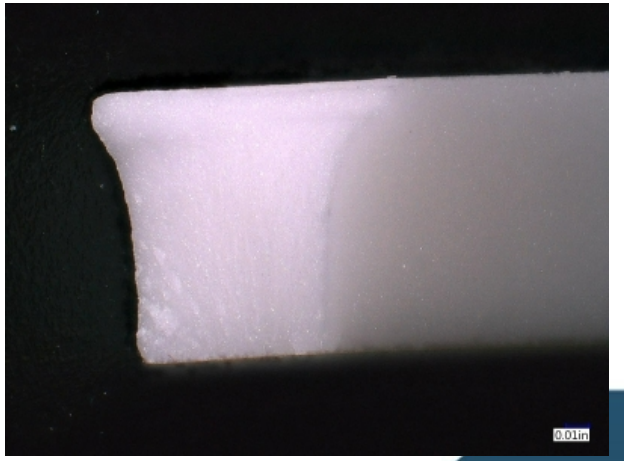






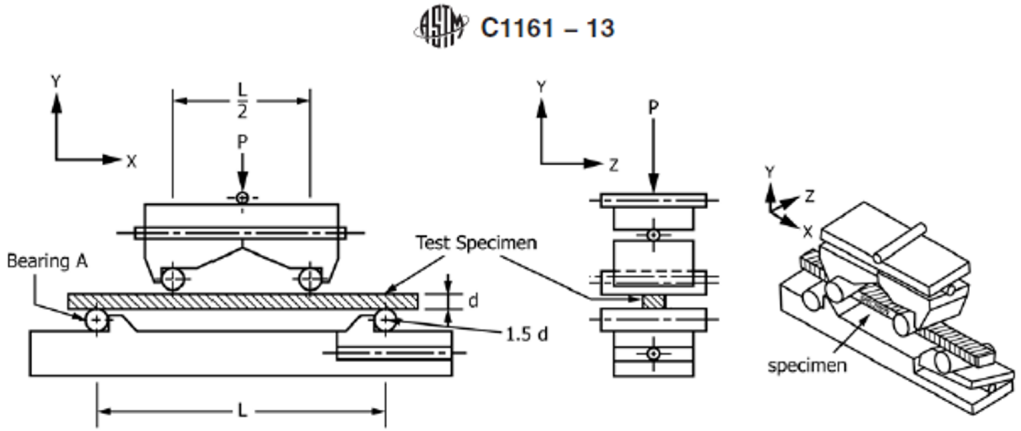


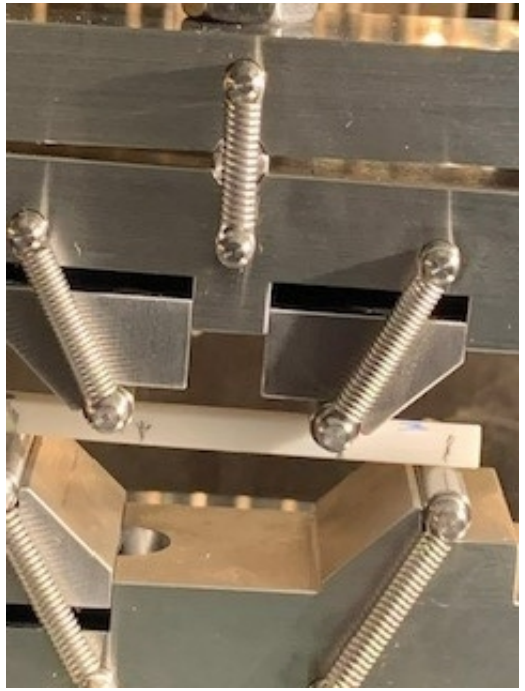


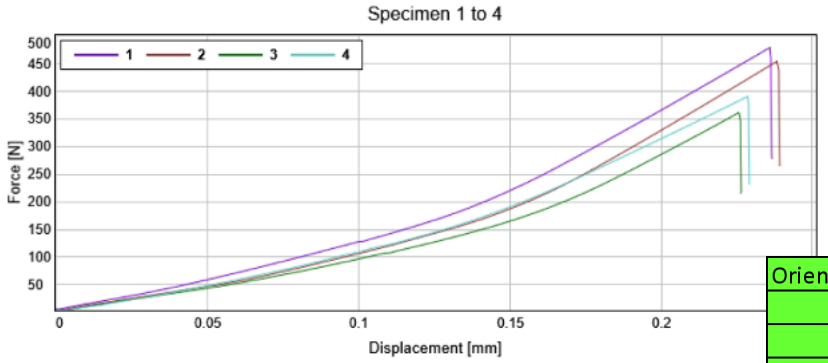


Flexural Bend Testing

- 5 kN Instron load cell
- ASTM C1161
- $S = \frac{3\,PL}{4\,bd^2}$;
  - S = specimen strength
  - P=break force
  - L = outer support span
  - b = specimen width (4mm)
  - d = specimen thickness (3mm)







