



MIPAR

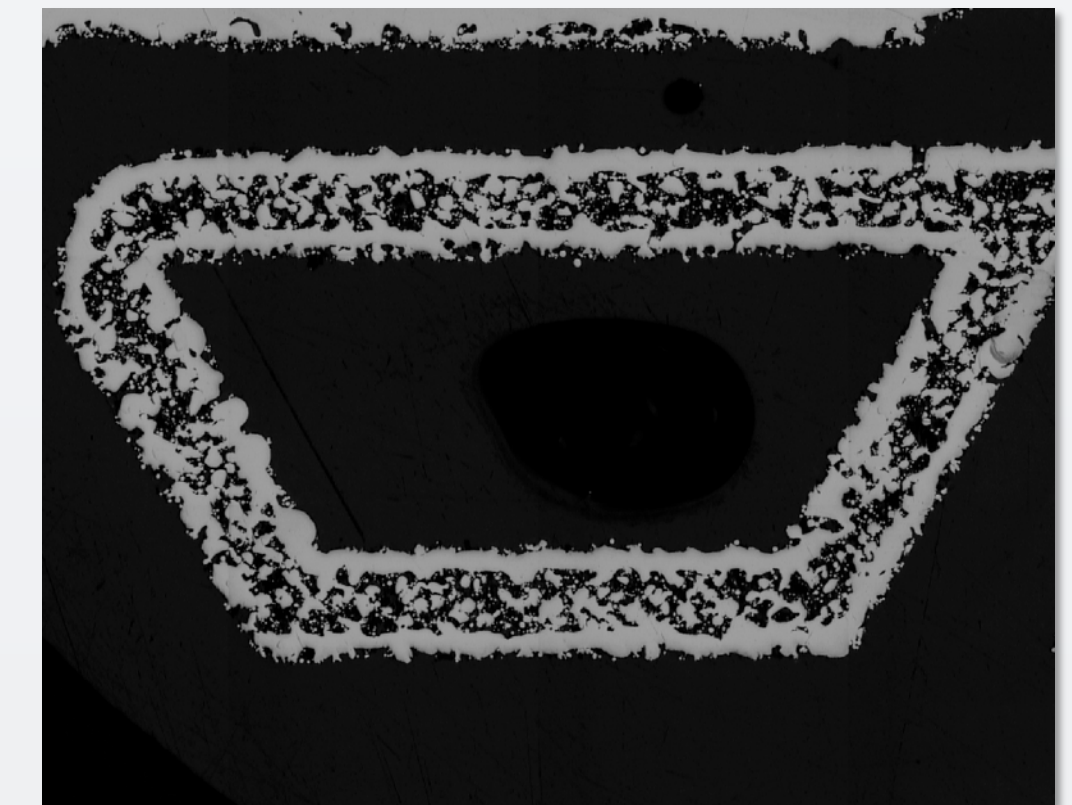
