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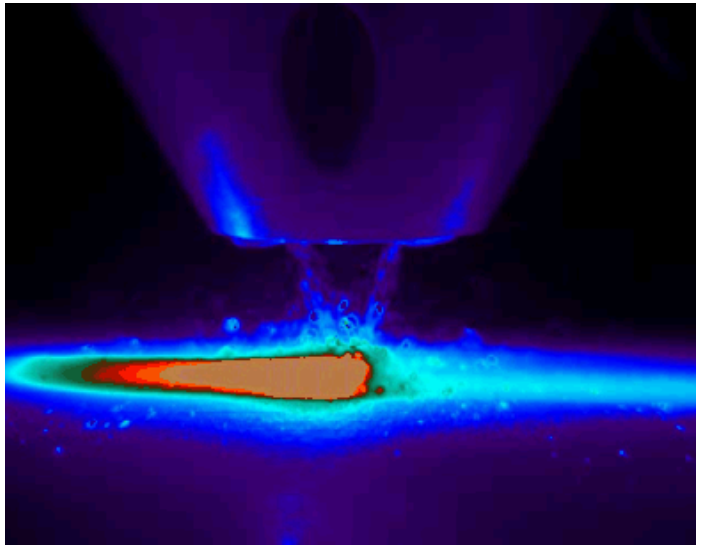
Directional Dependence of Mechanical Properties and Defects of LENS 304L

Cole Britt, David Keicher, and Shaun Whetten

Sandia National Laboratories



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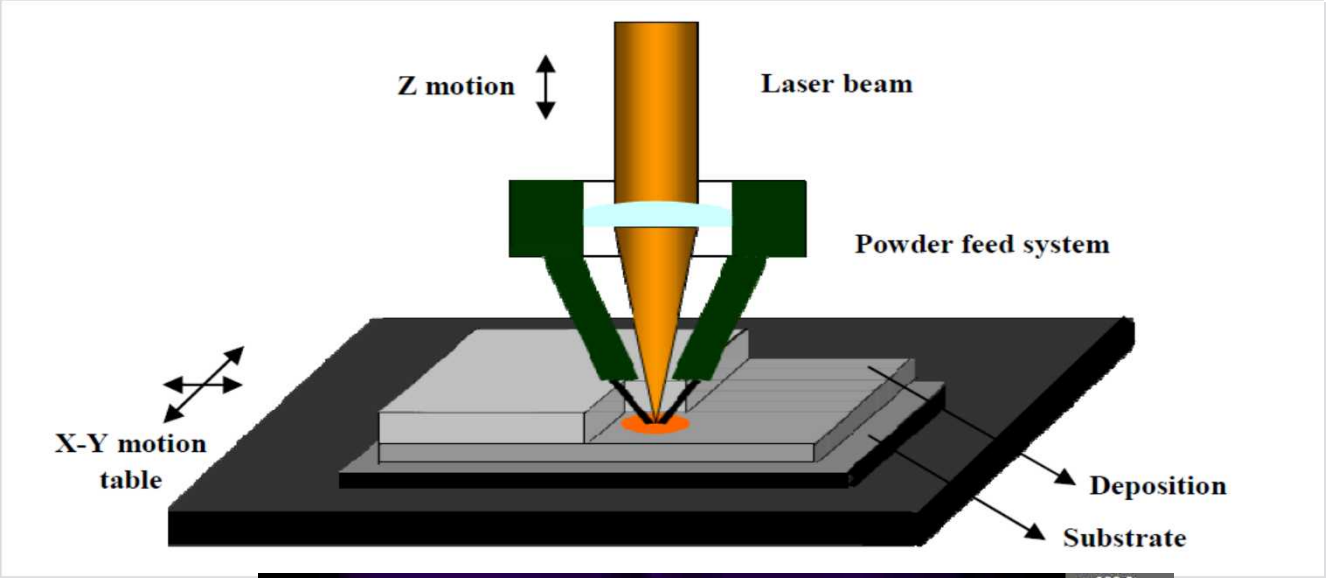
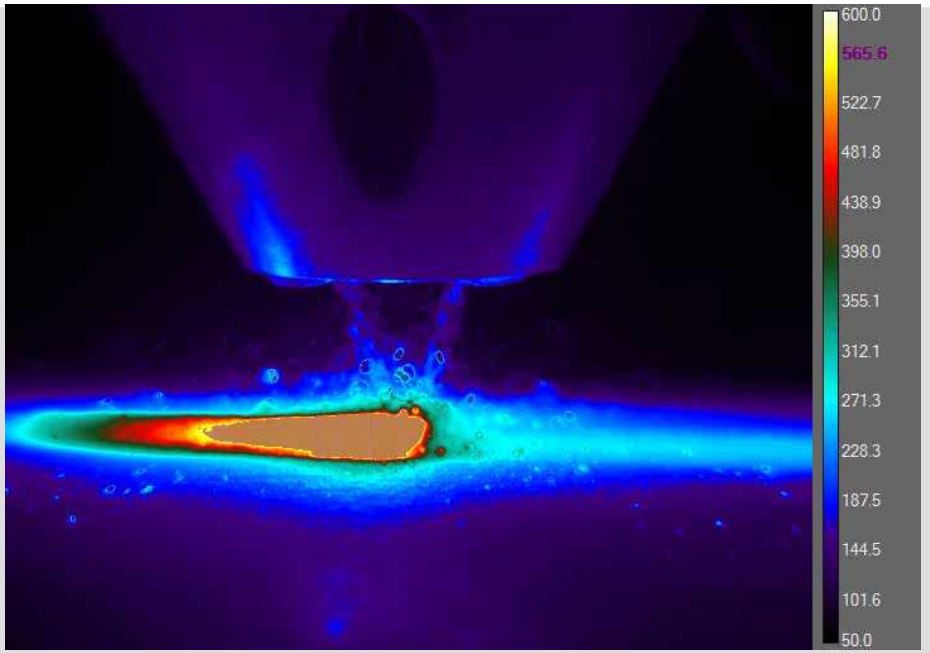
Outline

- Introduction
- High Throughput Tensile Testing
- Results
- Additional Testing
- Discussion

LENS

- Laser parallel to z axis creates melt pool
- Powdered metal feed into melt pool creates deposition
- X-Y motion table moves substrate to create continuous weld bead
- Z motion controls layer height

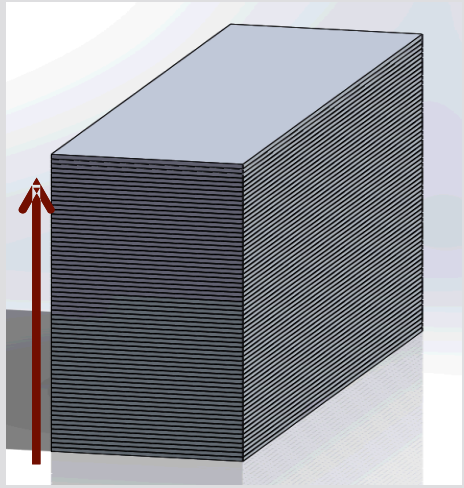


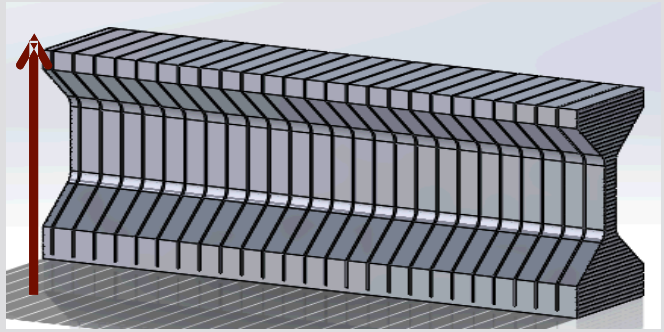


Print Parameters

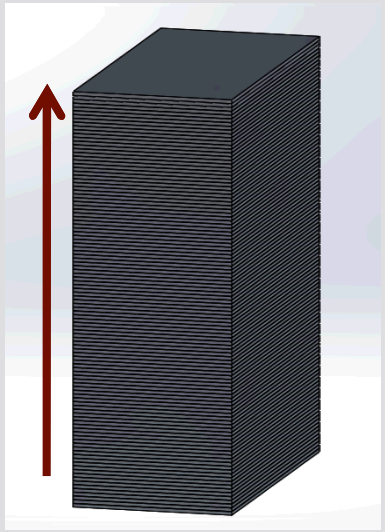
- Platten Temp - 30 C
- Powder Feeder Voltage - 3.5V
- Laser Power 450W
- Table Feedrate - 600 mm/min
- Layer height - .25 mm

