SAND2016-8857PE

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Physical Properties of Feedstock Powders and its Implications to Tap Density and Feed Rate for Additive Manufacturing

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Mentors: Nancy Yang and Josh Yee,

Jeff Chames and Ryan Nishimoto

U.S. DEPARTMENT OF ENERGY

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Overview

- Additive manufacturing process descriptions
- Experimental Procedures
  - Optical and Scanning electron microscopy
  - Flow rate and Powder tap density
- Results
  - Surface morphology
  - Particle size and distribution
  - Flow rate
  - Tap density
- Summary and Conclusions

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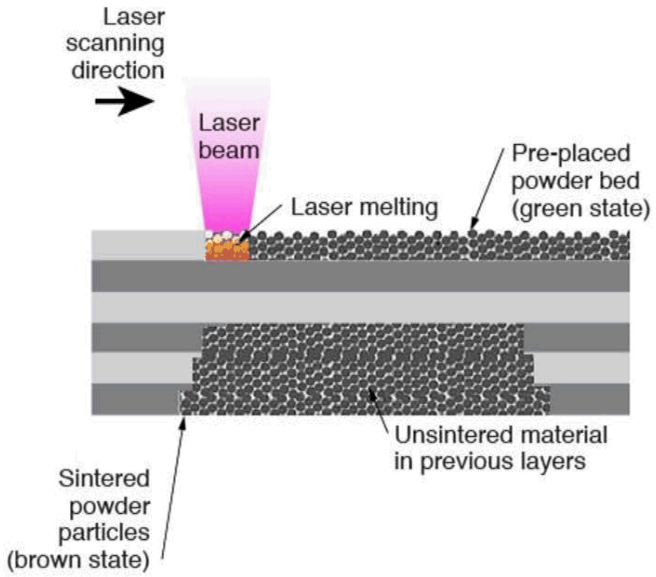

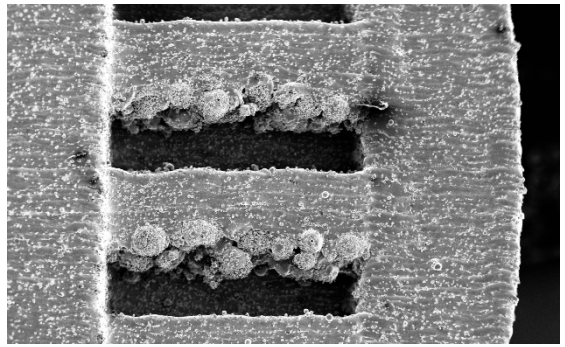

AM Process Descriptions

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Department 8341
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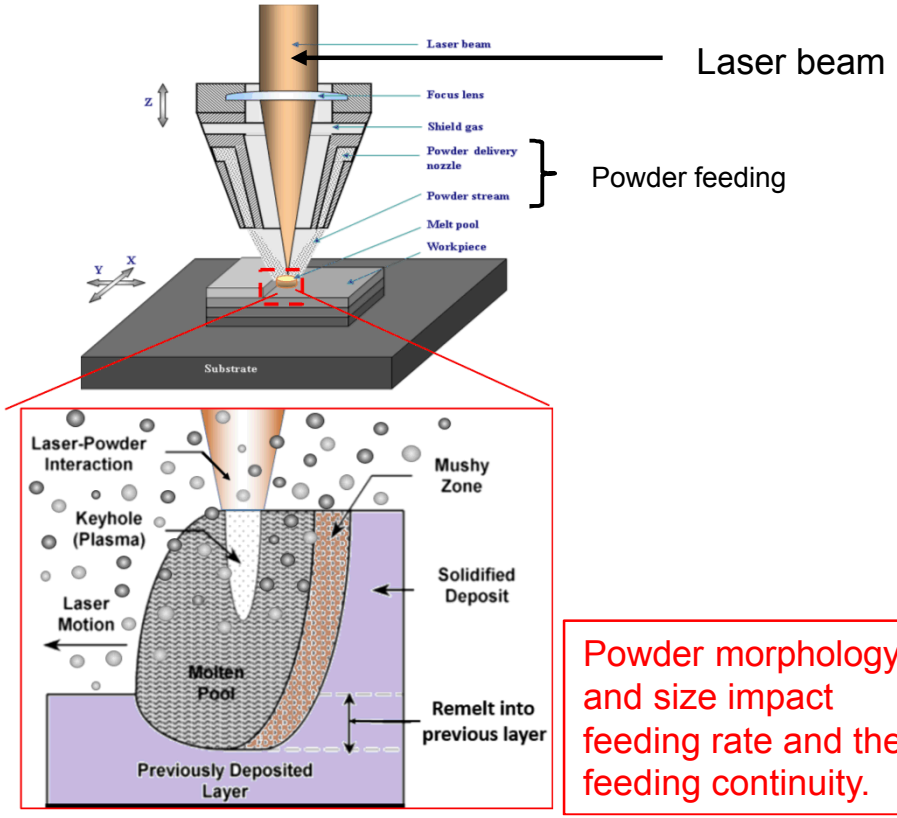
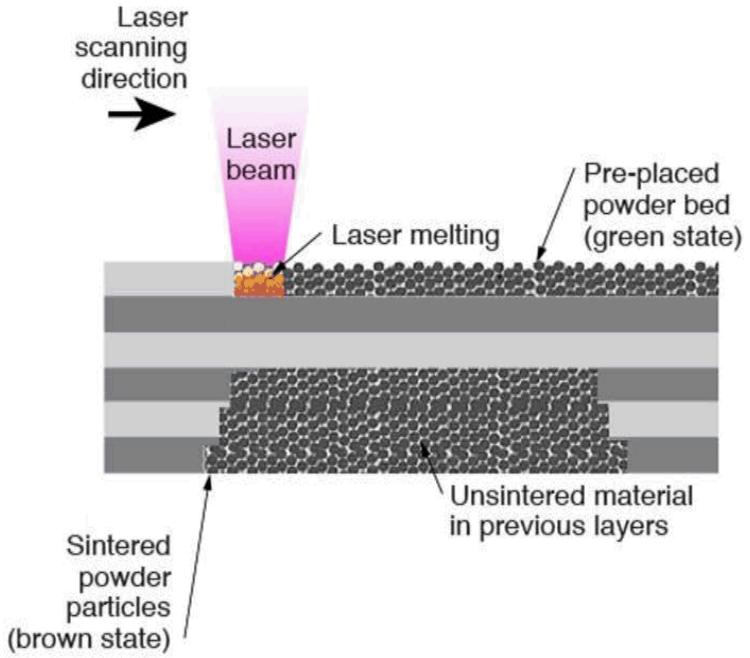
Sandia is interested in two types of powder-based AM processing: 3-D Laser Engineered Net Shaping (LENS) and Powder Bed Fusion (PBF)

LENS



Powder morphology and size impact feeding rate and the feeding continuity.

