



# Fabrication of Fe-based Bulk Metallic Glass via Direct Metal Laser Sintering

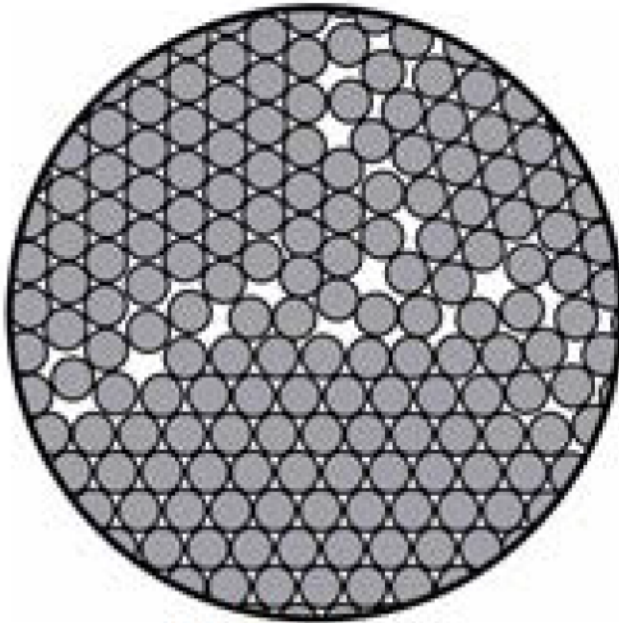
Zaynab Mahbooba<sup>1</sup>, Dr. Ola Harrysson<sup>1</sup>, Dr. Timothy Horn<sup>1</sup>, Dr. Harvey West<sup>1</sup>, Lena Thorsson<sup>2</sup>,  
Dr. Mattias Unosson<sup>2</sup>

1 Center for Additive Manufacturing and Logistics

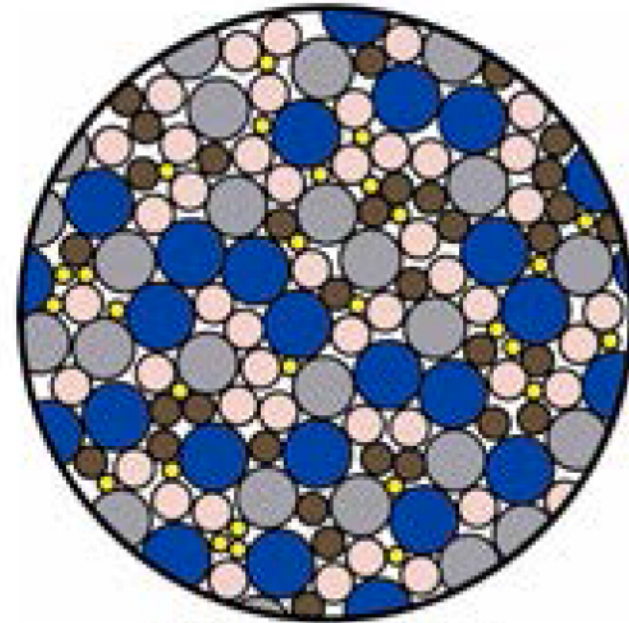
2 Sindre Metals



# What is an amorphous metal?



Crystalline Metal



Amorphous Metal

High cooling rates inhibit atomic rearrange into crystals.

Image: <http://www.reade.com/products/amorphous-metals>



# Amorphous Metal Properties

- ✓ Good wear resistance
- ✓ Good corrosion resistance
- ✓ High electrical resistance
- ✓ Low coercivity
- ✓ Low losses
- ✗ Low ductility