Orientation	number samples	Average failure stress (Mpa)	stdev	width avg (mm)	width std	Thick Avg (mm)	Thick Std	avg humidity (%)	stdev humidity
1	32	314.66	35.16	4.01	0.08	3.04	0.03	48.94	8.00
2	32	320.59	60.71	4.09	0.07	3.02	0.08	50.30	0.52
5	32	328.07	39.10	4.07	0.05	3.04	0.02	50.49	0.45
6	32	313.21	55.74	4.09	0.04	3.05	0.03	50.57	0.43
STC (2021)	30	347.08	19.18	4.01	0.01	3.01	0.01	49.94	0.57
STC (2017)	29	357.93	17.58	4.00	0.00	3.01	0.00	50.00	-

Archimedes Density

Archimedes Density per ASTM C830

Initial testing shows Additively Manufactured densities are consistent with traditionally manufactured densities.

Density measurements conducted on As-printed samples

Sample ID	Dry Weight (g)	Suspended Weight (g)	Saturated Weight (g)	Bulk Density (g/cc)**	Open Porosity (%)
4 - TRADITIONAL	1.06	0.777	1.062	3.719	0.702
T5A2	1.074	0.788	1.077	3.716	1.038
T2A3	1.408	1.033	1.409	3.745	0.266
T3A2	1.192	0.875	1.196	3.713	1.246
T8A2	1.059	0.778	1.06	3.755	0.355

