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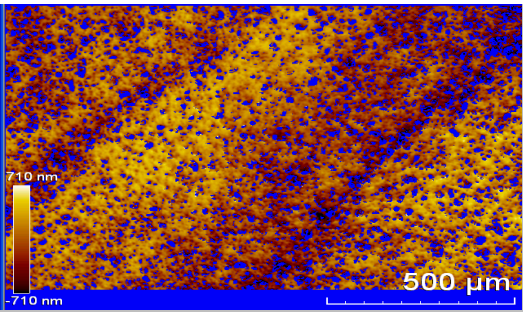

Additive Manufacturing of Ceramic Optical Components

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12th Pacific Rim Conference on Ceramic and Glass Technology, May 21st- 26th, 2017

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Motivation for Additively Manufactured Ceramic Optical Components

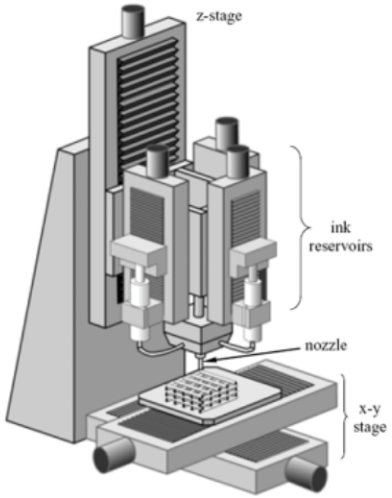
- Benefits of additively manufactured (AM) ceramic optical components
  - Rapid prototyping
  - Printing of light-weighted structures
    - Integrated component design
  - Higher modulus of elasticity
  - Lower coefficient of thermal expansion
  - Multiple materials
- Current challenges for AM ceramic optical components
  - Large gap between “near-net shape” and optical surface
    - Surface figure and surface roughness
- Goal is to fabricate AM ceramic optical components
  - Characterize printed surfaces
  - Polish to obtain optical finish with reflective coating

Standard Optical Mirror Components

Introduction to the Robocasting Method for Ceramic AM

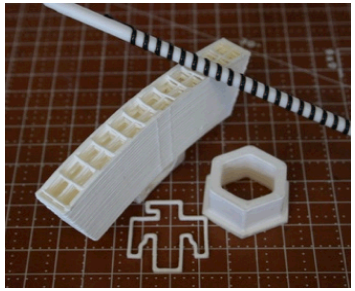
- Introduced and patented by Sandia National Laboratories as a direct digital fabrication process in 1997

- A controlled micro-extrusion technique for forming solids from an ink, paste, or slurry



- Rheological properties of the "ink" must be tightly controlled to promote formation of engineered near-net shape green bodies

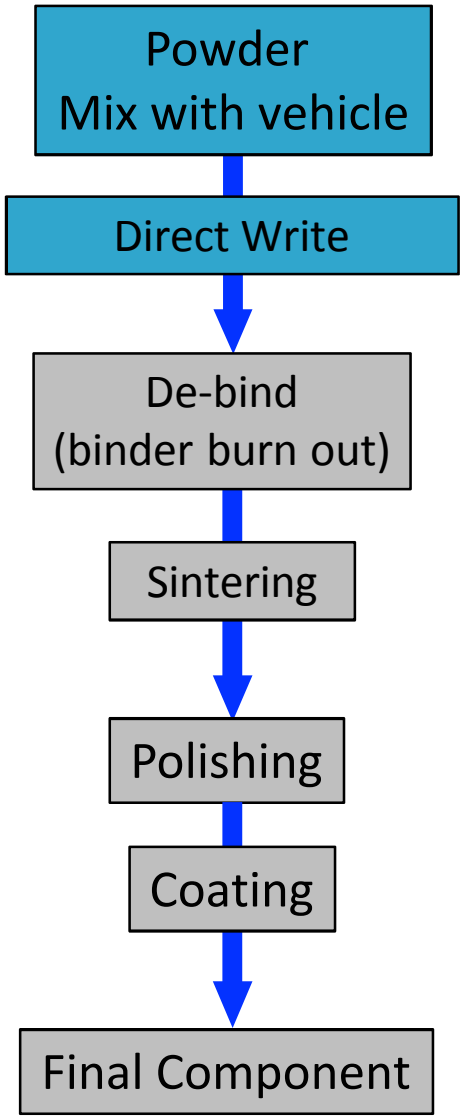
- High temperature consolidation and sintering is employed to achieve near full density ceramic bodies