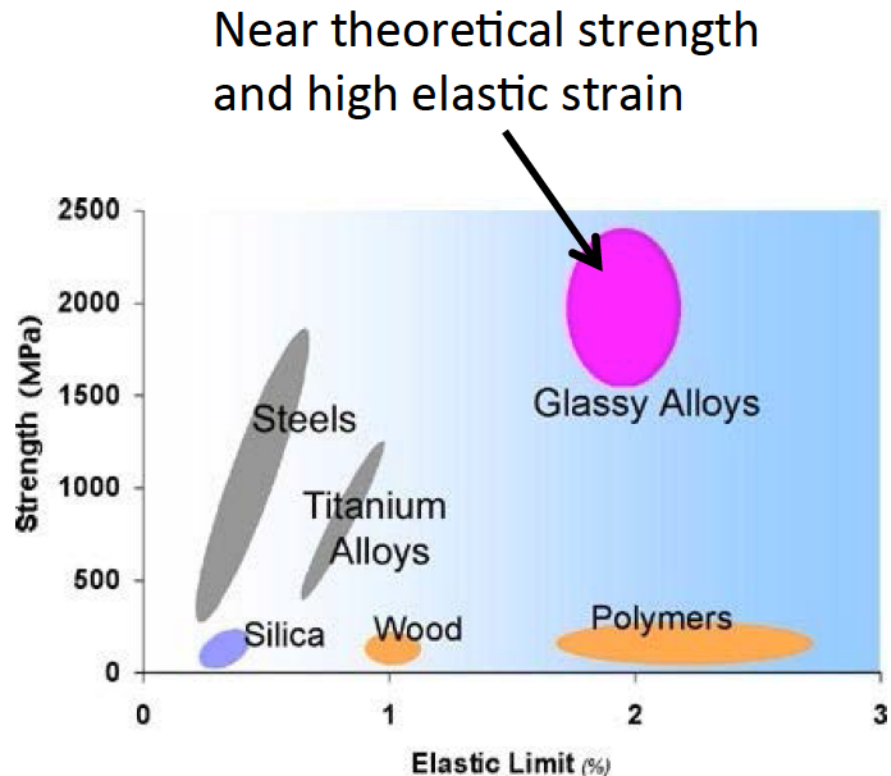


Image: <https://www.quora.com/Which-metal-alloys-are-stronger-than-steel>



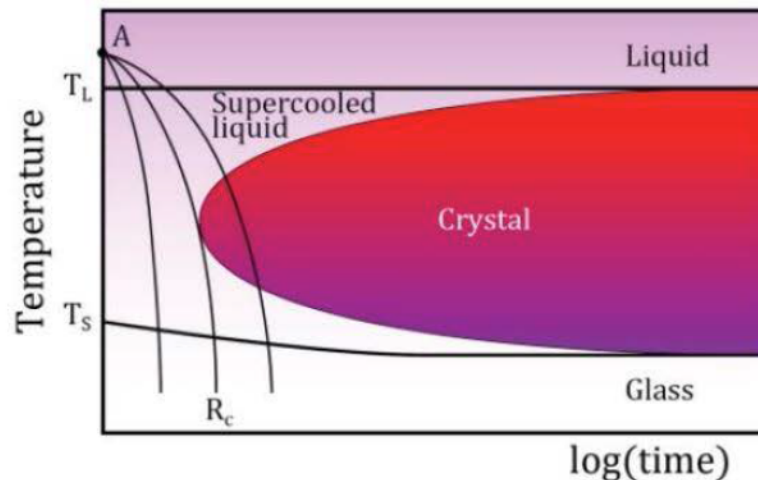
# Production of Amorphous Metals

## Production Techniques

- Casting (Cu molds)
- Thermoplastic forming
- Hot pressing
- Spark plasma sintering

## Limitations

- Dimension is limited by critical cooling rate
- Simple geometries
- Require good glass formers
- Strong glass formers are often toxic or expensive elements (Be, Pt, Pd, Au)
- Powder metallurgy requires binders