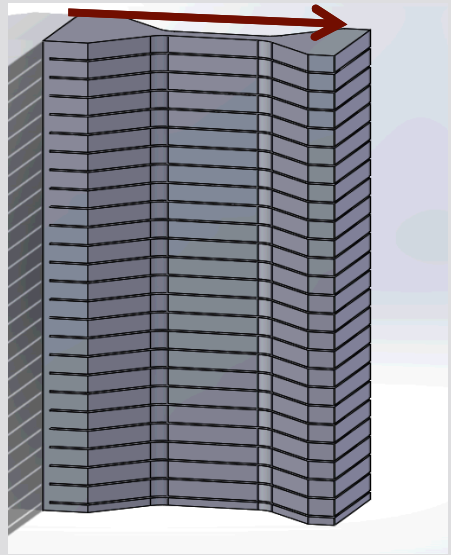
Sample Sets 1 & 2





Pull direction, transverse to build plane

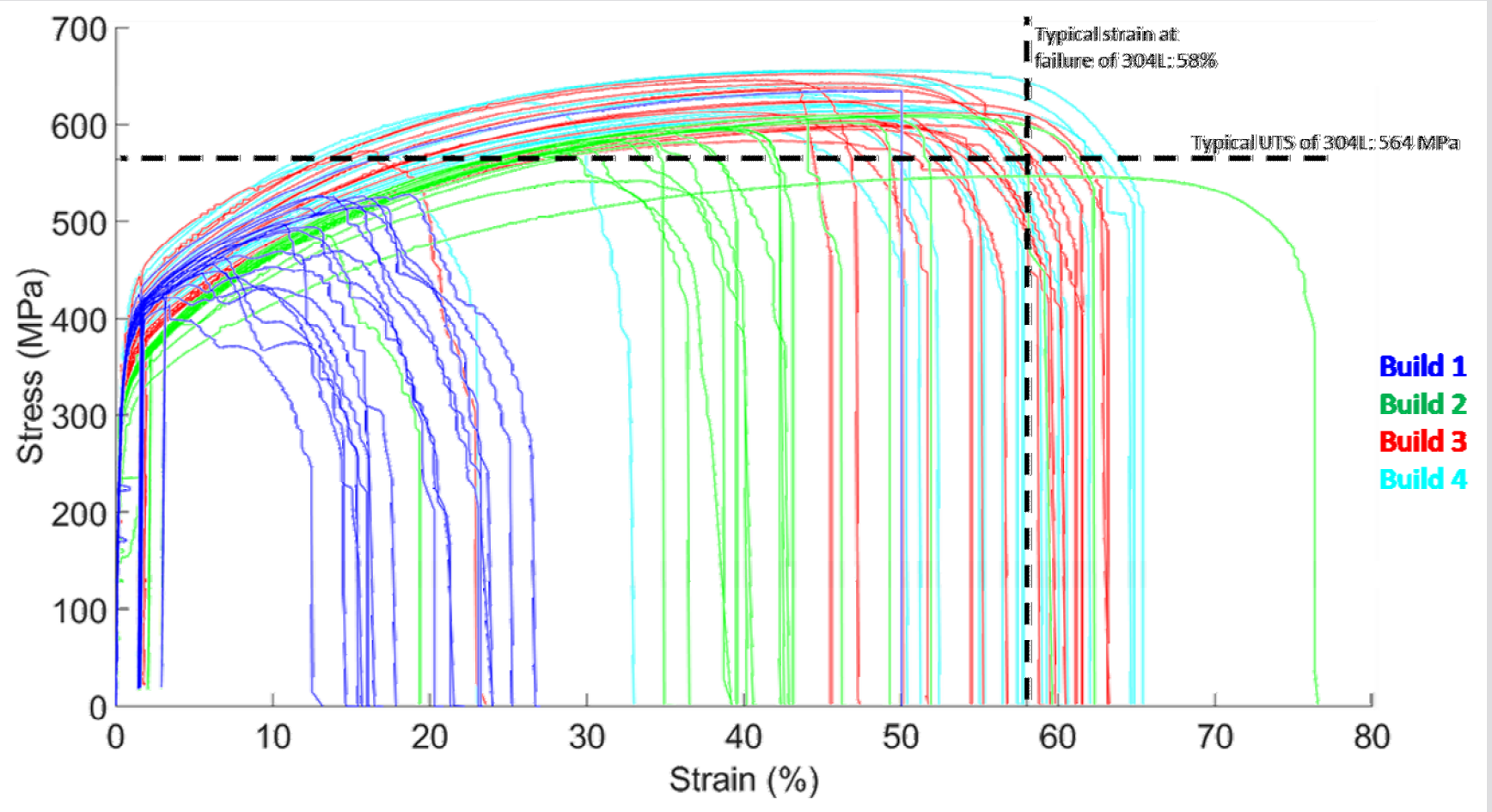




Pull direction, parallel to build plane

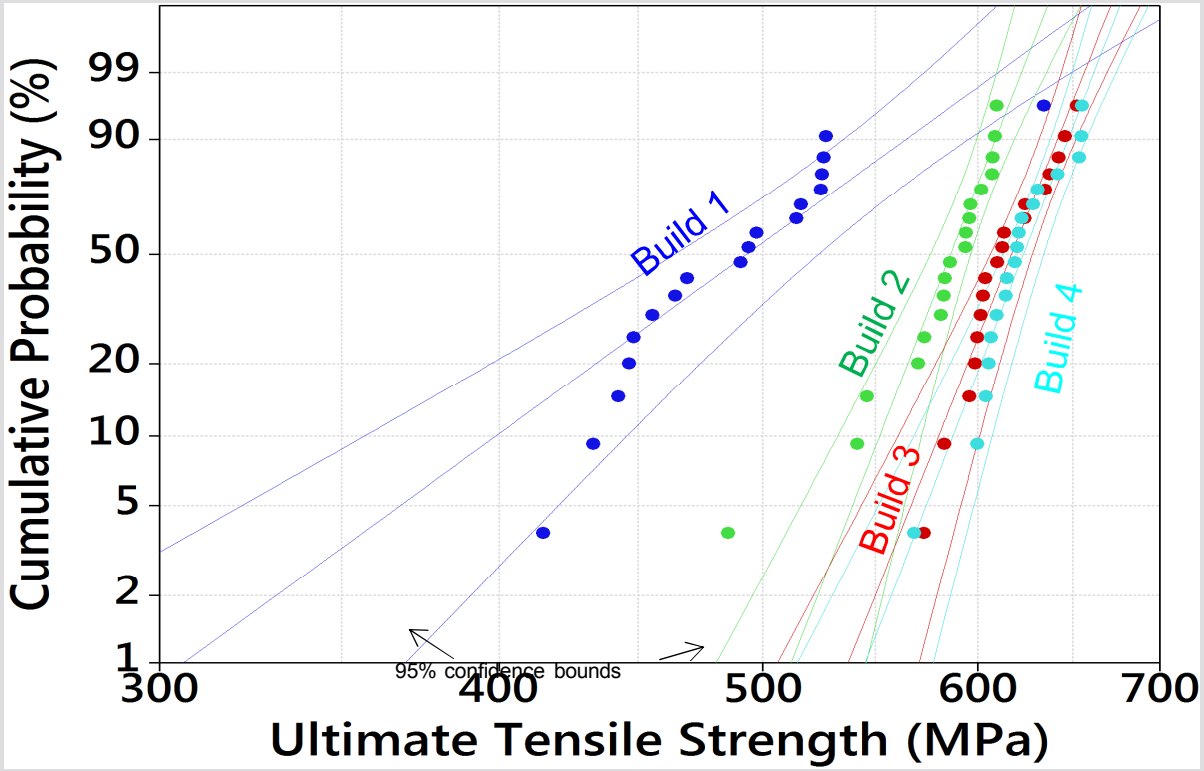
Sample Sets 3 & 4

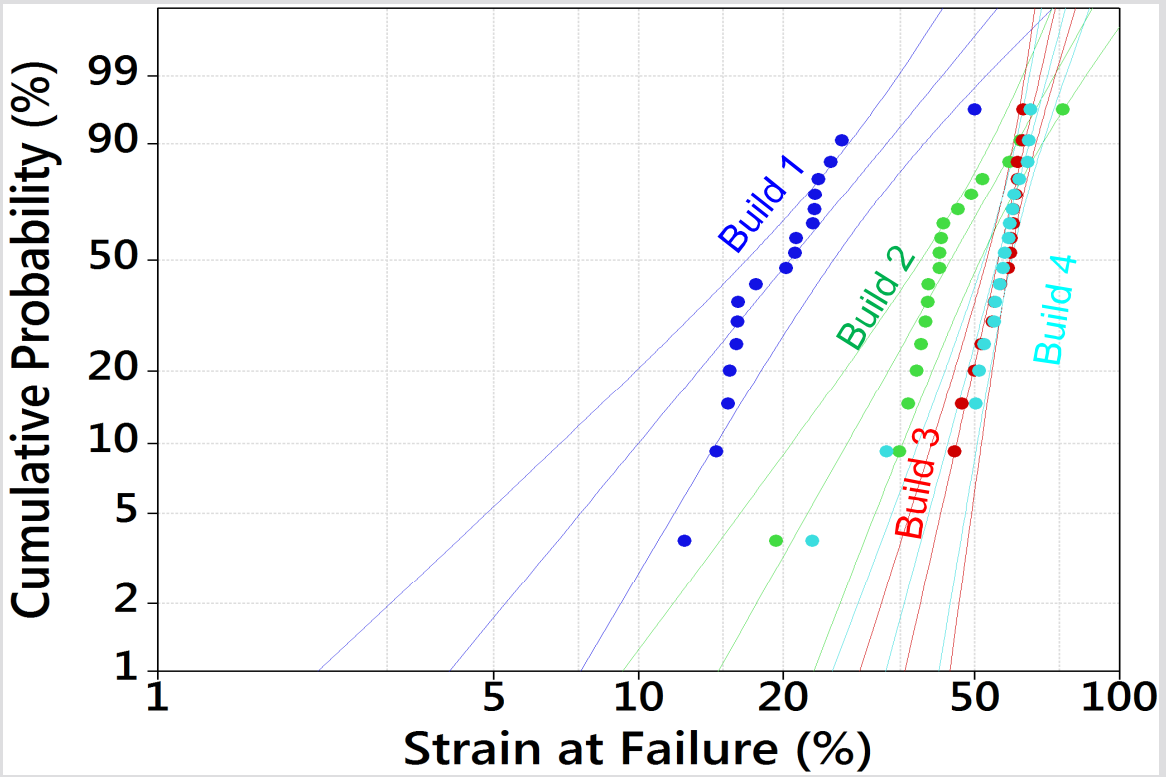
Stress and Strain of Samples



- On average, builds 2, 3, and 4 surpassed the typical UTS for wrought 304L.