PBF



- Tap density is important to ensure a full print coverage no pores

LENS and PBF Machines

LENS Machine

Optomec MR-7
Building 906/152

PBF Machine

3D Systems ProX 300
Building 979

Demonstrations of LENS and PBF metal processing

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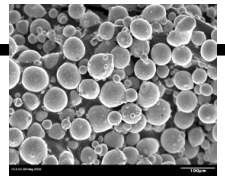
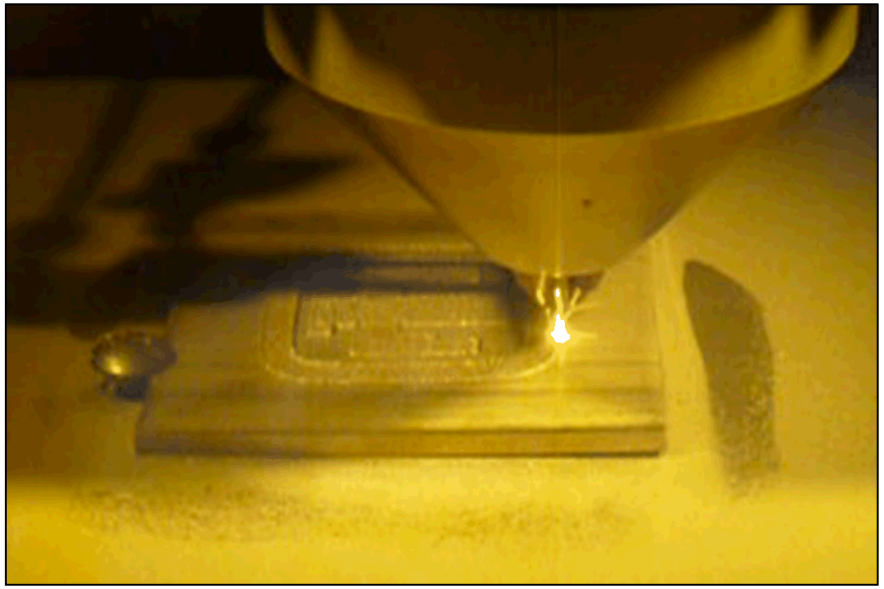
Starting 316L atomized feedstock powders



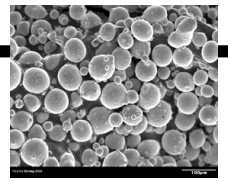
3-D LENS deposit



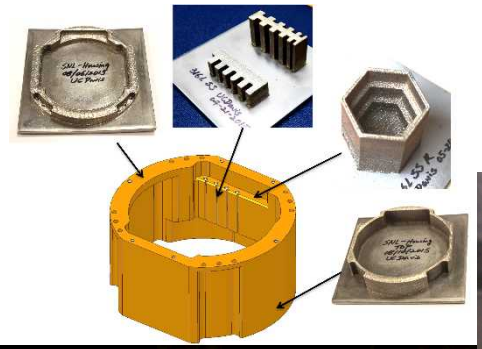
3-D PBF printing

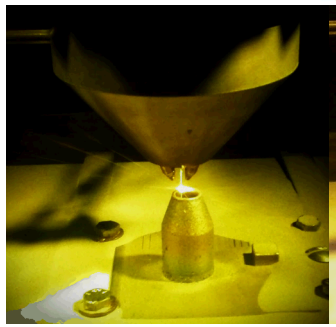
Example parts made by the LENS and PBF processes

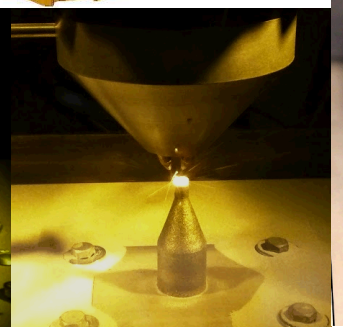
Starting 316L atomized feedstock powders



LENS

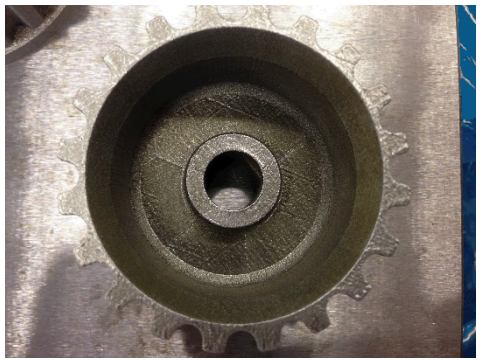




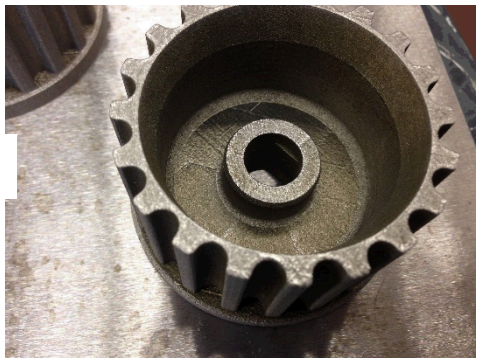


2”

PBF

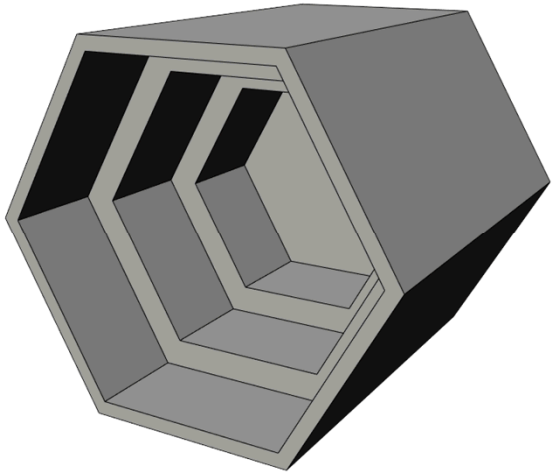


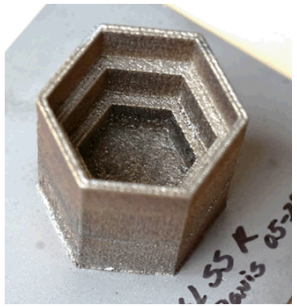
21/2”