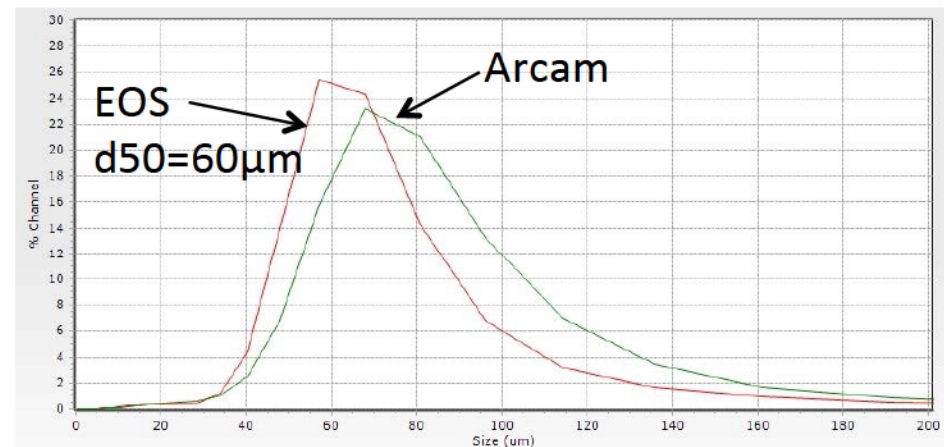
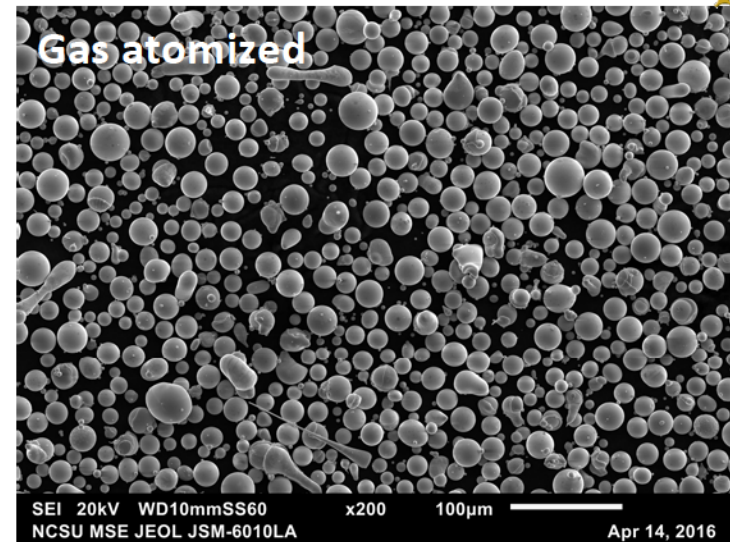






# Fe-based Amorphous Alloy

- 5 Constituents
- Critical casting thickness 1-5mm
- Critical cooling rate  $10^3$ - $10^4$  K/s
- Crystallization temperature 800-1000K
- Glass transition temperature 700-900K
- Melting temperature 1200-1500K