- Roughly half of the samples from builds 3 and 4 surpassed the typical strain for 304L.
- Only one sample from build 1 surpassed the typical UTS for 304L.

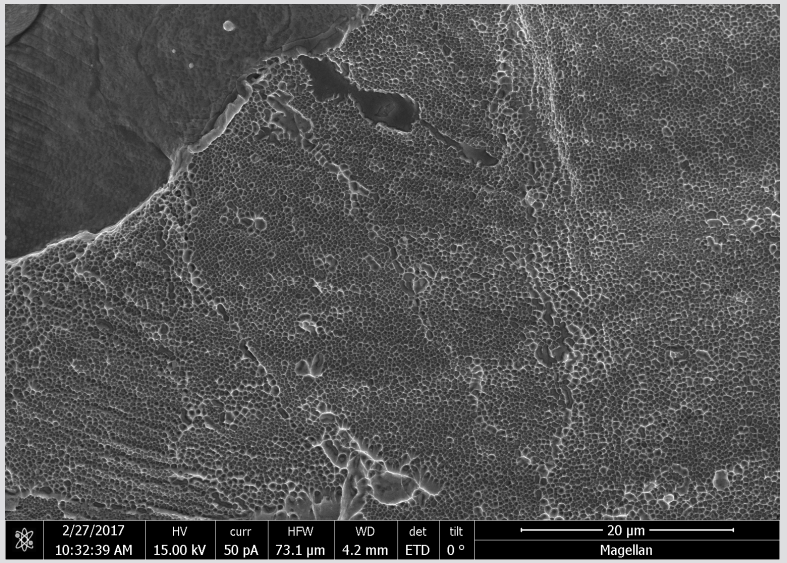
Weibull Distributions UTS and Strain at Failure

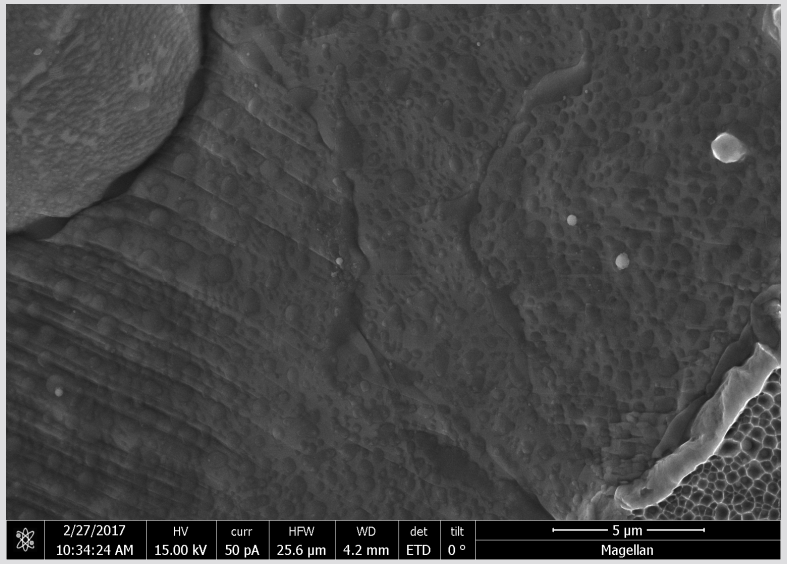


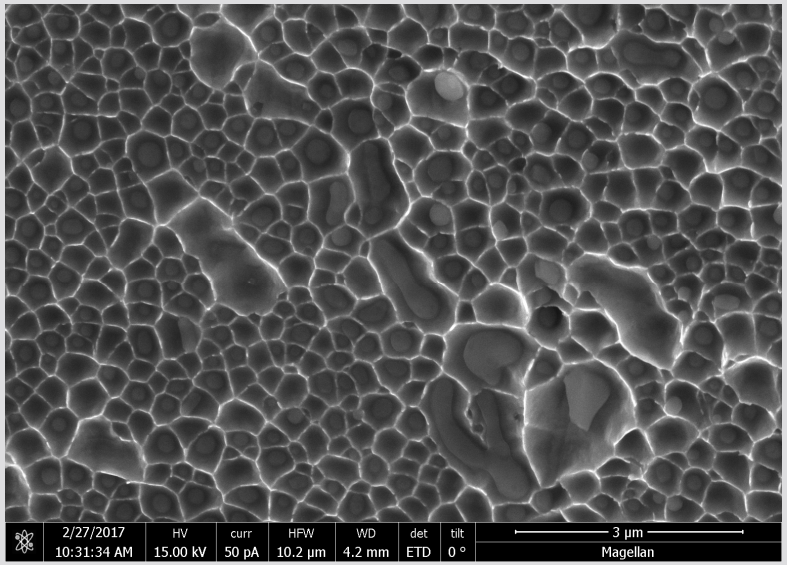


- Samples pulled orthogonal to build planes have much lower ductility than samples pulled parallel to build plane.