AM Ceramic

Coefficient of Thermal Expansion

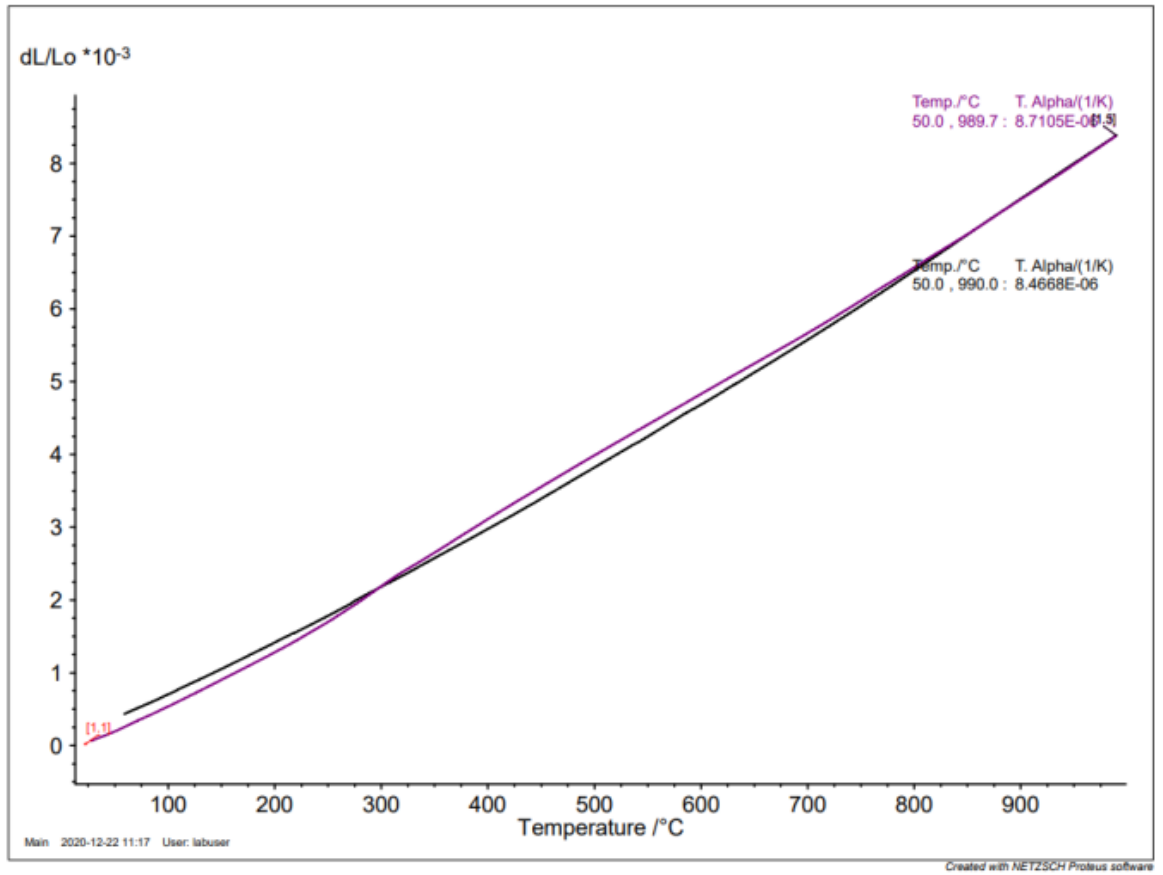
CTE testing ASTM E228-11

Similar to density, the CTE initial test results indicate the printed material performed similar to the traditionally processed ceramic material.

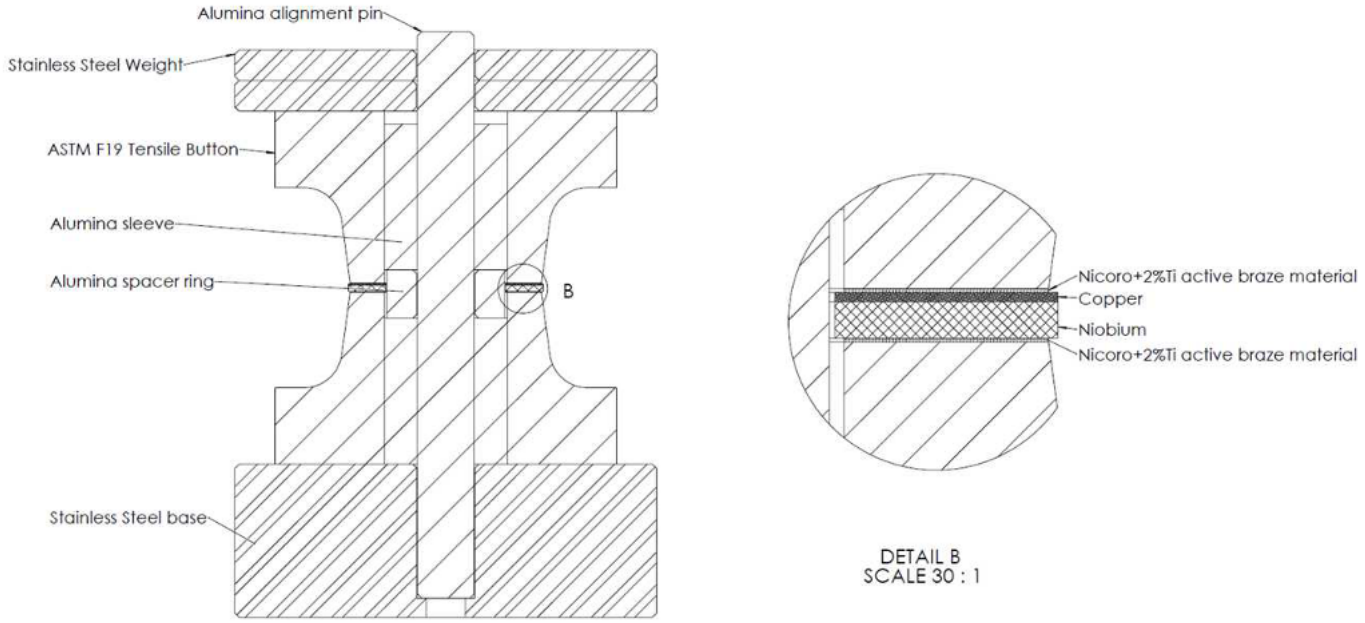
Minor discrepancy noted in the heating curve. From the cooling curve 990 C – 50C the CTE was calculated at 8.47 x10^-6/C.