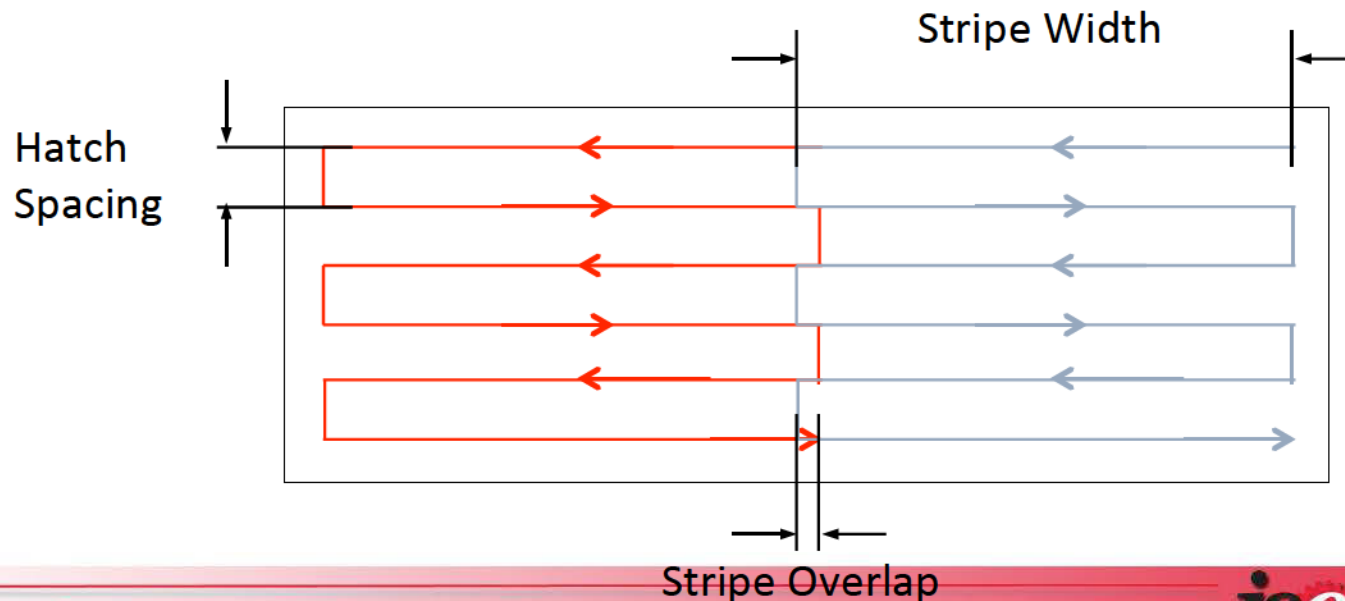
# Selective Laser Melting: EOSINT M 280

- Constant Parameters

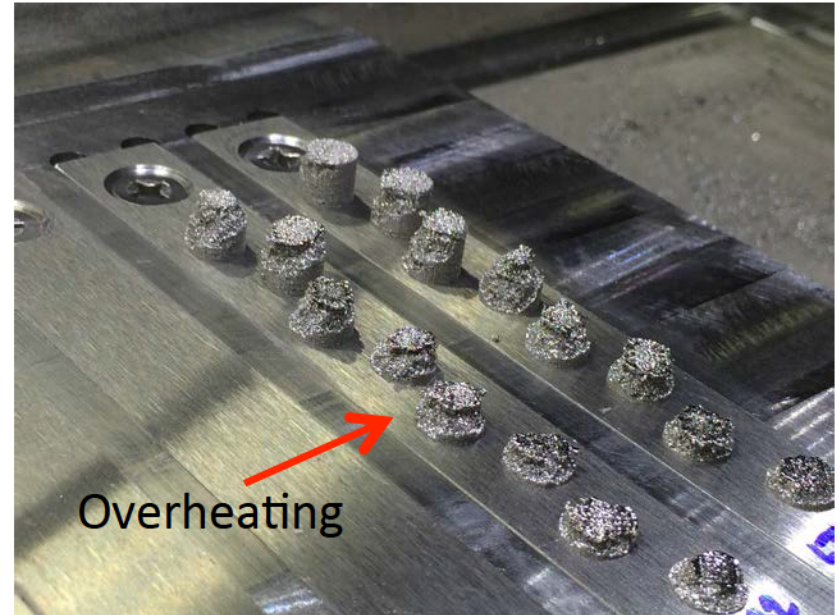
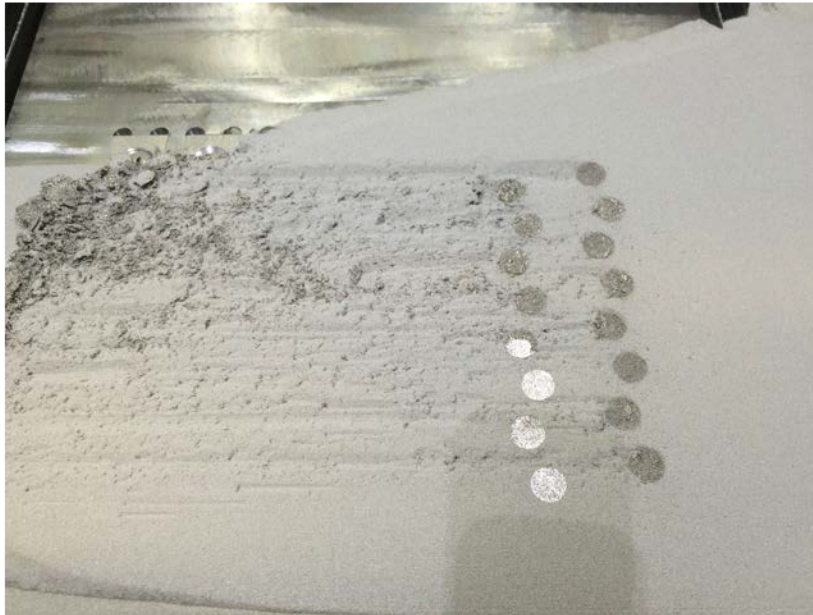
- Build plate temperature- 80°C
- Layer thickness- 20μm
- Build plate material-Steel