Build 1 (Transverse to Build Plane)

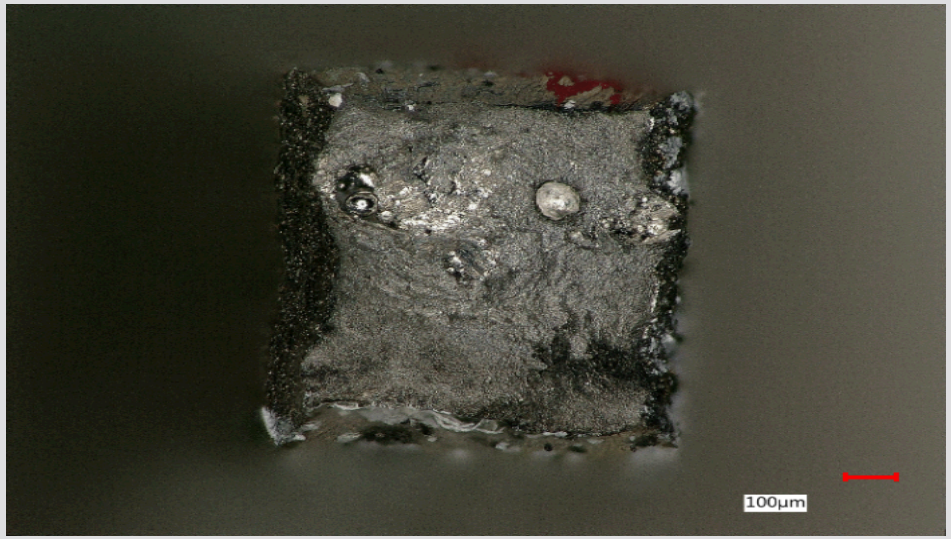


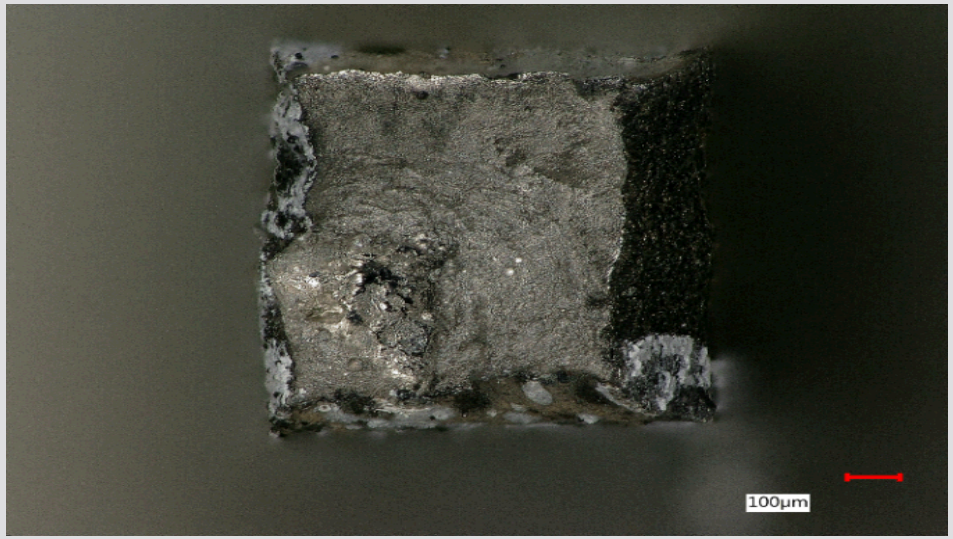


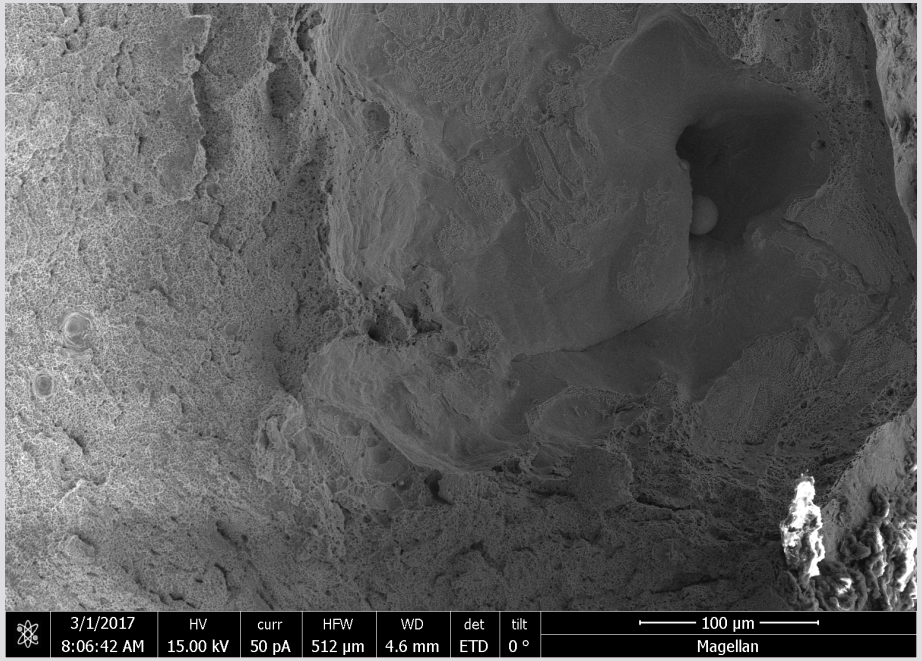


- Large lack of fusion defects around one edge.
- Oxide particles are present throughout microstructure.

Build 2 (Transverse to Build Plane)