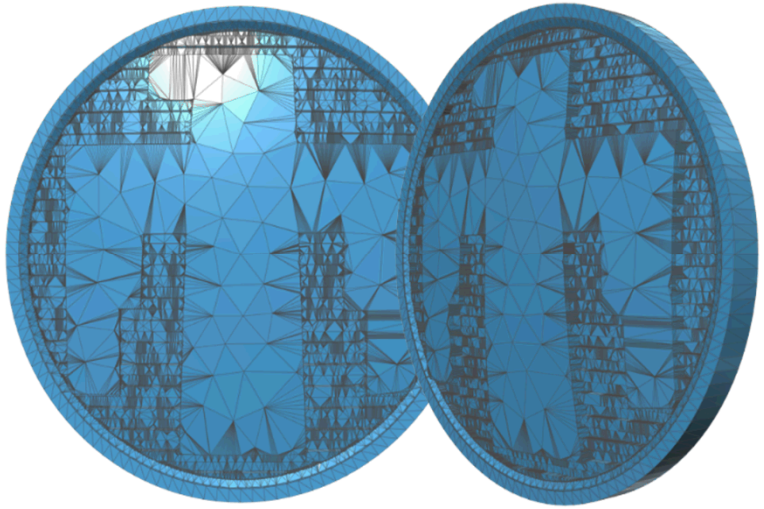
3-D CAD drawings (STL file format) of AM test artifacts