- Variable Parameters

- Laser power
- Scanning speed
- Beam offset
- Hatch distance
- Stripe width
- Stripe overlap



# Initial Trials



**High laser power** induces large thermal stresses and causes samples to crack.

**Low laser power** does not input enough energy to melt powders, so samples are porous.

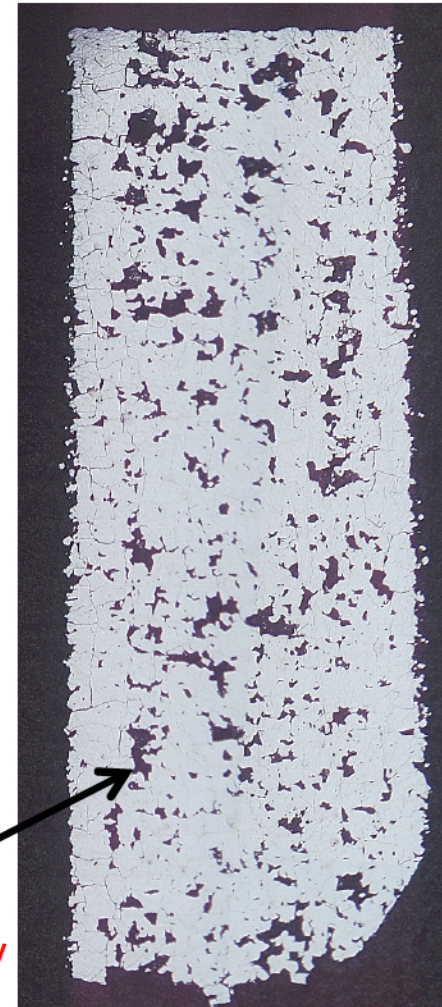




# Microstructure: Porosity

- Keyhole and pullout pores
- Liquid does not sufficiently flow to fill in gaps (high viscosity)
- Cutting and grinding causes cracking and porosity
- ✧ Decreasing scan speed and increasing power may eliminate porosity
- ✧ Eliminate cracking