The elastic constants were measured to be

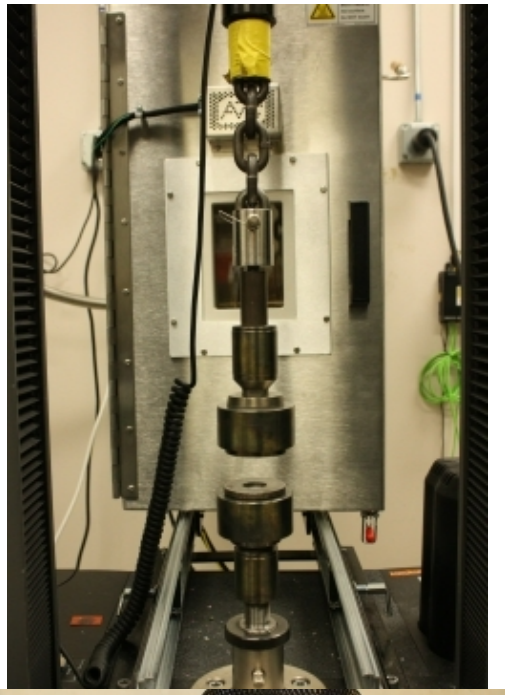
Yong's Modulus (E) – 317 GPa
Shear Modulus (G) – 127 GPa
Poisson's Ratio – 0.246
Bulk Modulus (K) – 208 GPa



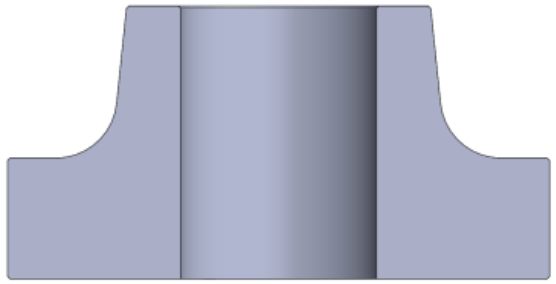
ASTM F19 Tensile Button Braze Testing



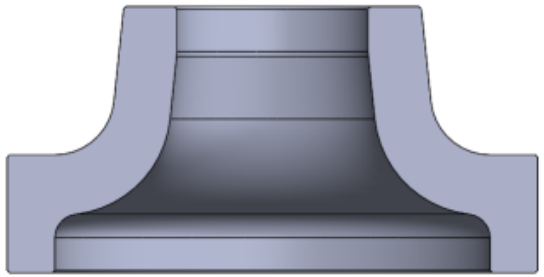
DETAIL B
SCALE 30 : 1



Standard Test Profile
Cross Section



Lithoz Test Profile
Cross Section



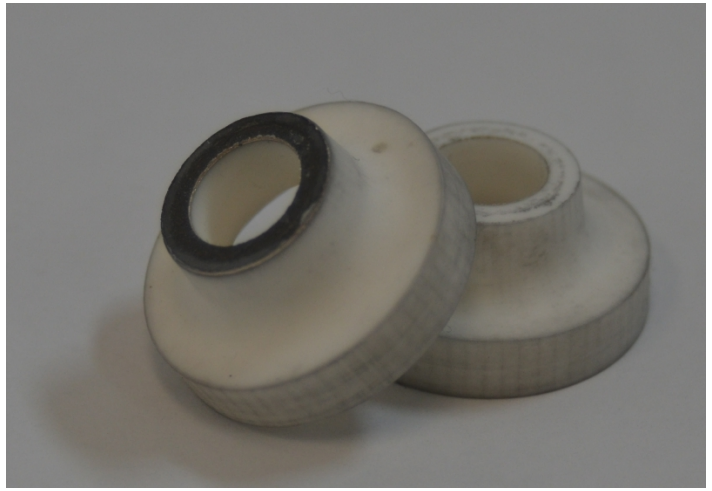
ASTM F19 Tensile Button Testing Results

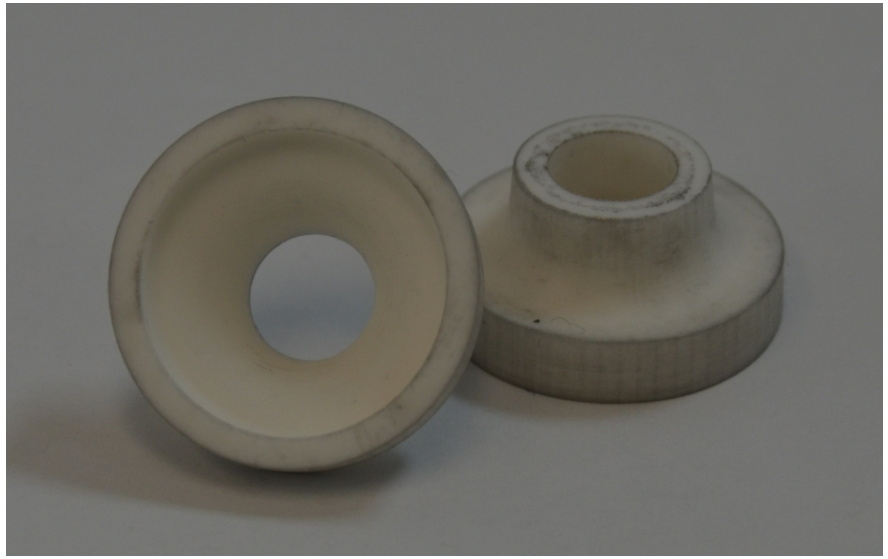
SNL ceramic tensile button manufactured using Lithoz CeraFab 8500.