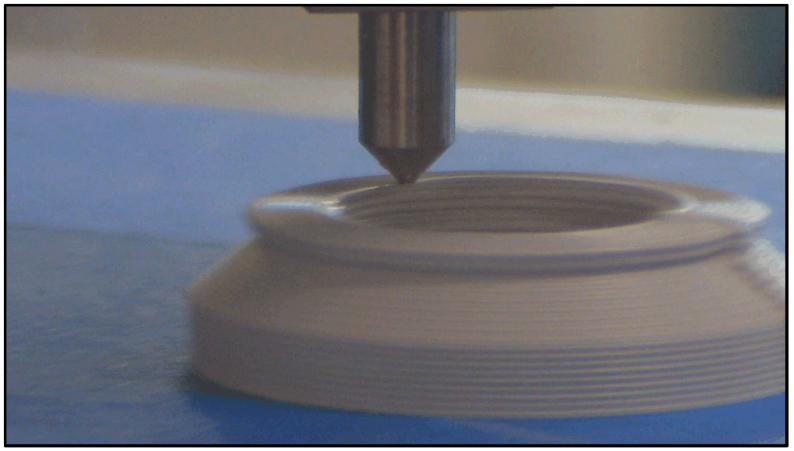


Printed and sintered alumina

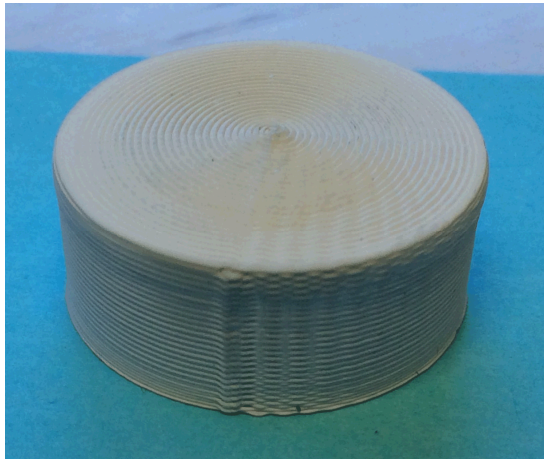
Printed and sintered ferrites

Printing of Near-net Shape Green Bodies





Direct Write printing of composite alumina at 30 mm/sec (video)



Green state bulk sample

Burn-out and Sintering of Pre-polymer Ceramics

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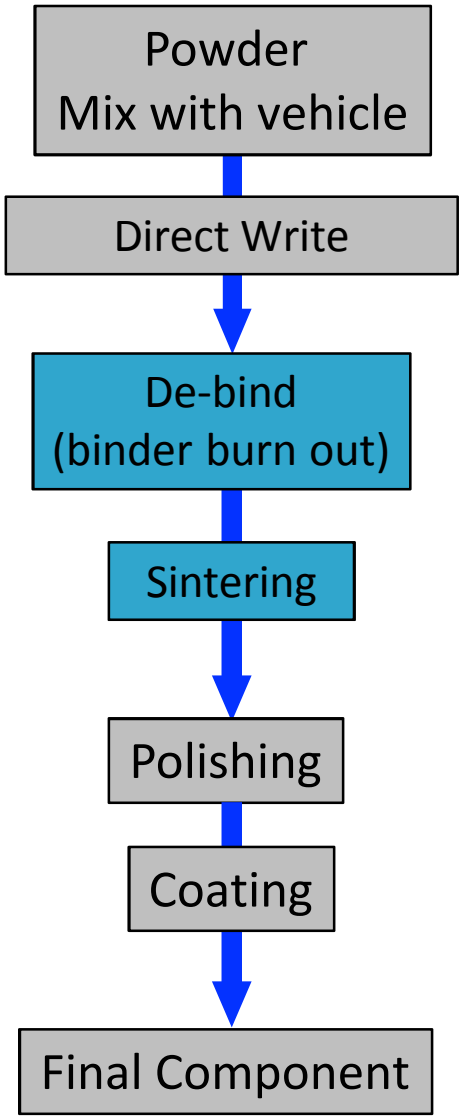
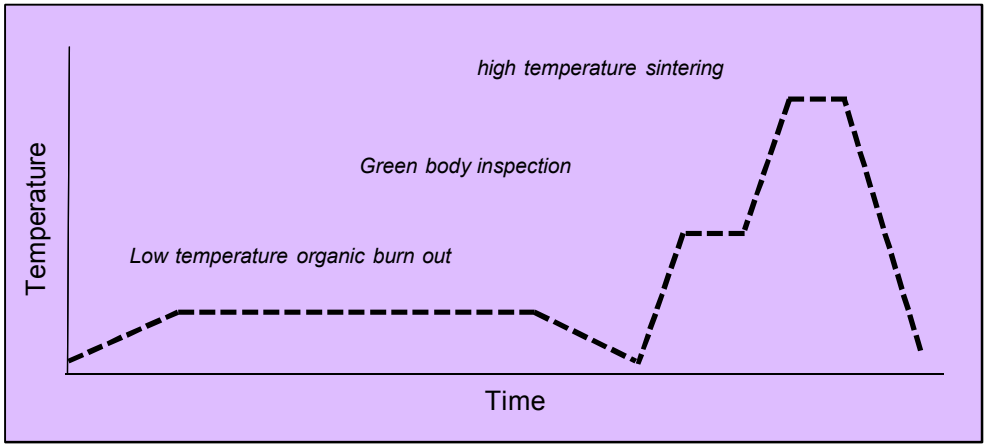