Pullout porosity  
from cutting

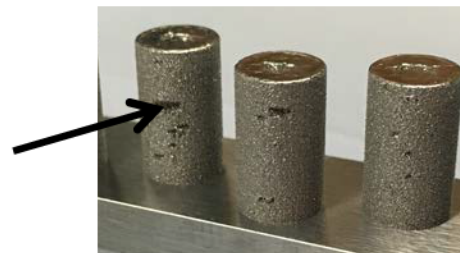


1mm



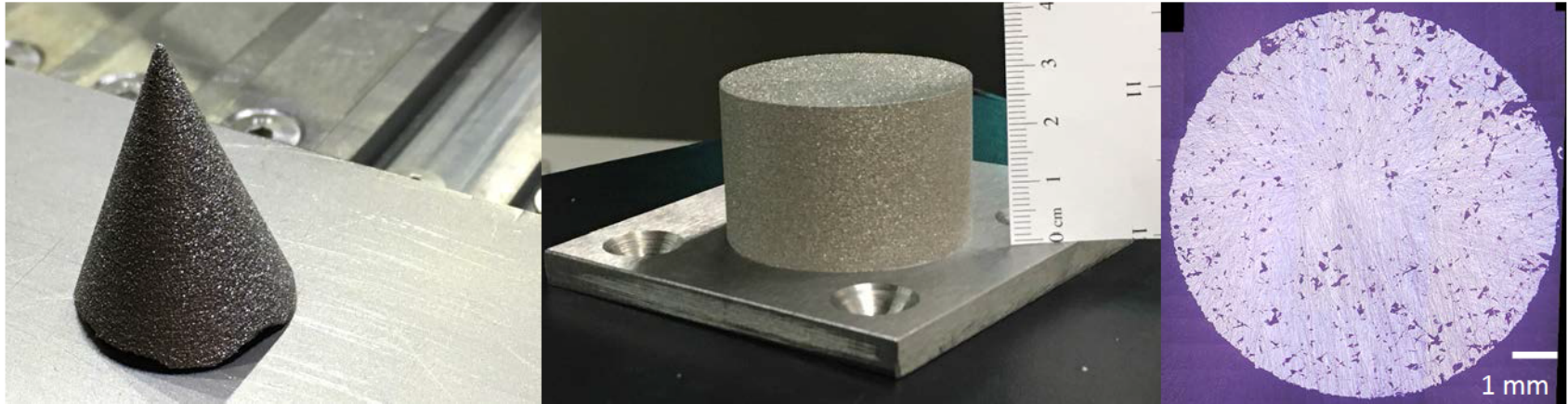
# Microstructure: Cracking

- Process induced cracks
- Thermal mismatch between hot melted layer and previous colder layers
- Stresses caused by rapid solidification
- ✧ Increase substrate temperature to reduce temperature differences (EBM)





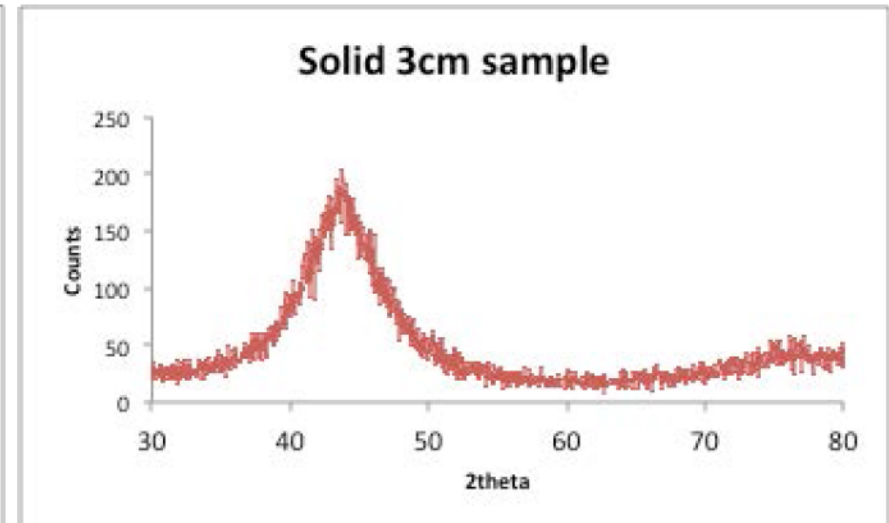
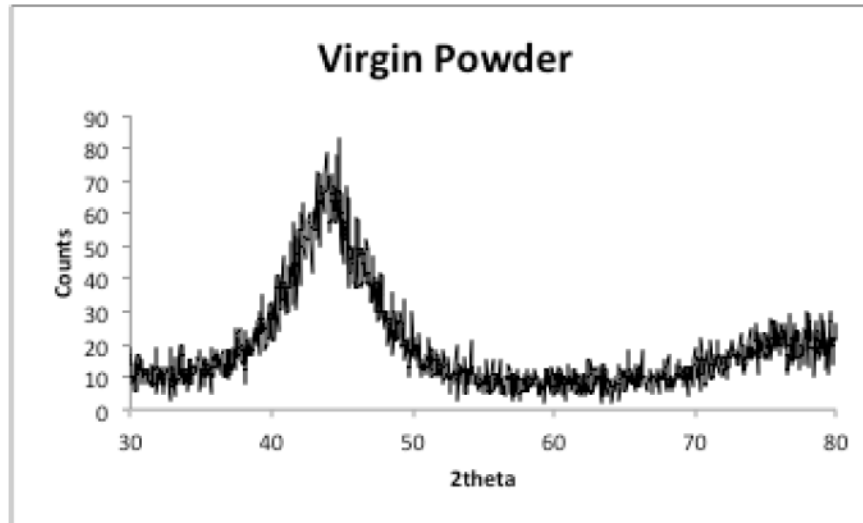
# Parameter Development



3x3cm cylinder exceeds critical casting thickness in all dimensions. The outside surface is free of cracking.