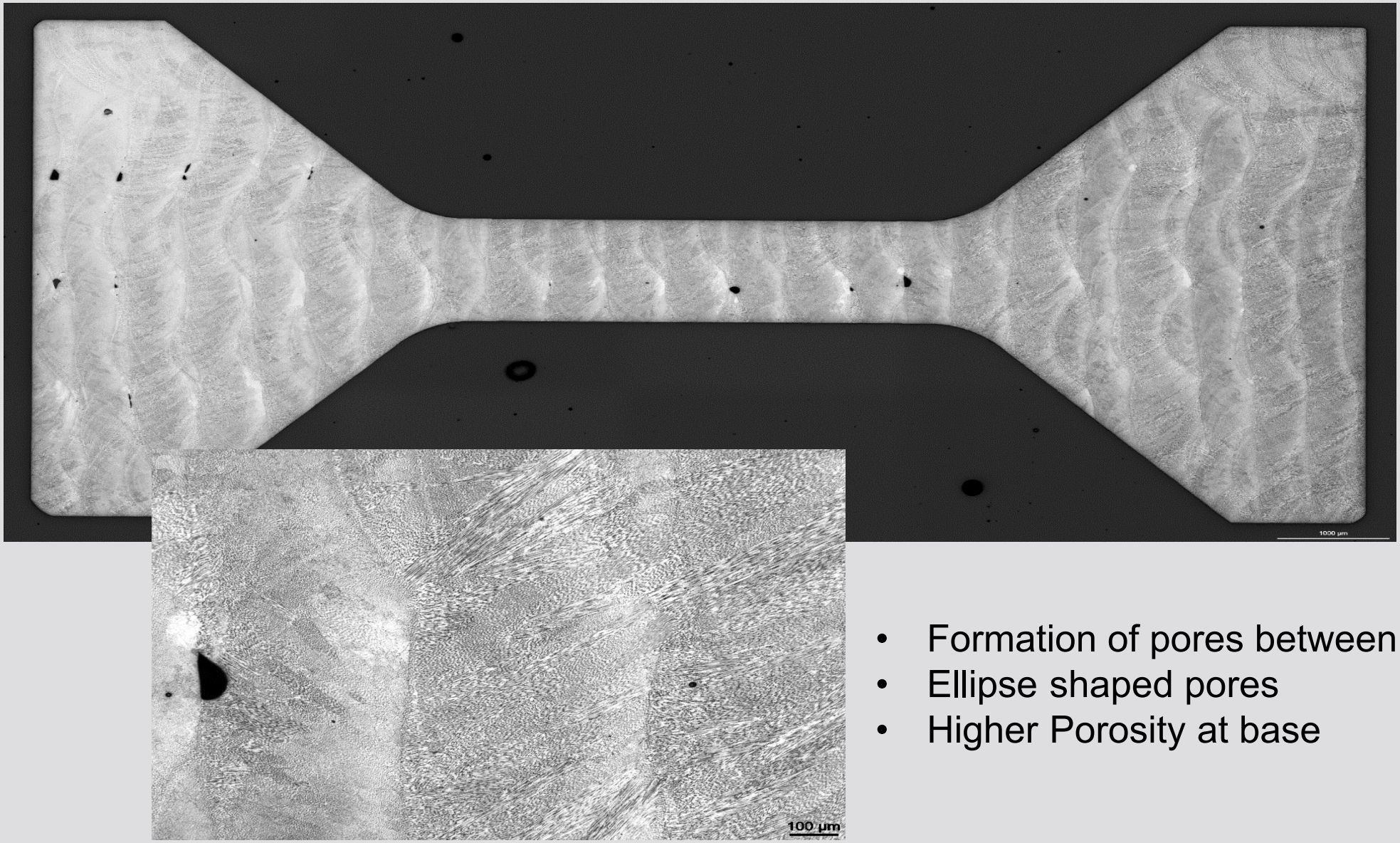






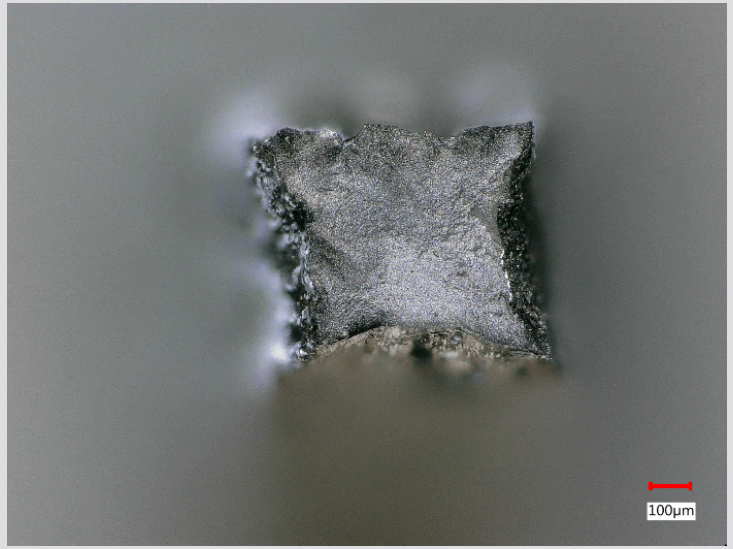
- Large lack of fusion defects.
- Defect based failure mode accounts for wider distribution of the set and lower strength than sets 3 and 4.

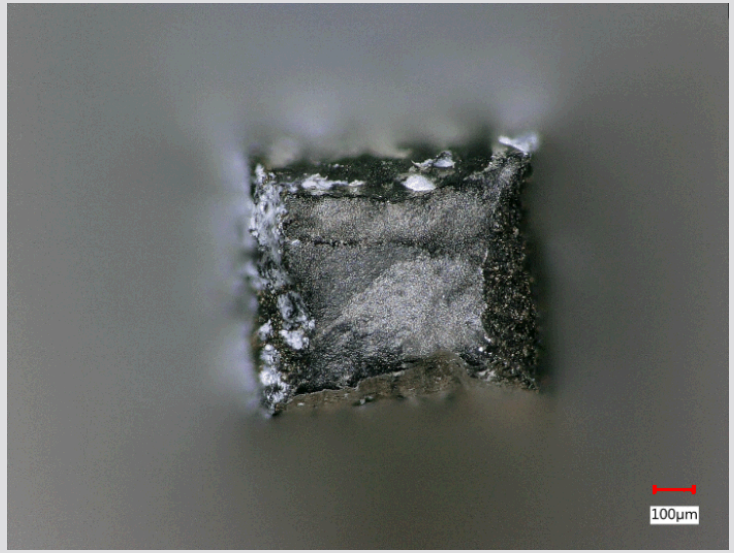
Build 2 Metallography

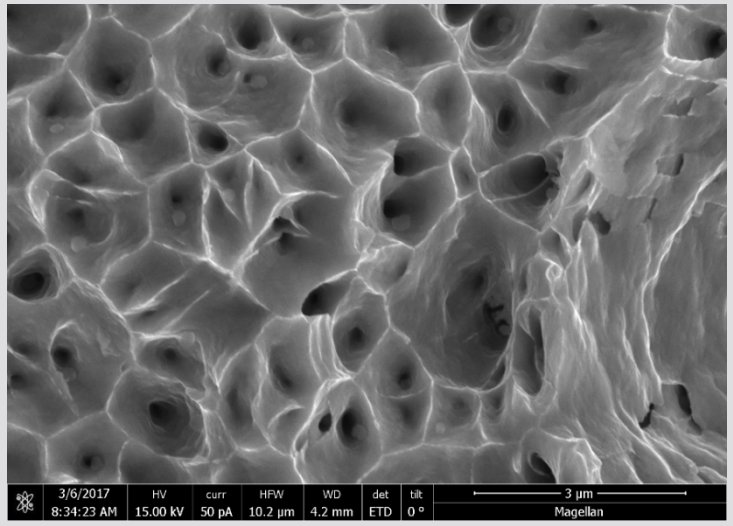


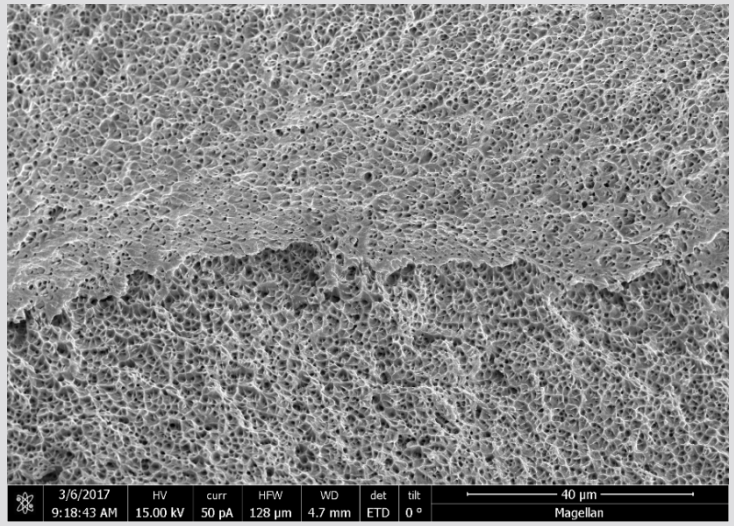
- Formation of pores between layers
- Ellipse shaped pores
- Higher Porosity at base