Parts in a crucible for de-binding and sintering

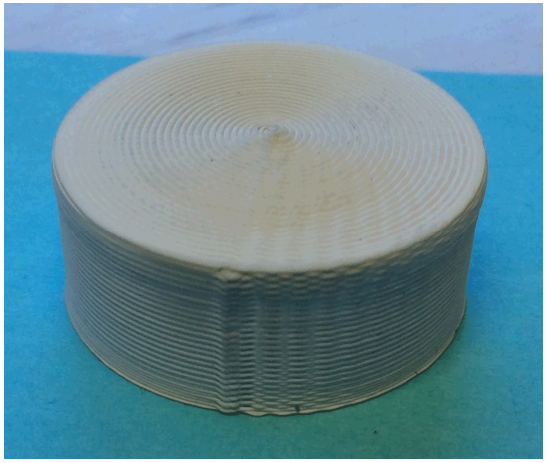


Low temperature organic burnout followed by a high temperature sintering

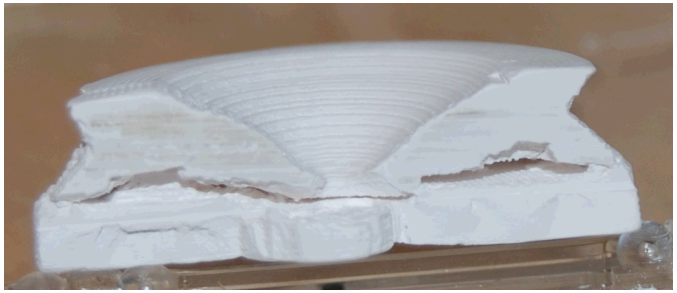
Challenges of Sintering Bulk Ceramics

- Cracks from thermal stress during de-binding/sintering

Sintered bulk sample



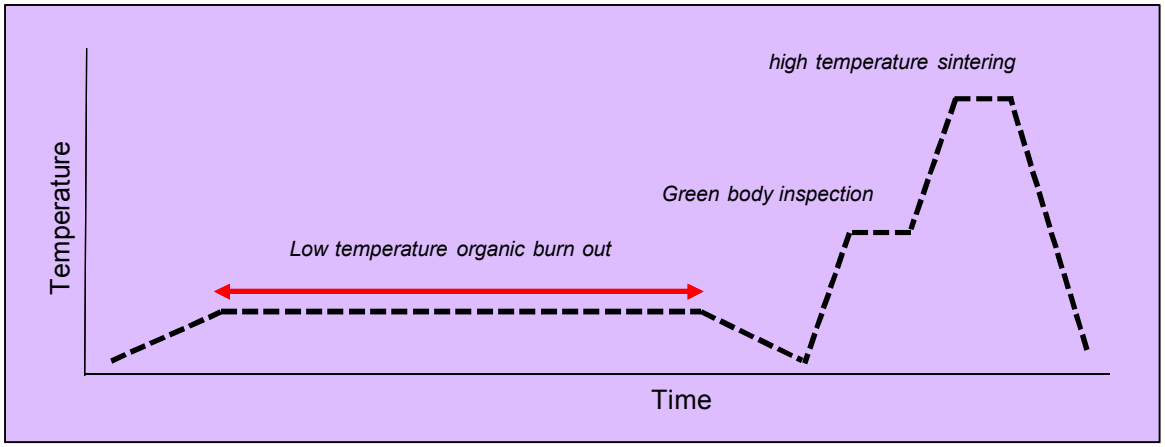
Green state bulk sample



Cross-section of fractured ceramic sample

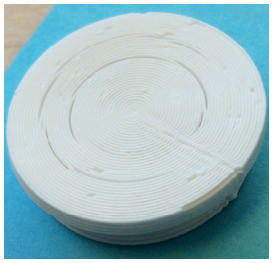
Thermal Stress Mitigation

- Extend low temperature burn out phase

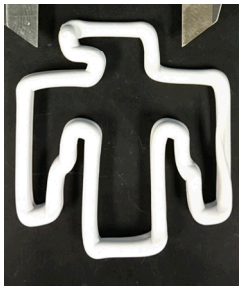


Longer low temperature burn out

- Remove “bulk” of the component



Bulk samples with fractures due to thermal stress



“Wire frame” design with large surface area and small mass

Design Revision & Slower Burnout

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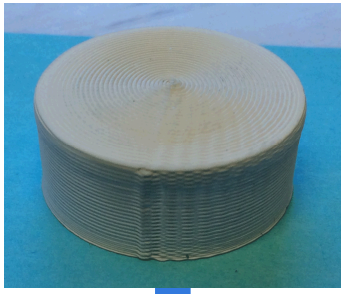
Component Design Changes