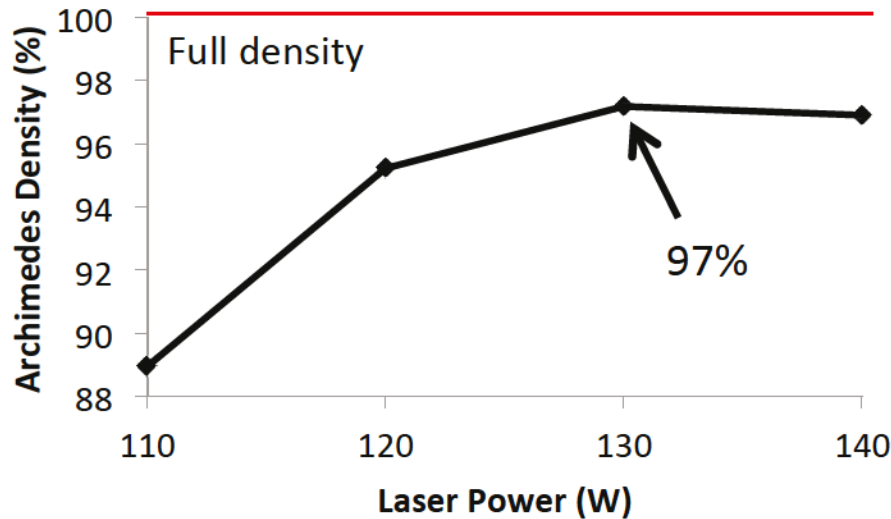
# X-ray Diffraction



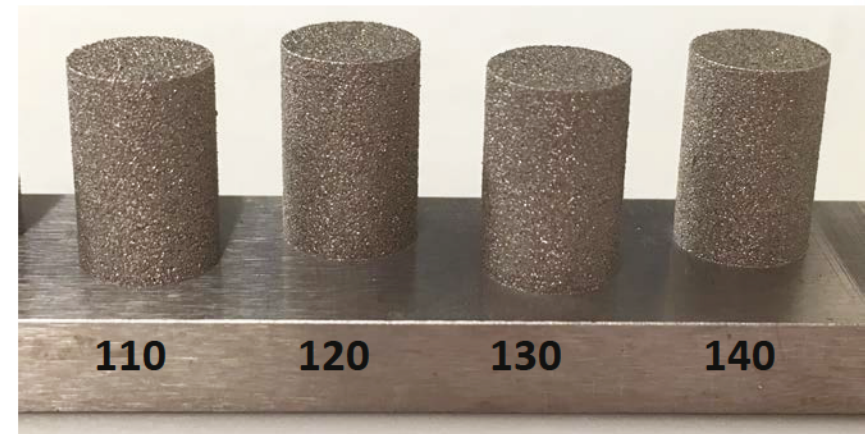
XRD data suggests that solid samples are **fully amorphous** despite being more than 5x the critical casting thickness.



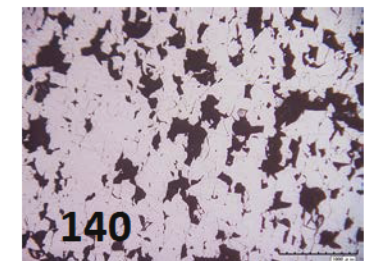
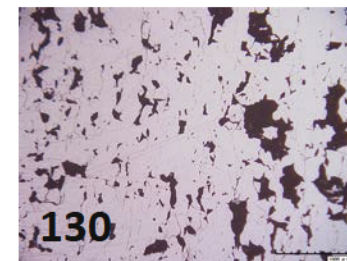
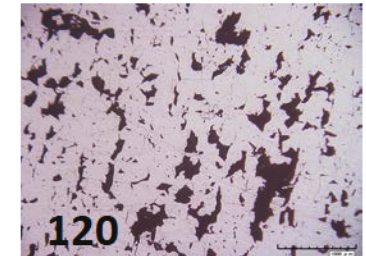
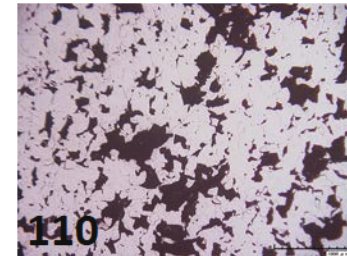
# Solid Density



Similar surface appearance



- SLM fabricated samples are close to full density
- Excessive porosity in micrographs are produced during cutting and grinding





# Continued work

- Eliminate cracking (Arcam)
- DSC to measure amorphousness
- Develop support, upskin and downskin parameters
- Determine if there is a size limitation
- Mechanical characterization





# Thank You



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