Build 3



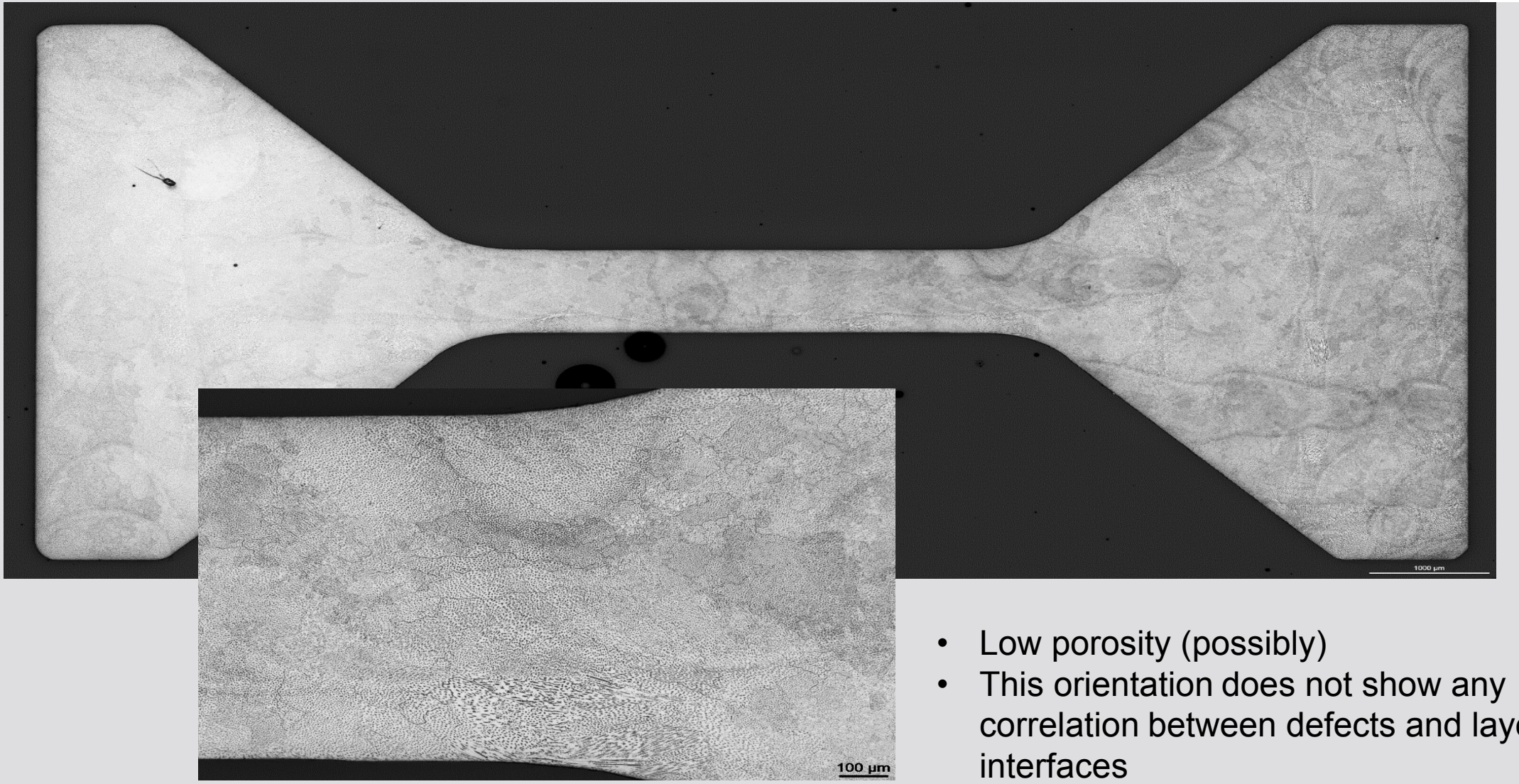






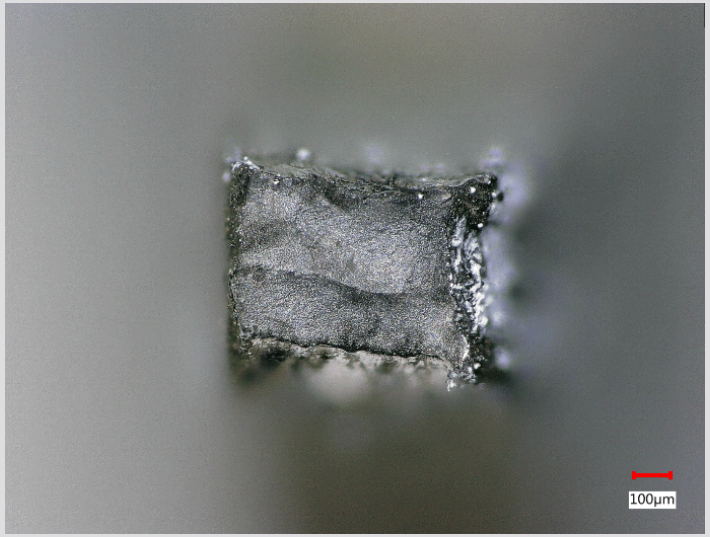
- More ductile fracture, with few defects in fracture surfaces
- Difference in topology, ridge behavior in some samples

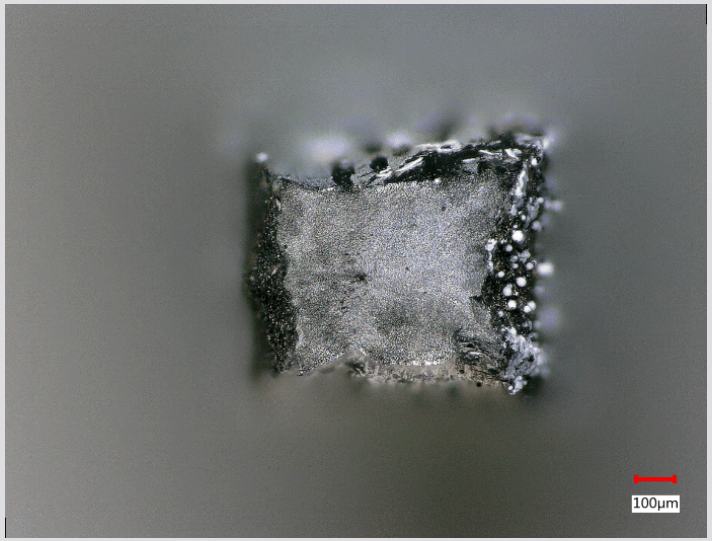
Build 3 Metallography

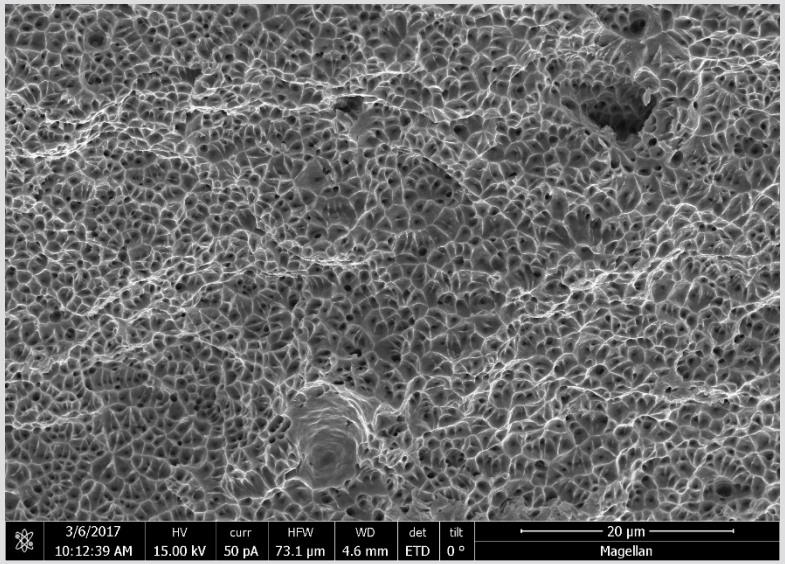


- Low porosity (possibly)
- This orientation does not show any correlation between defects and layer interfaces
- Possible defects at build layer interface