Tensile button braze tested for hermeticity.

Test verified AM Tensile Button ceramic was not the failure point.

Study to be continued with different braze materials and larger sample size.





SNL Cermet Development

Lithoz America and SNL teamed together in 2021 to develop an Alumina based Cermet

To develop the cermet, Lithoz America pursued parallel material developmental paths.

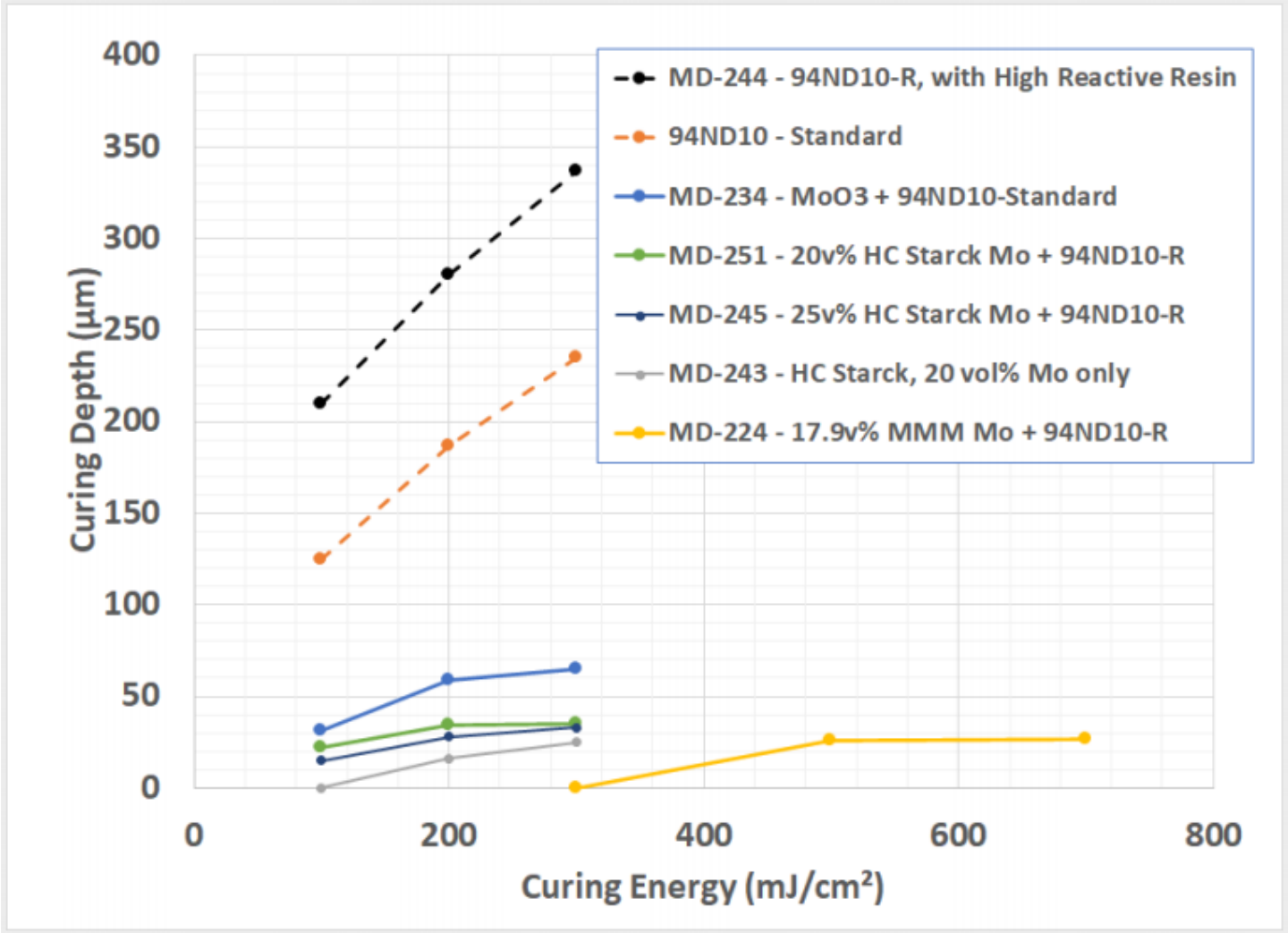
- The Lithoz photosensitive resin combined with SNL's Alumina Ceramic and Molybdenum powder
  - Identification of a molybdenum powder that meet the requirements for DLP printing proved to be challenging.