Bulk design

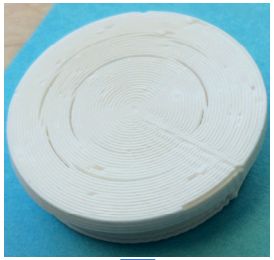
Remove mass

Light-weighted, integrated design

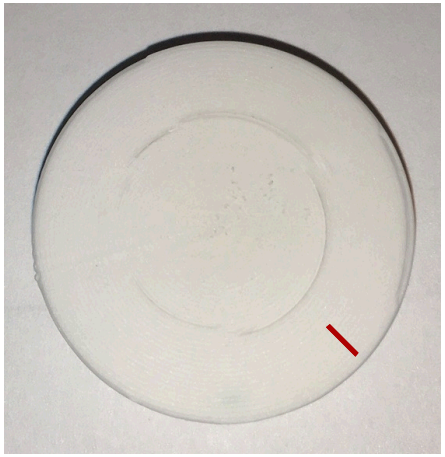
Minimize cross-section

Constant cross-section design

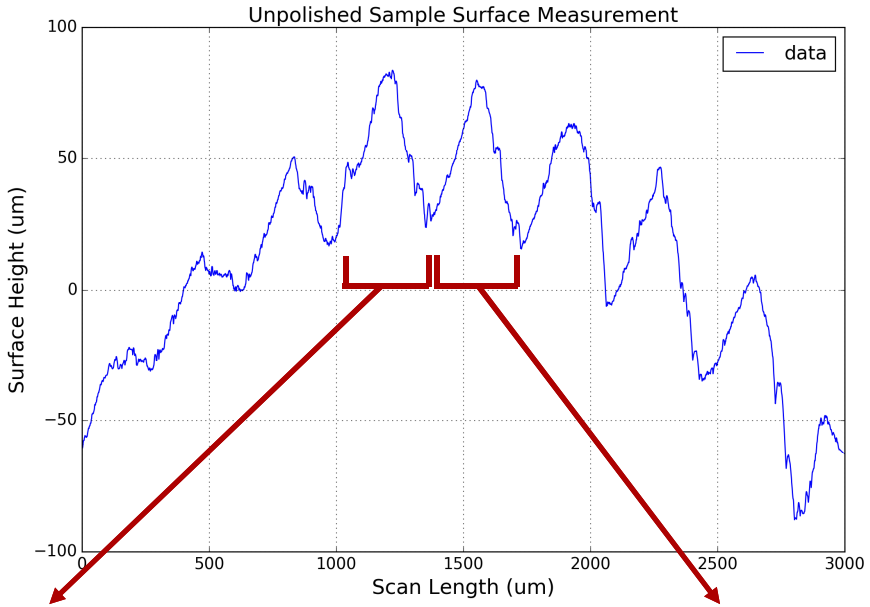
Sintered Samples

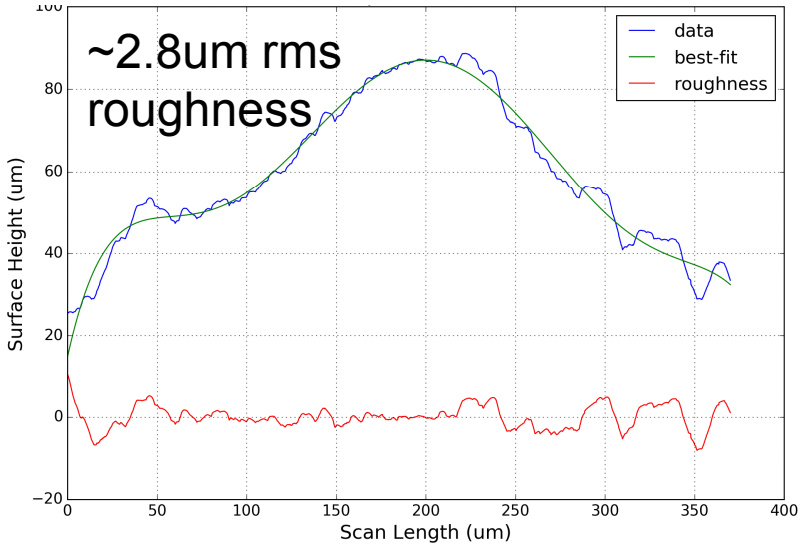