Build 4

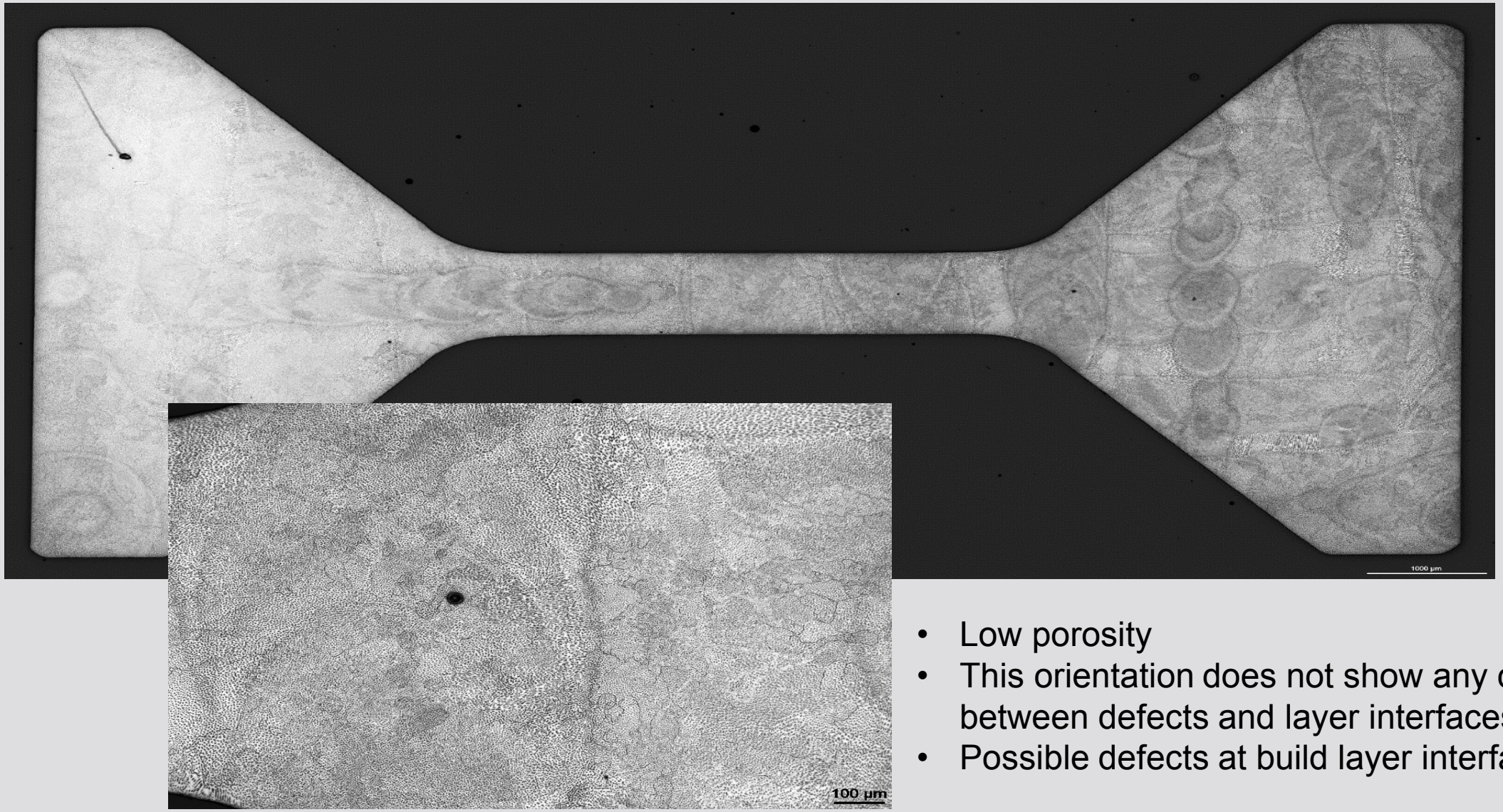






- More ductile fracture, with few defects in fracture surfaces
- Difference in topology, ridge behavior in some samples

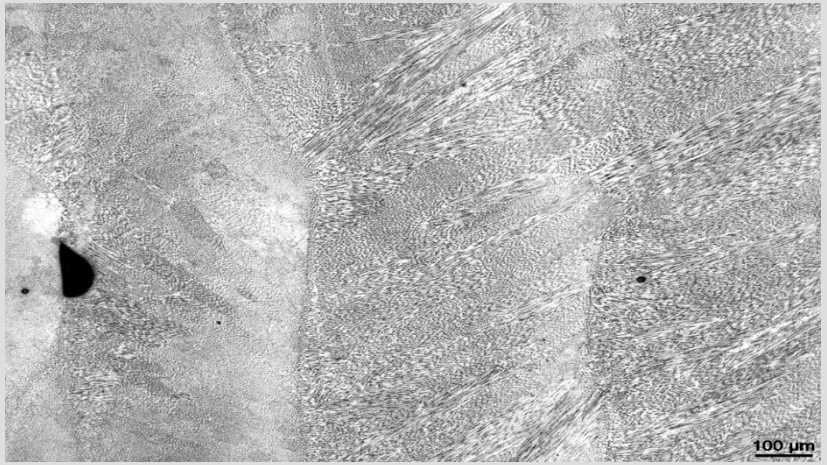
Build 4 Metallography

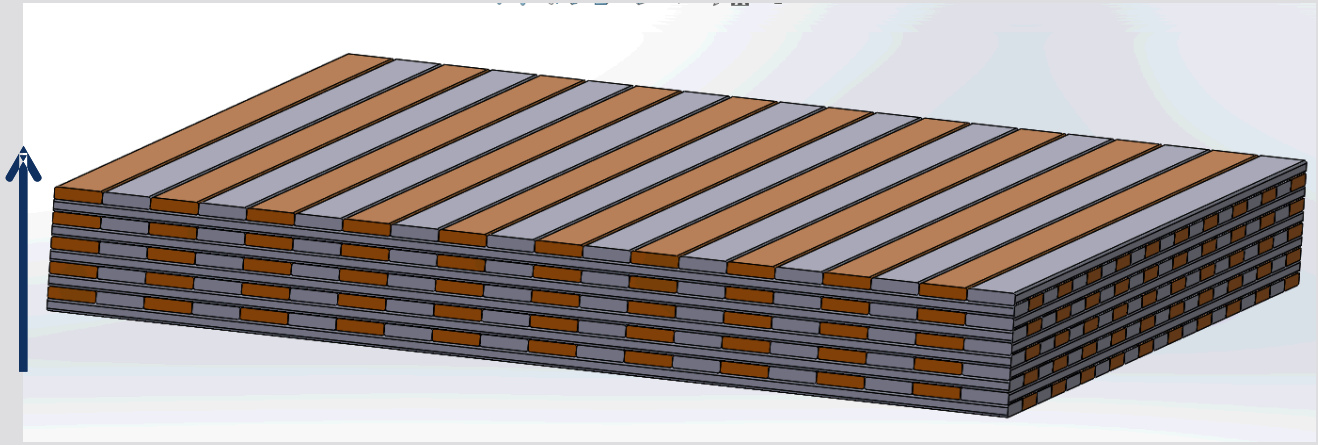


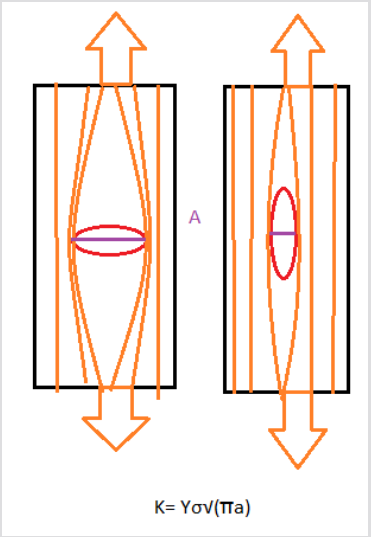
- Low porosity
- This orientation does not show any correlation between defects and layer interfaces
- Possible defects at build layer interface