- The Lithoz photosensitive resin combined with SNL's Alumina Ceramic and Molybdenum Oxide powder

Curing Studies

To test for manufacturability, a curing study was conducted by Lithoz America.

As expected, the molybdenum powder reduced the transparency of the material and resulted in less light penetration.



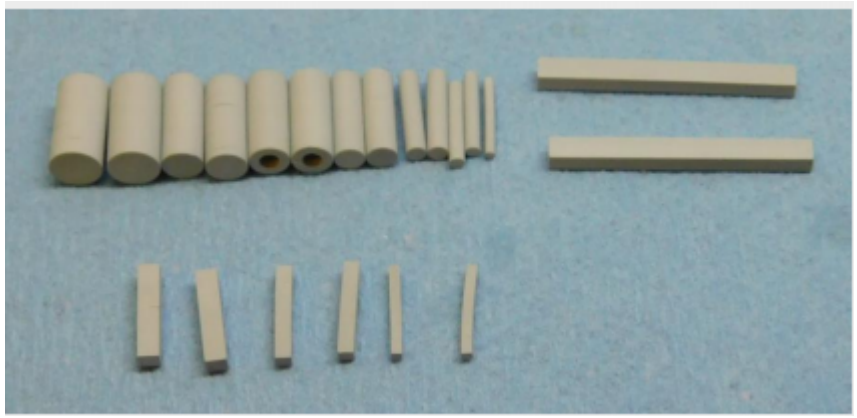
Cermet Manufacturing

Lithoz America manufactured test samples for processing at SNL.

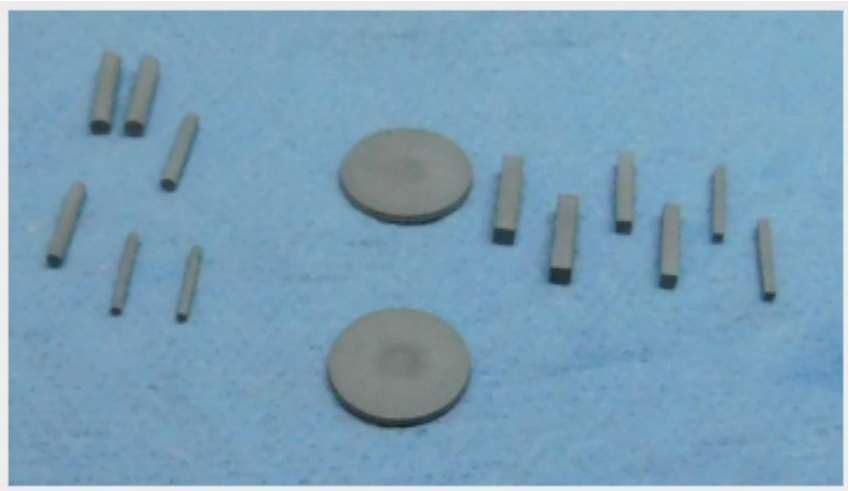
Green samples delivered to SNL for controlled atmosphere sintering.

Material characterization is underway. Samples are being evaluated by XRF.

Molybdenum Oxide thermally condition samples



Molybdenum Powder thermally condition samples



Conclusion

By use of the Lithoz CeraFab 8500 we see continuous growth in Ceramic Additive Manufacturing at Sandia National Laboratories.

SNL ceramic materials manufactured with the Lithoz CeraFab technology result in similar performance characteristics to a traditional manufactured component.

The Lithoz DLP technology provides endless opportunities for material exploration and component design.

By continued investments from our stakeholders, ceramic additive manufacturing is enabling our designers to push the limits for next generation products.

Thank You!

Sandia National Laboratories

“This work was supported by the Production Operations Program and the Laboratory Directed Research and Development program at Sandia National Laboratories, a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525”