LENS-Hexagon

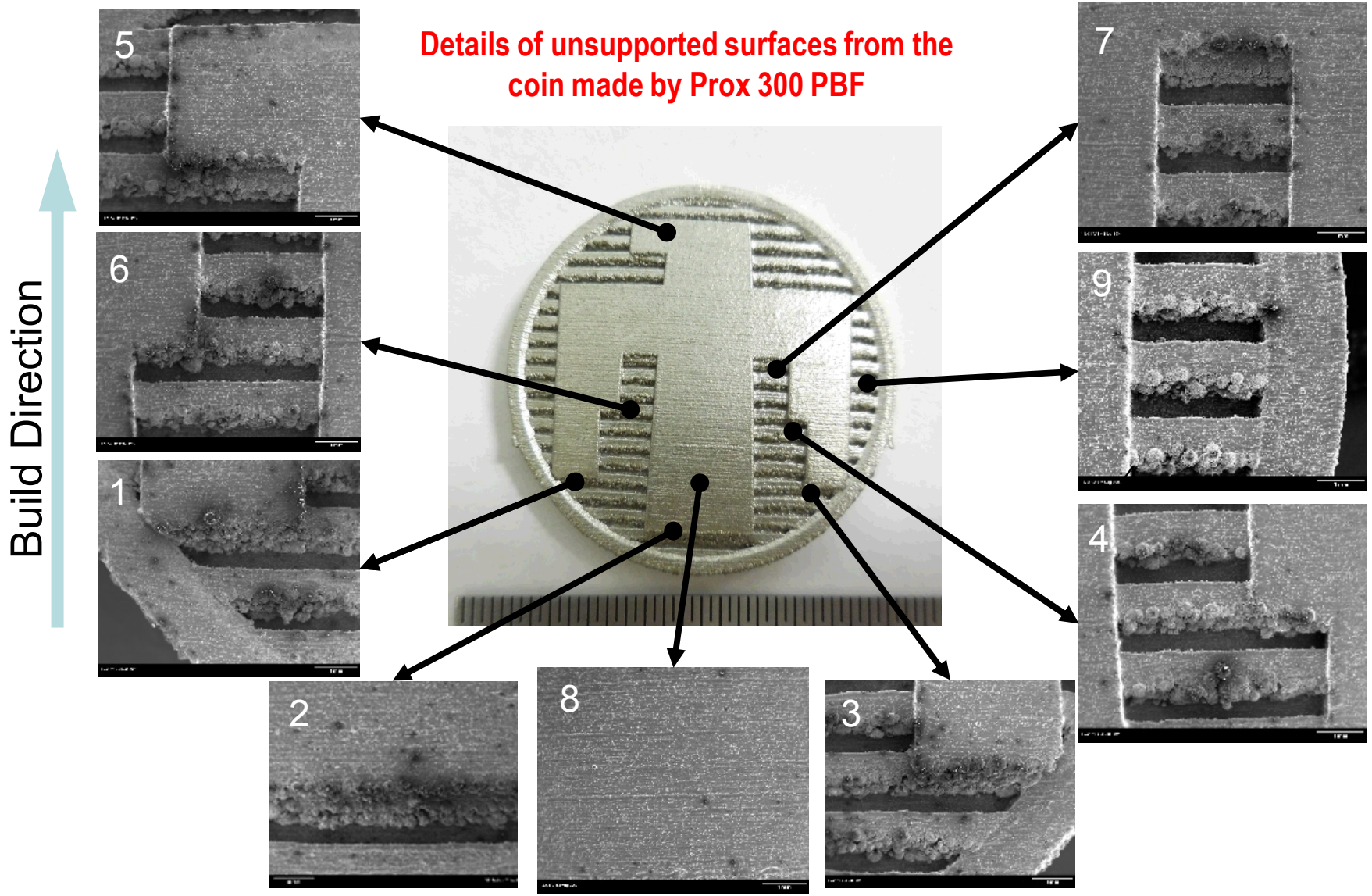




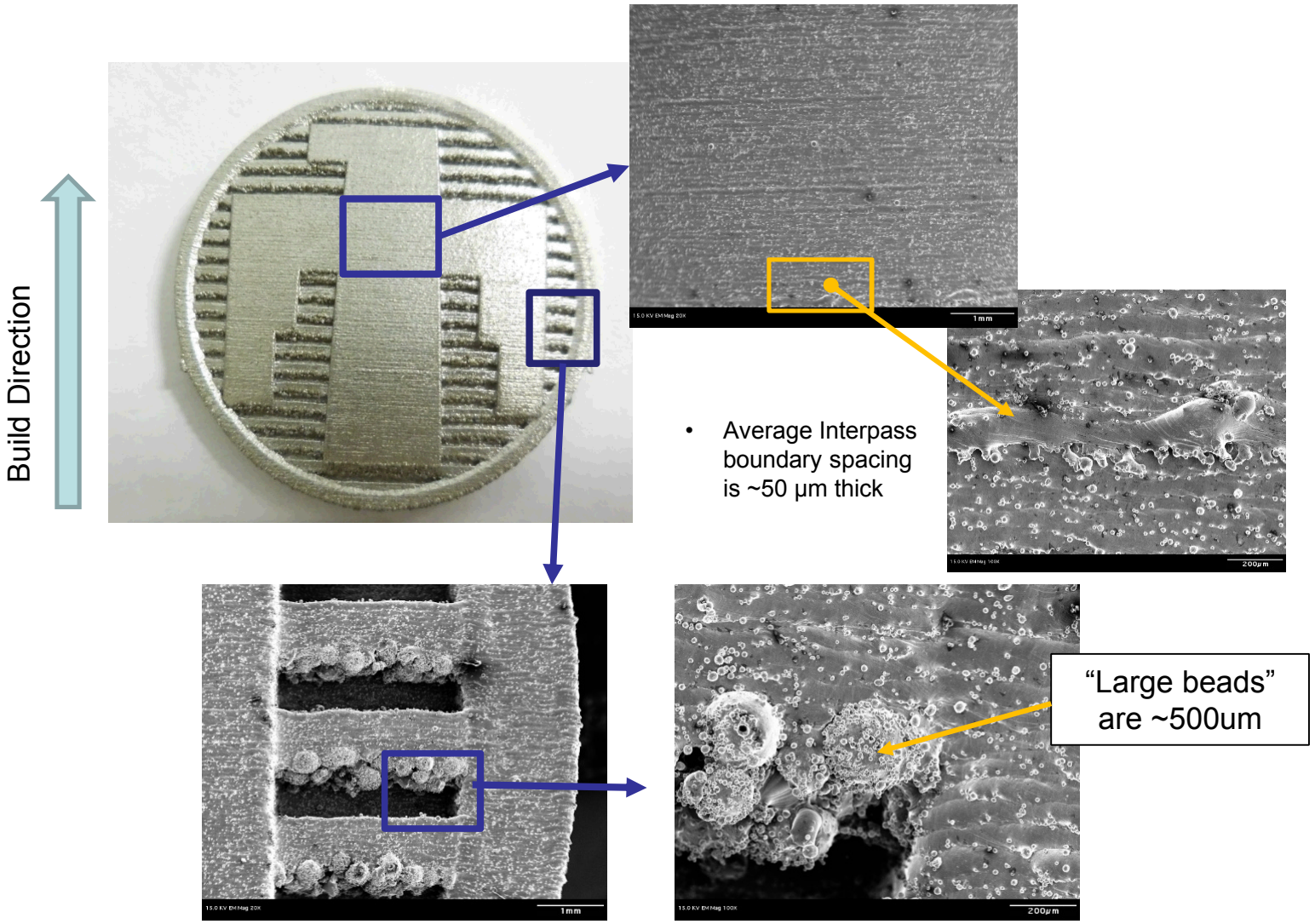
PBF-coin



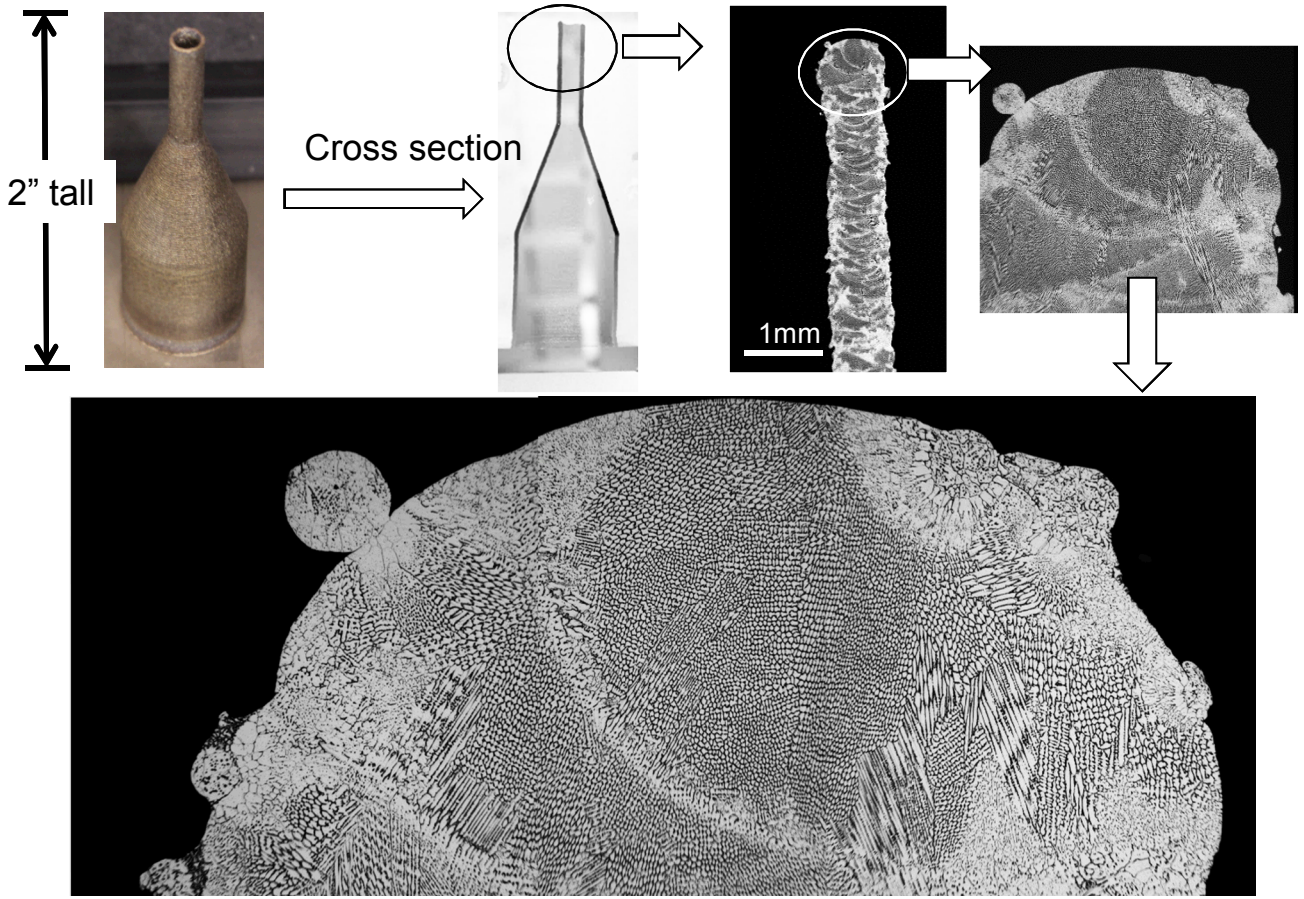
Scientists/engineers need to study the material properties using SEM



Coin Produced by ProX 300 PBF at SNL/CA



The partially fused powders are also a problem with LENS



Summary

There are two powder-base AM processes, called LENS and PBF, that produce the parts with different surface properties.

We observed dripping beads on PBF unsupported features and unmelted feedstock powders on LENS part's surface.

These surface properties can be revealed clearly by SEM images.