Possible Causes of Directional Dependence

- Directionality of Defects
- Possibility of heat buildup in substrate

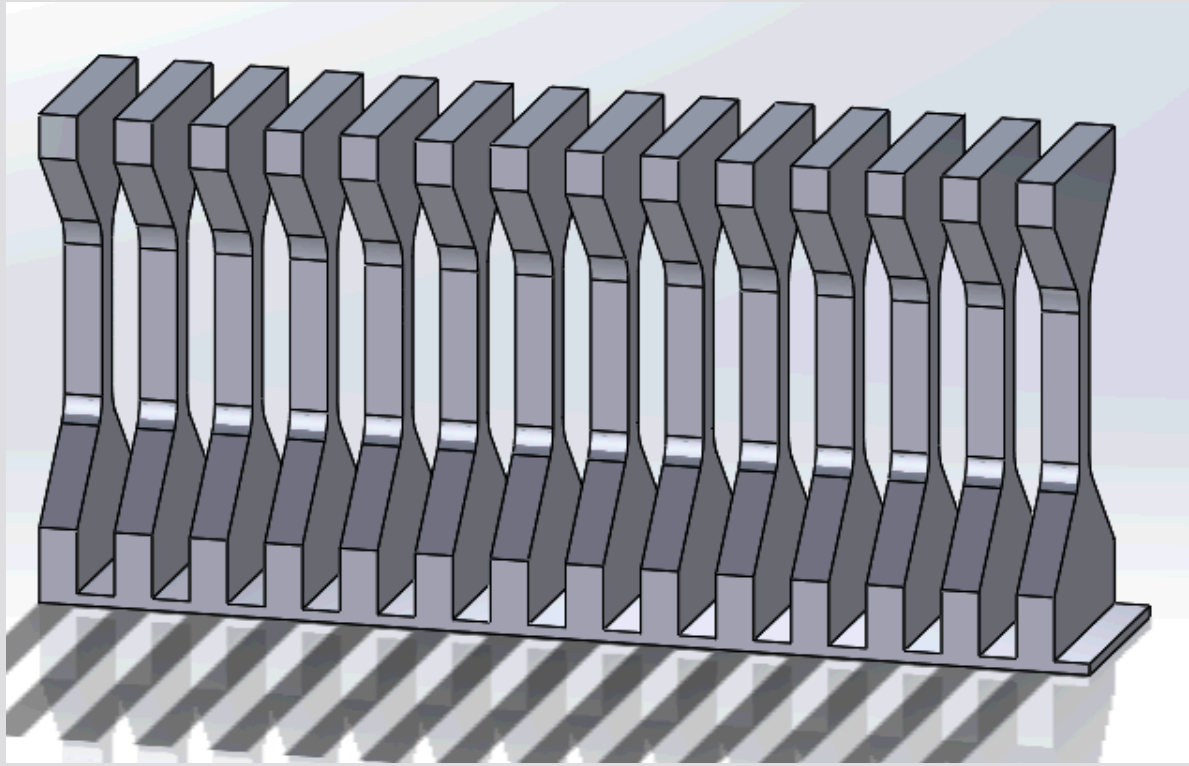




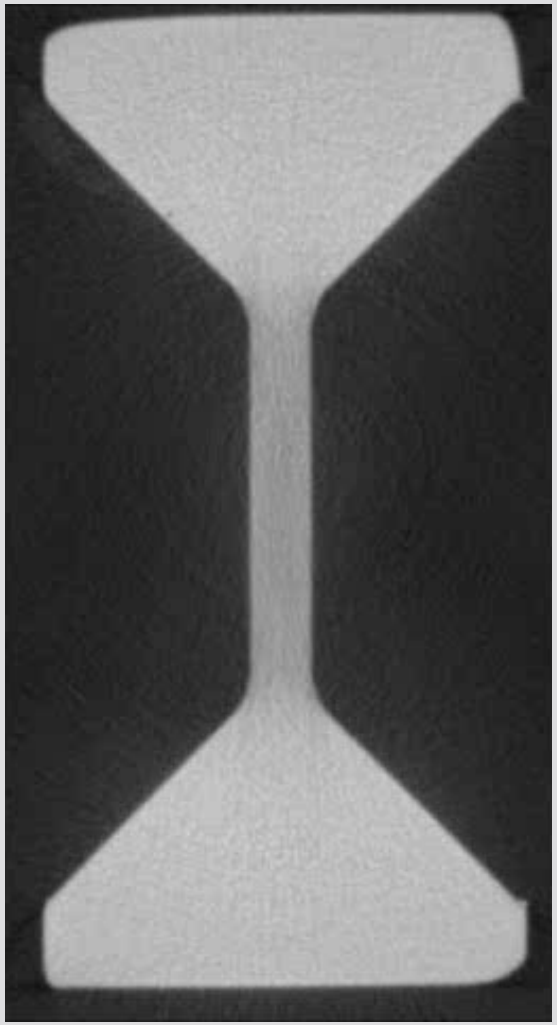


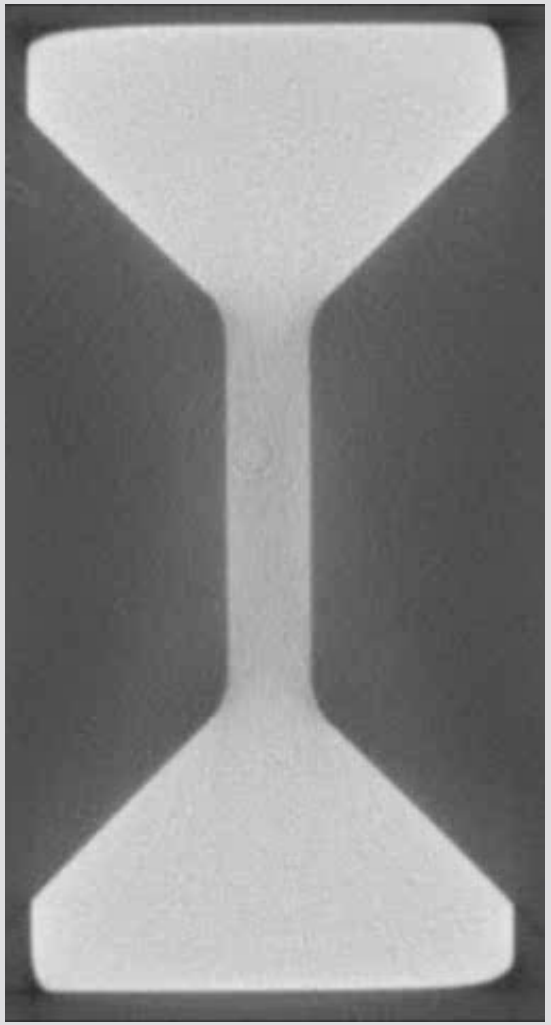
Additional Exploration

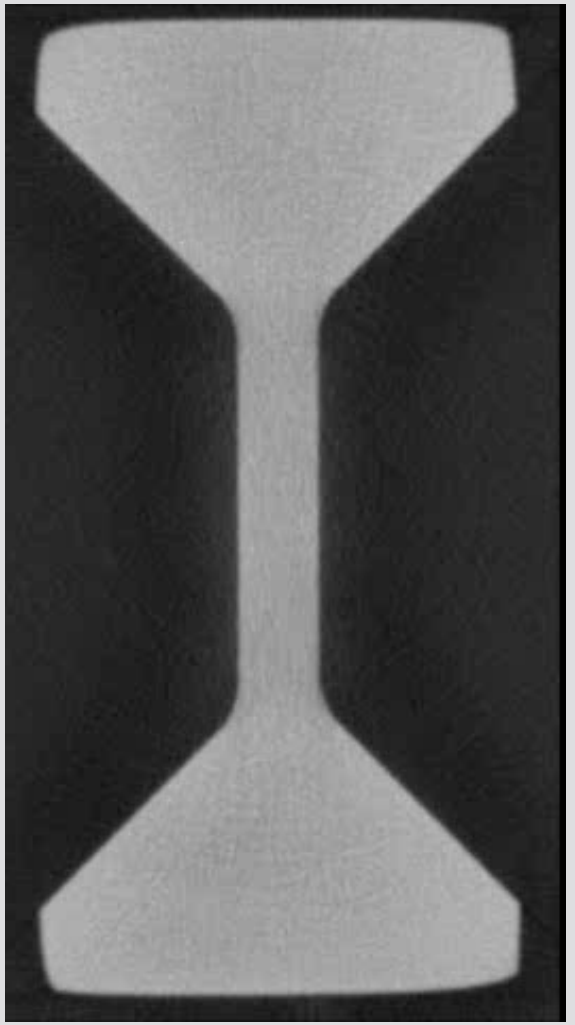
- Analyze samples 3 and 4 for interface defects
  - Tomography to identify internal defects
  - Additional sectioning as needed
- Analyze samples 1 and 2 for interface defects
  - Analysis of grain structure at build interface
- Repeat tensile testing
  - More samples fabricated
    - Heated Platent
  - Tomography performed to ensure high density
  - Samples in testing



Tomography Images







Discussion

- Additional work ongoing
- Possibility of part alignment to build direction

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Thank You