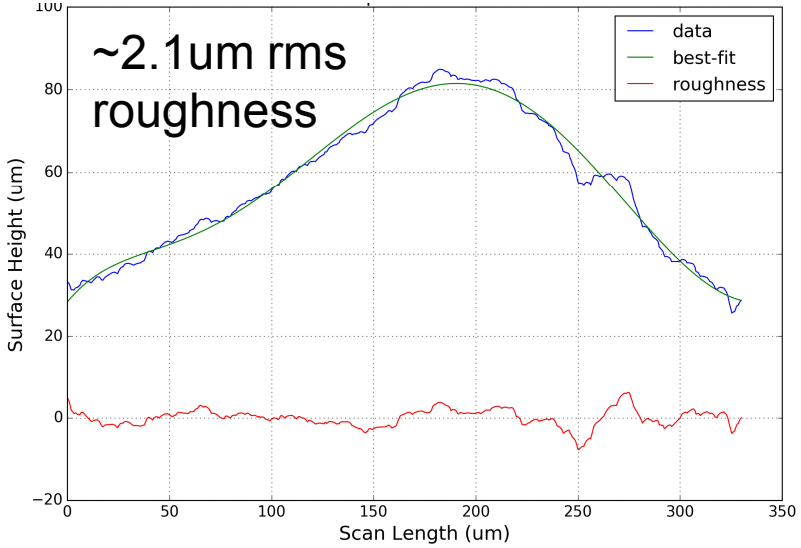
Surface Roughness of Sintered Sample 1



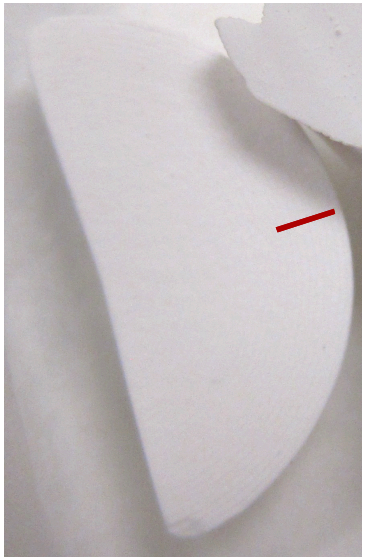
Sintered, unpolished AM ceramic



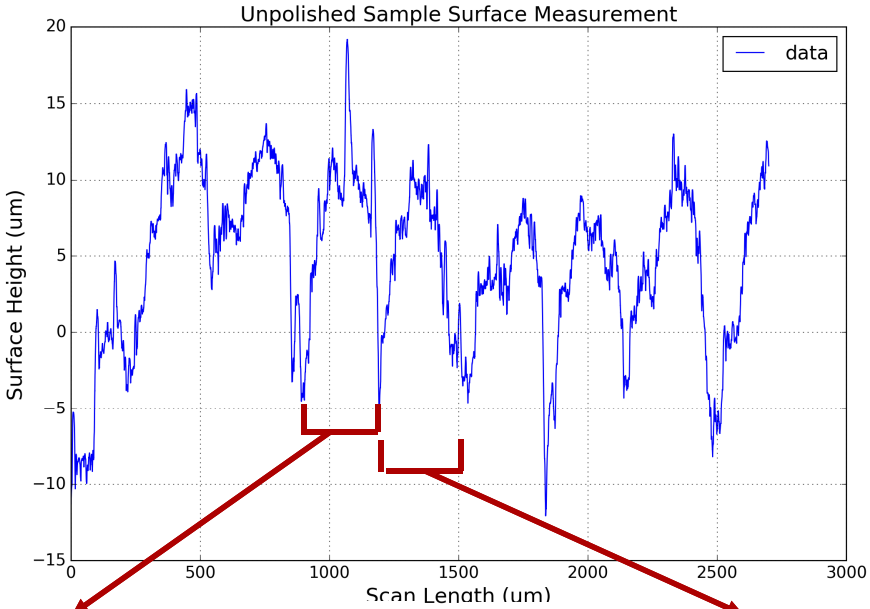


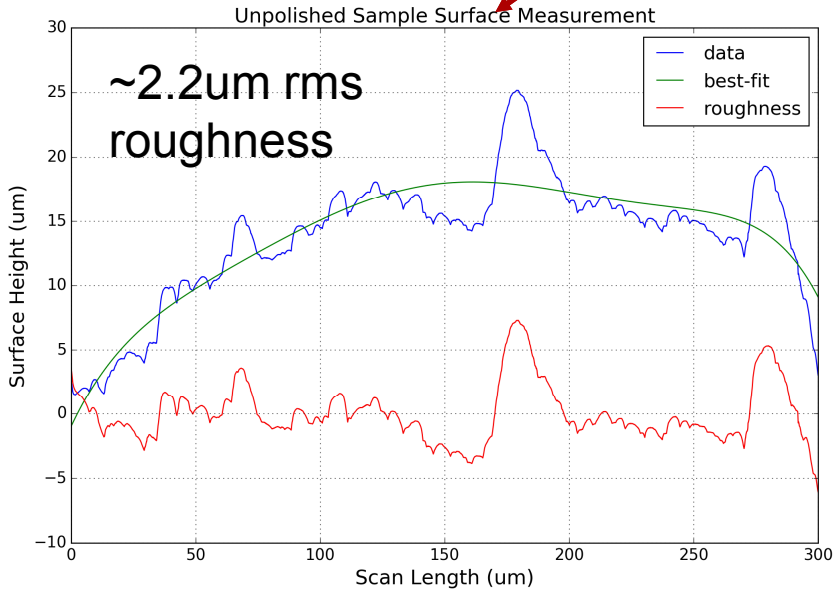


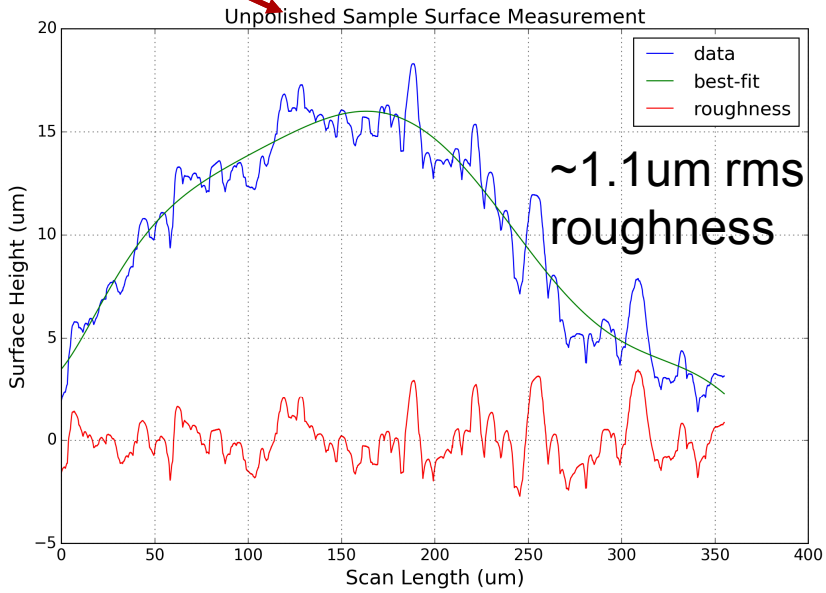
Surface Roughness of Sintered Sample 2