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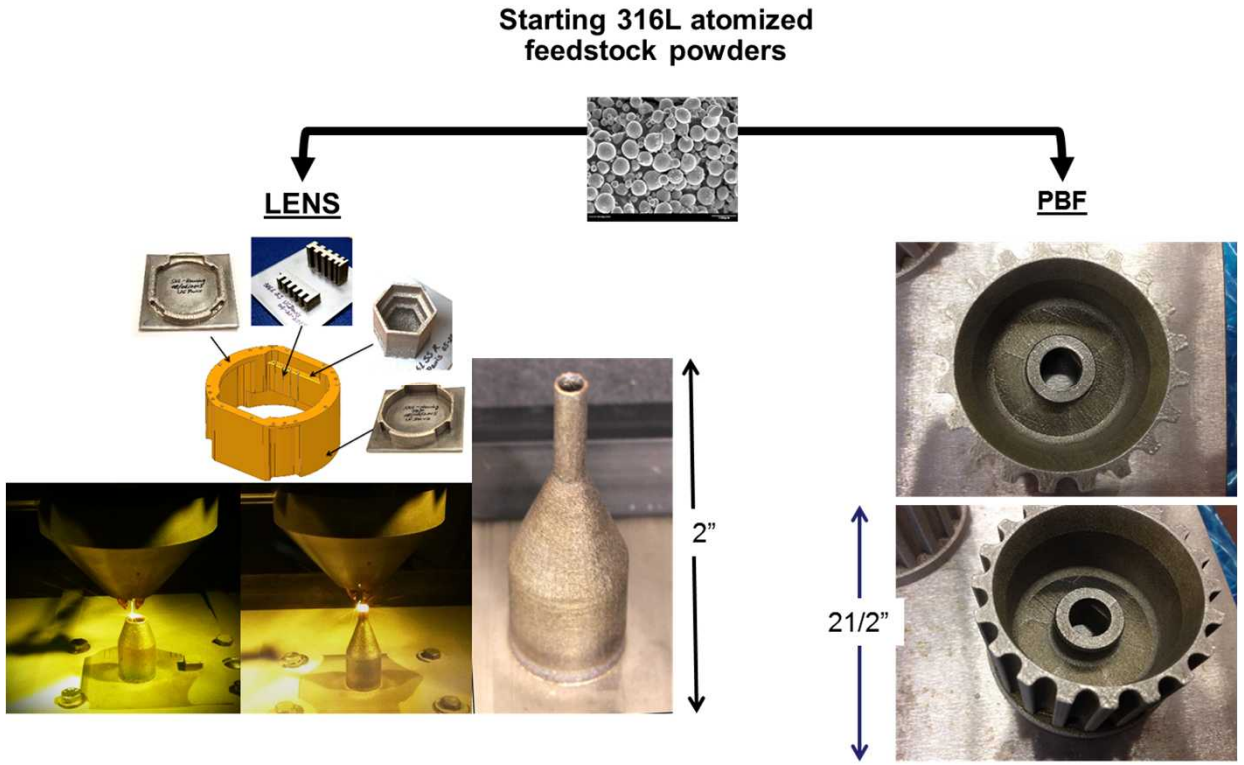
Thank You!

Programmatic Background and Objective

- Sandia is developing AM technology to build engineering components.
- For technology maturation, we need to understand how the feedstock powder affects AM processing, i.e., tap density and flow rate.



Overview

- Compare LENS AR and Recycled Powder
  - OM and SEM imaging
  - Tap Density
  - Flow Rate

- Compare PBF Dug and Recycled Powder
  - SEM imaging
  - Tap Density
  - Flow Rate

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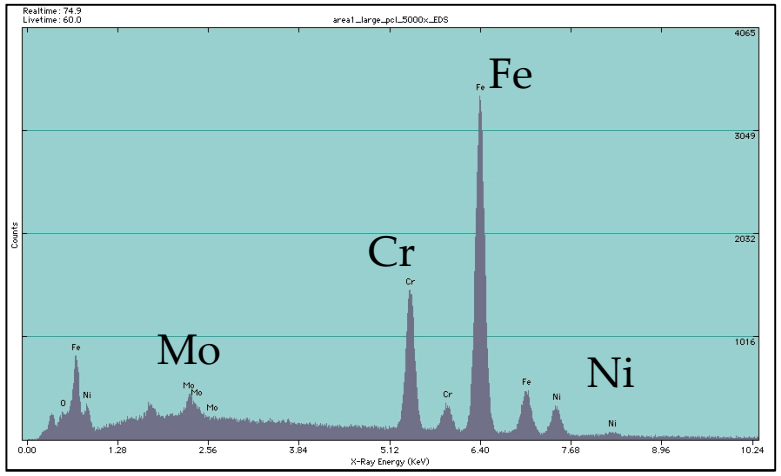
Materials of Interest

316L Stainless Steel is atomized into powder

- LENS printing, UCI (> 50 μm)
  - As received
  - Recycled ~6-8 times
- PBF printing, SNL,CA (< 40 μm)
  - Dug from 3D printer
  - Recycled ~44 hours

316L Alloy Composition by EDS



Quantitative Results for area1_large_pcl_5000x_ED
Analysis: Bulk Method: Standardless
Acquired 22-Jan-2015, 15.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	MDL	Atomic %
Cr	16.86	0.86	0.26	18.10
Fe	70.84	1.77	0.22	70.77
Mo	1.84	0.58	1.18	1.07
Ni	10.41	0.70	0.83	9.89
O ?	0.05	0.02	2.68	0.17
Total	100.00			

? This element is statistically insignificant.

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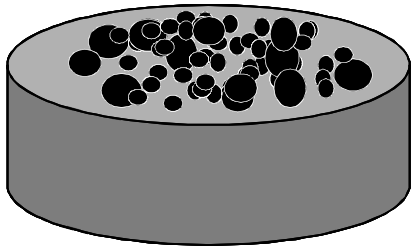
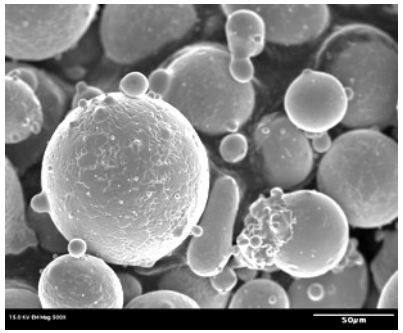
Experimental Procedures

Shape and Surface Roughness



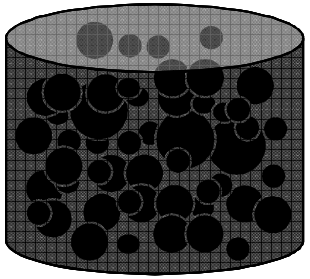
Mount

SEM

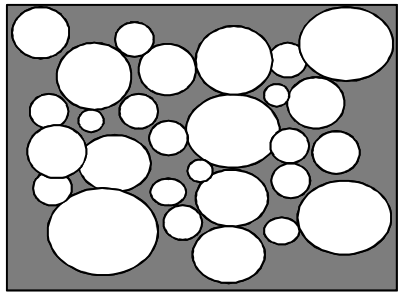


Analyze

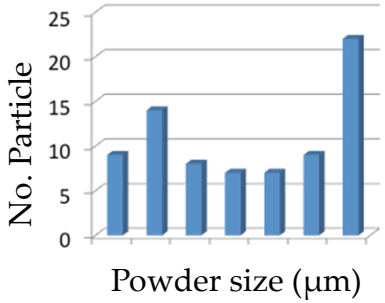
Powder Size and Distribution



Cross section



OM



Analyze with Image J

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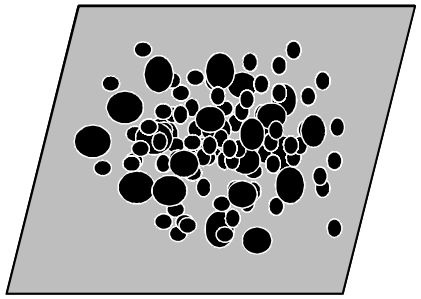
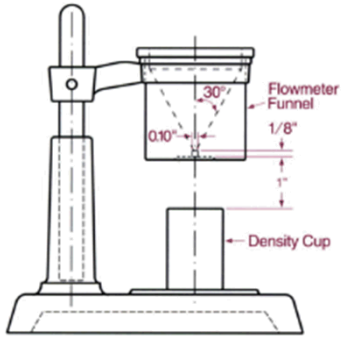
Experimental Procedures

Powder Feed Rate



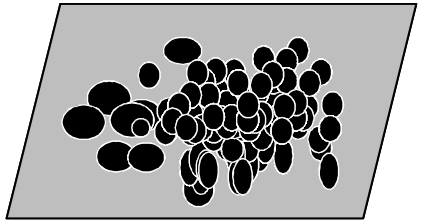
Weigh



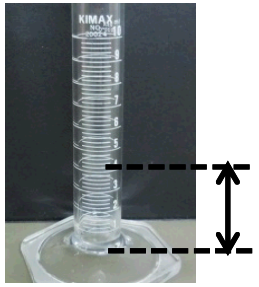
Fill

Time

Tap density



Weigh



Measure

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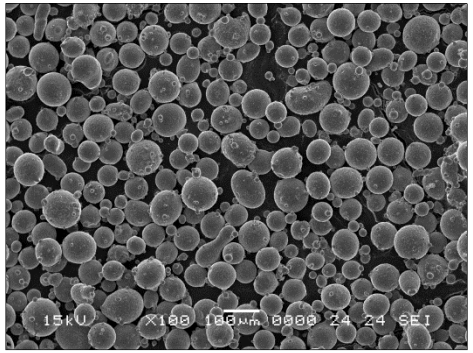
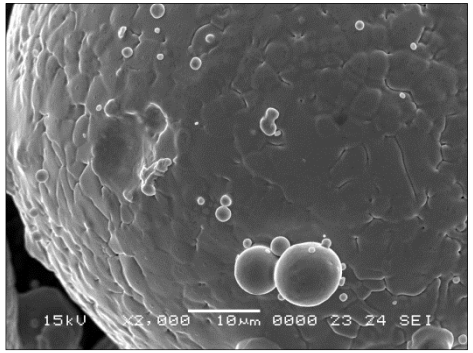
Experimental Data: Powder Shape and Surface Roughness

LENS AR

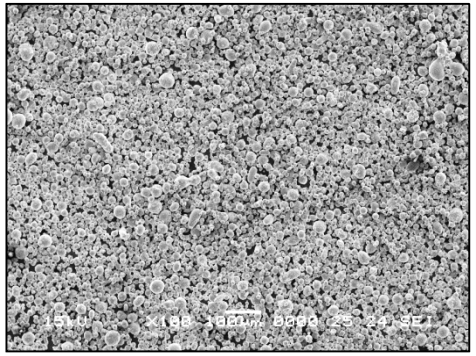


100x



2000x

PBF Dug



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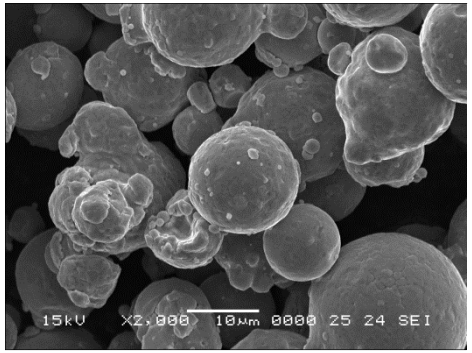
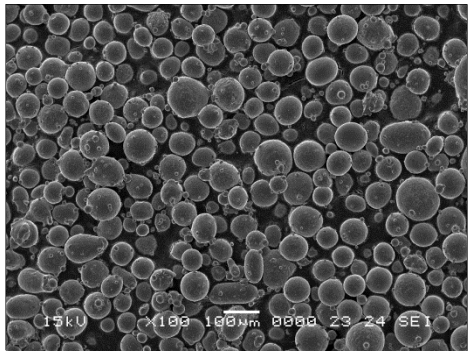


2000x

LENS Recycled



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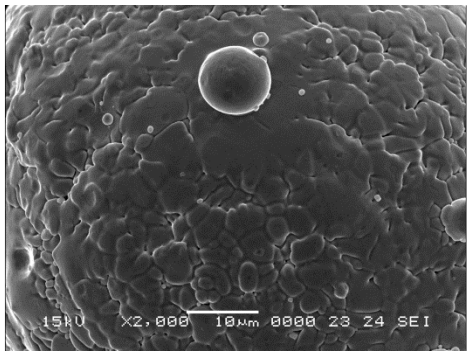
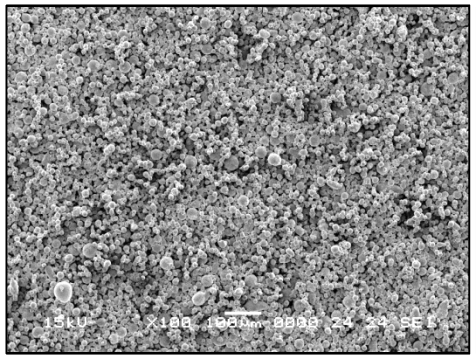