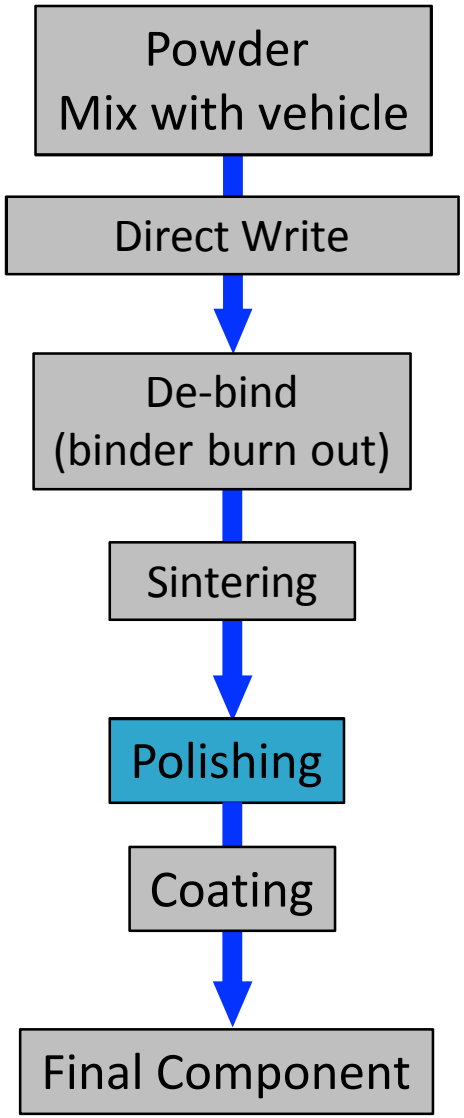
Sintered, unpolished AM ceramic

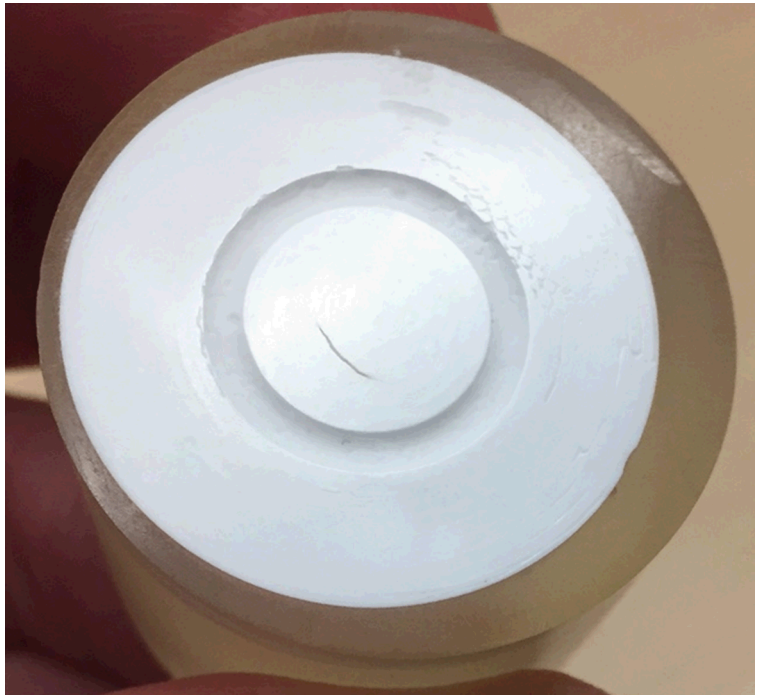






Polishing of Sintered Ceramic

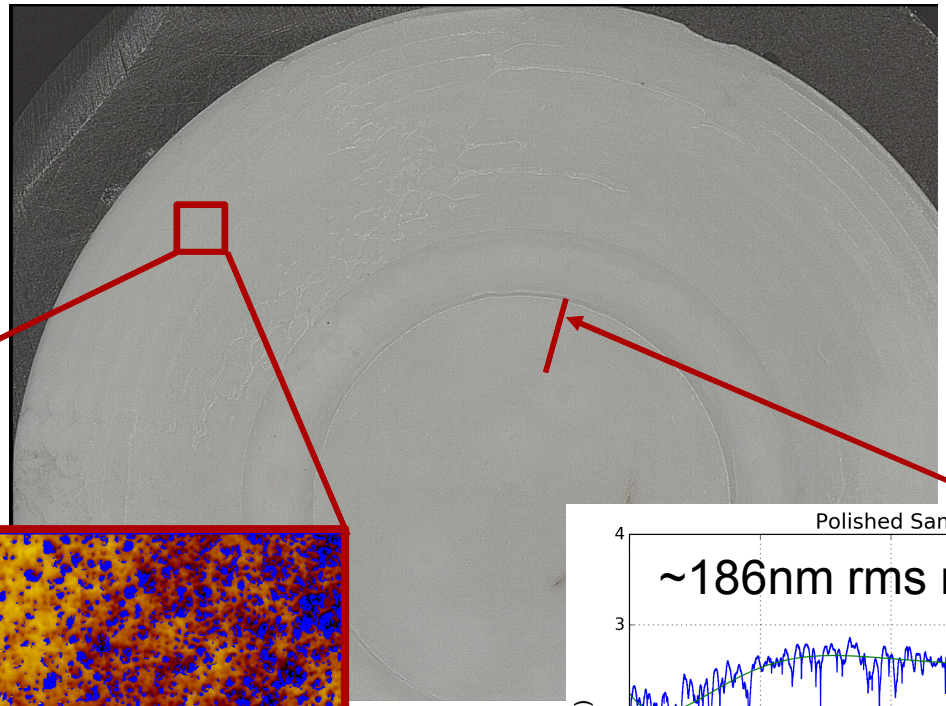


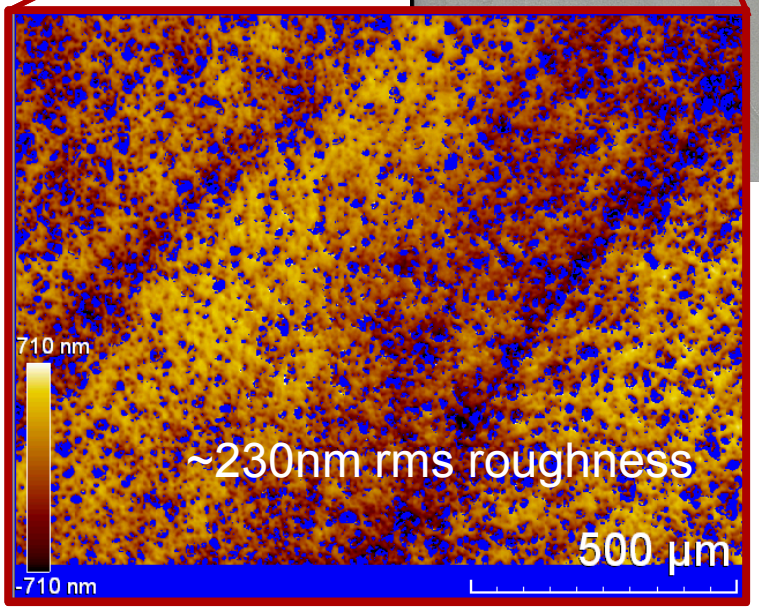


Sintered, polished AM ceramic

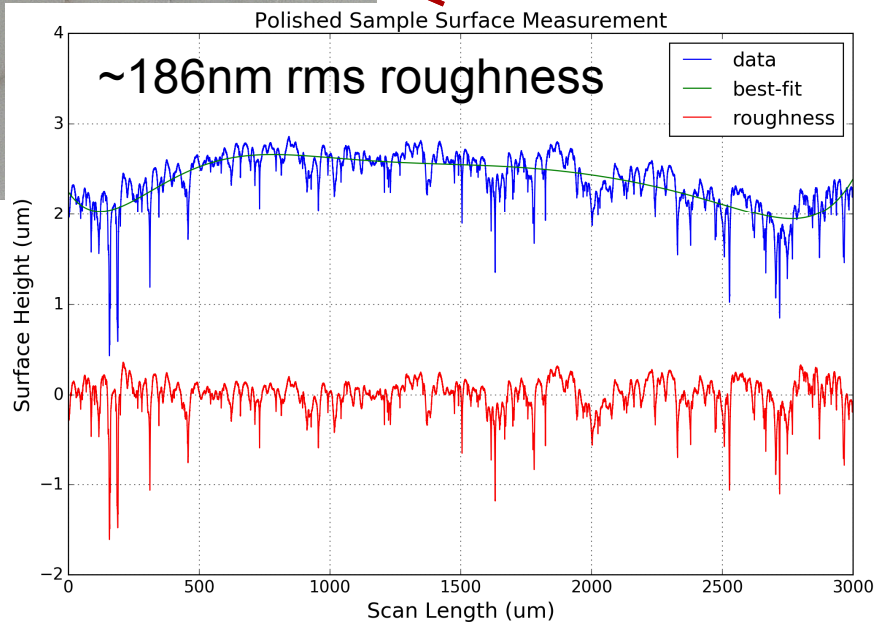