2000x

PBF Recycled



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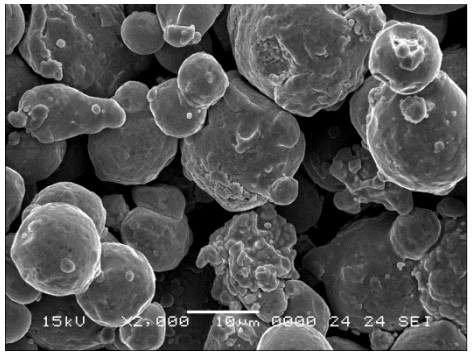
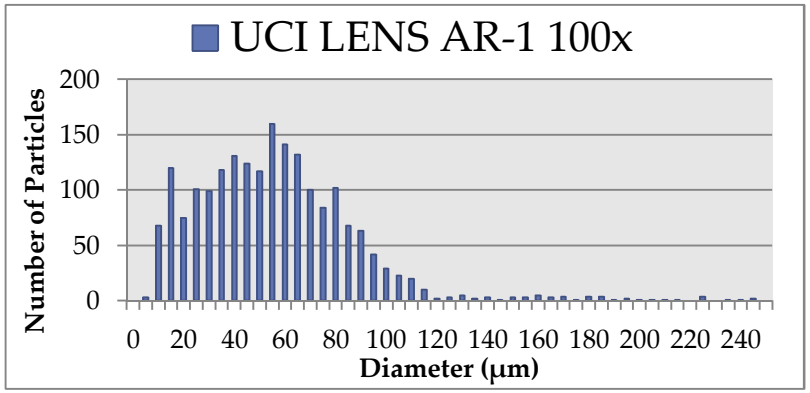
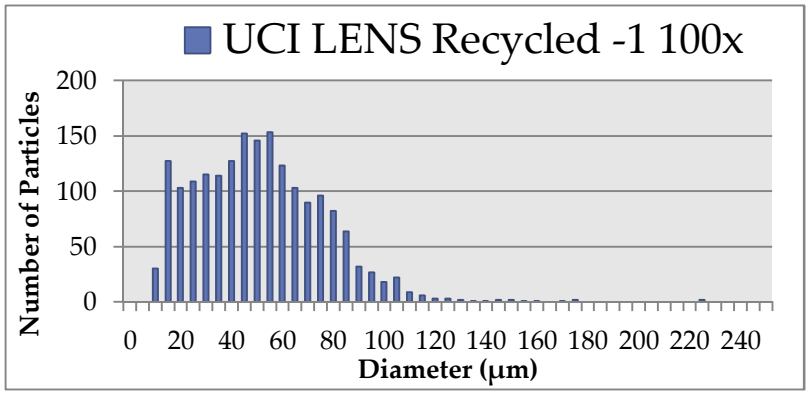
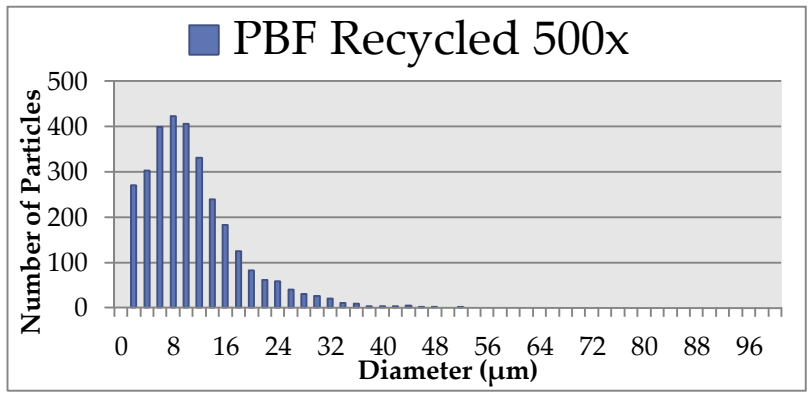


2000x

Experimental Data: Powder Size and Distribution







Average Size of Feedstock Powders (µm)				
		NP	RH	Average
UCI LENS AR-1	100x	54.152	51.159	52.656
	200x	47.474	43.958	
UCI LENS Recycled-1	100x	48.847	48.902	48.875
	200x	50.088	64.936	

Average Size of Feedstock Powders (µm)				
		NP	RH	Average
PBF Dug	N/A			
PBF Recycled	200x	N/A	8.141	<< 40
	500x	10.005	N/A	

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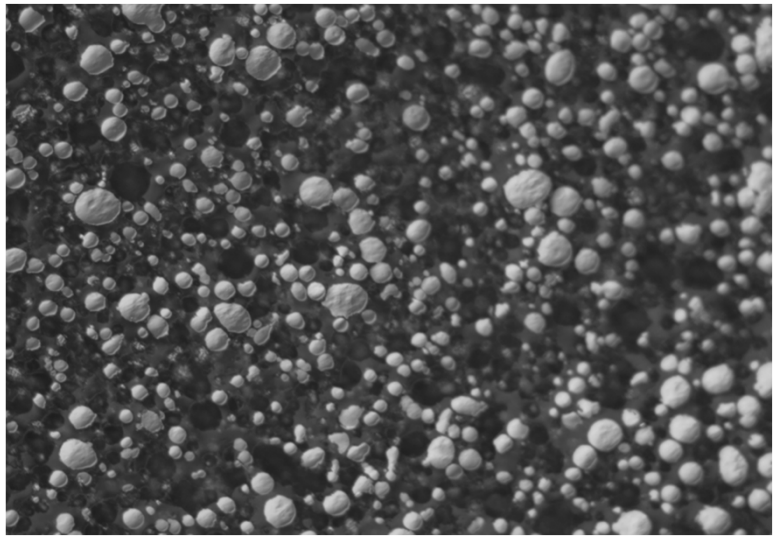
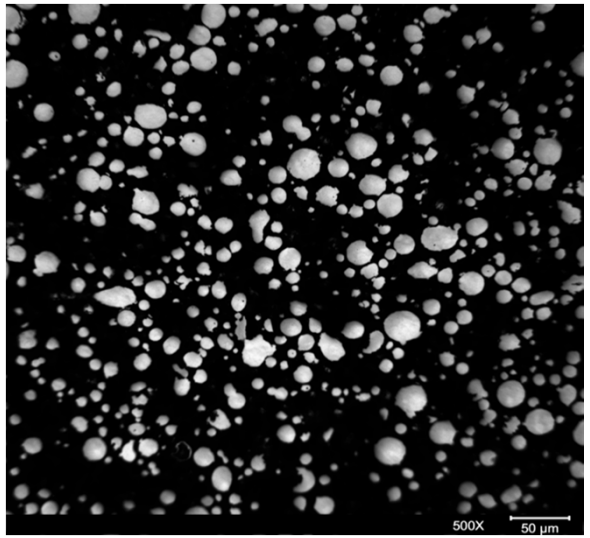
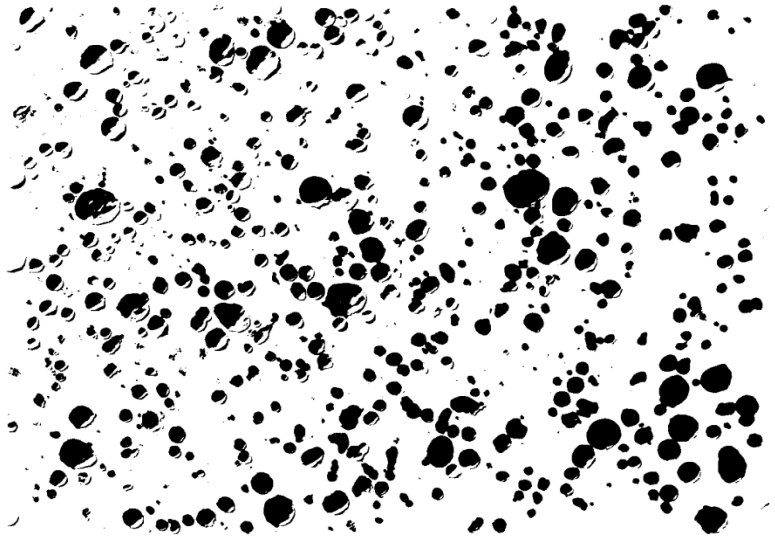
Experimental Data: Powder Size and Distribution

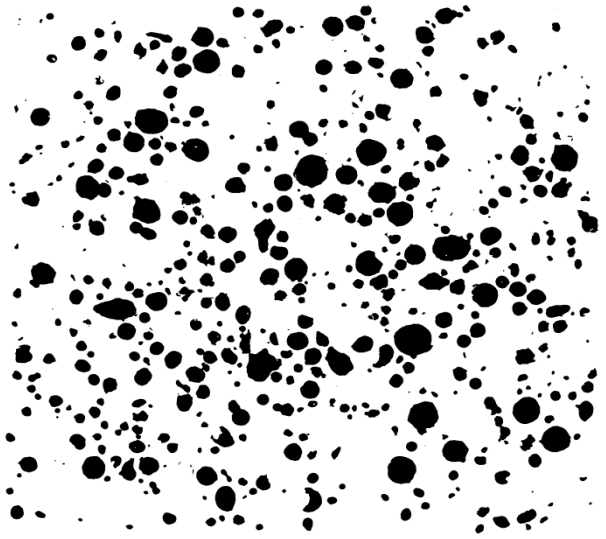
PBF Recycled Leica 200x



PBF Recycled Leitz 500x







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Experimental Data: Powder Flow Rate

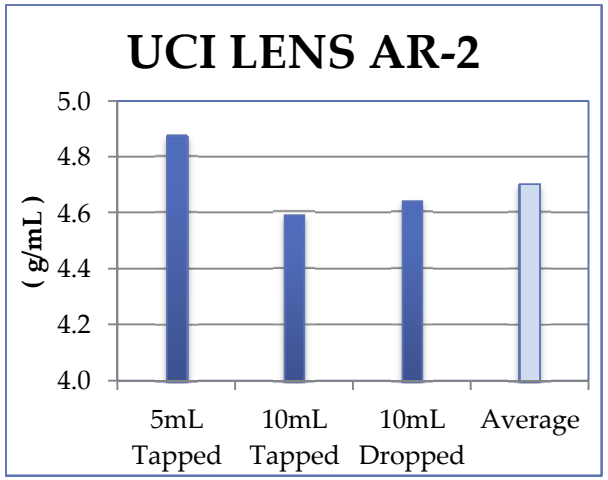
0.10” Orifice
Flow Rate (g/sec)

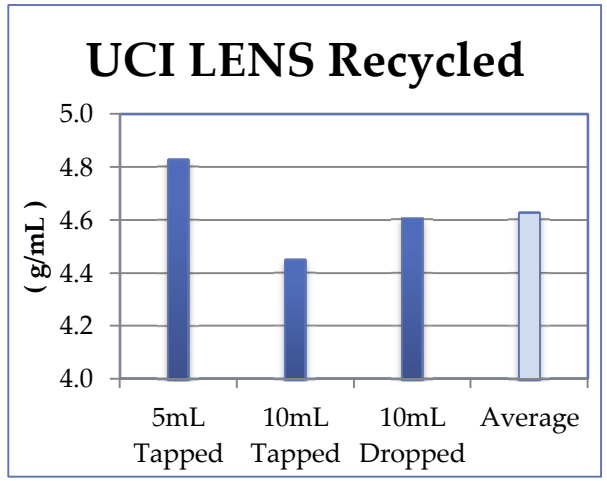
UCI LENS AR	
Carney Meter	
NP	RH
13.42	14.69
13.65	14.83
13.42	15.02
13.54	15.26
13.65	14.98
14.25	

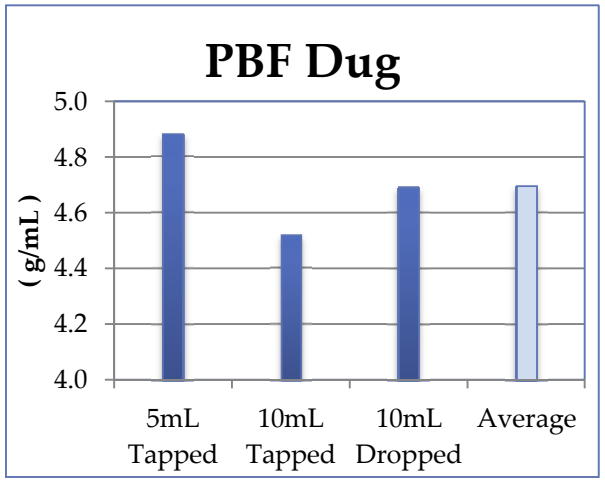
UCI LENS Recycled	
Carney Meter	
NP	RH
14.84	15.59
14.57	15.40
14.43	15.55
14.06	15.60
14.26	15.56
14.99	

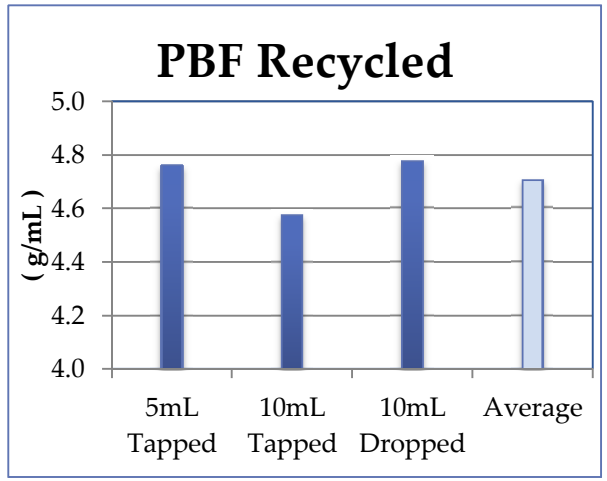
5.2% increase

Experimental Data: Tap density









UCI LENS AR - 2			
Tapped		Dropped	Average
5mL	10mL	10mL	
4.88	4.59	4.64	**4.702**

UCI LENS Recycled			
Tapped		Dropped	Average
5mL	10mL	10mL	
4.83	4.45	4.61	**4.629**

PBF Dug			
Tapped		Dropped	Average
5mL	10mL	10mL	
4.88	4.52	4.69	**4.695**

PBF Recycled			
Tapped		Dropped	Average
5mL	10mL	10mL	
4.76	4.58	4.78	**4.703**

Minimal changes in tap density for both LENS and PBF

Summary and Conclusions

Flow Rate
- LENS AR vs Recycled:
  - 5.2% increase
  - More powder per second

Tap Density
- LENS AR vs Recycled:
  - 1.6% decrease
  - Less particles fit in volume
- PBF Dug vs Recycled:
  - < 1% increase
  - Insignificant change

Shape and Surface Roughness
- LENS AR vs Recycled:
  - Both maintain spherical shape
  - Recycled increases in roughness
- PBF Dug vs Recycled:
  - Recycled becomes more deformed
  - Losing spherical shape, increasing roughness

Particle Size
- LENS AR vs Recycled:
  - ~7% decrease
  - Minimal differences

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Thank You!

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