Buehler EcoMet 250 polisher

Surface Finish of a Polished AM Ceramic



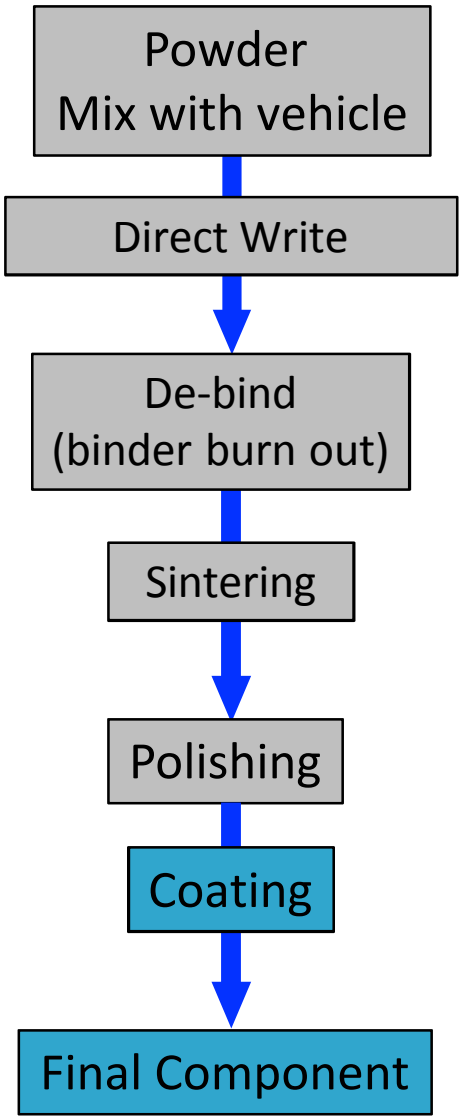


White light interferometer measurement



Contact profilometer measurement

Next Steps



- Identify and explore more potential materials
- Expand printing capabilities
- Improve de-binding and sintering processes to minimize failures due to thermal stress
- Improve accuracy of surface figure and achieve finer surface roughness
- Test reflective coating options

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Thank You!

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