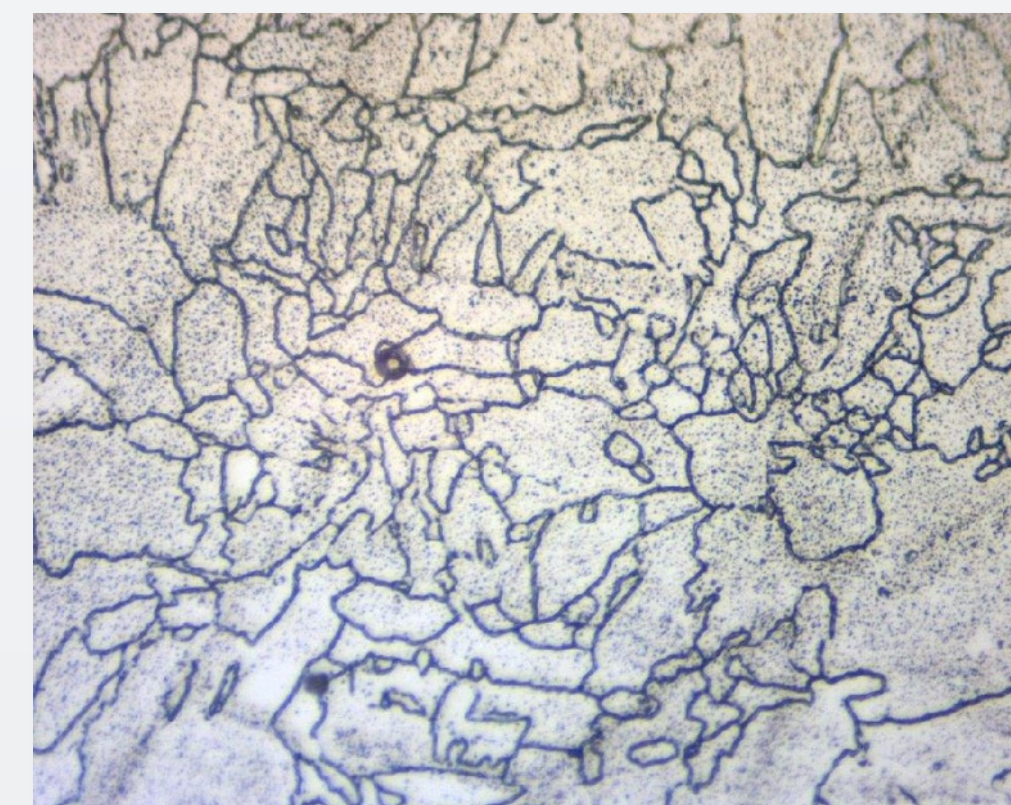
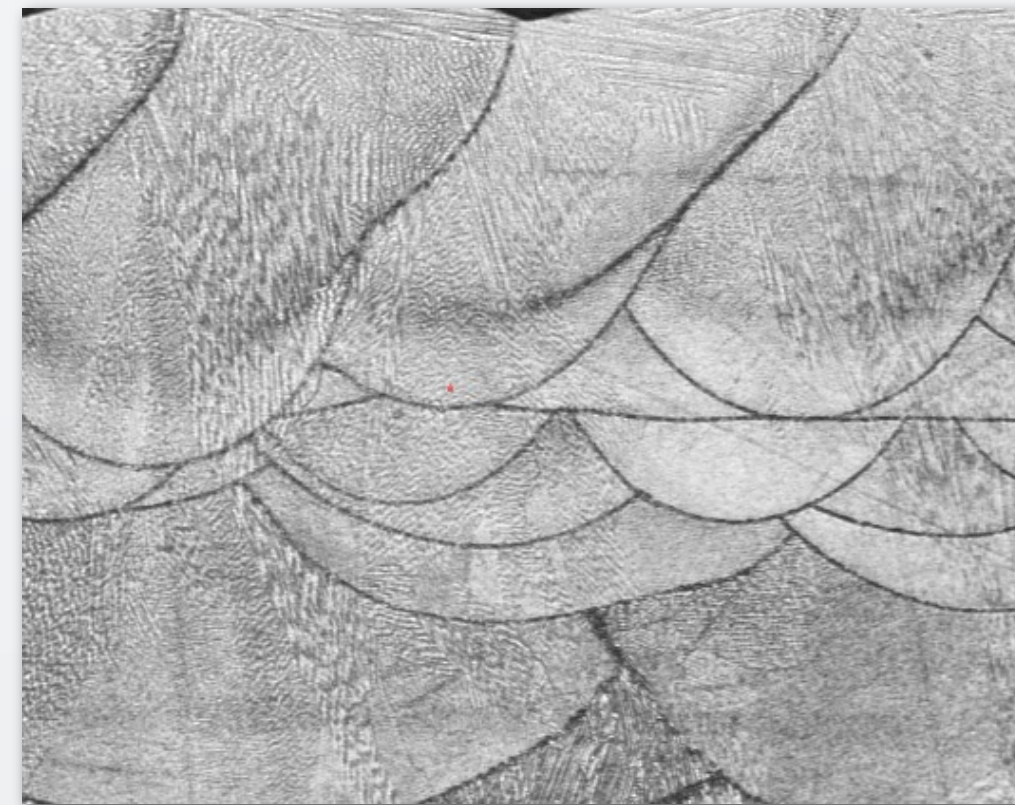
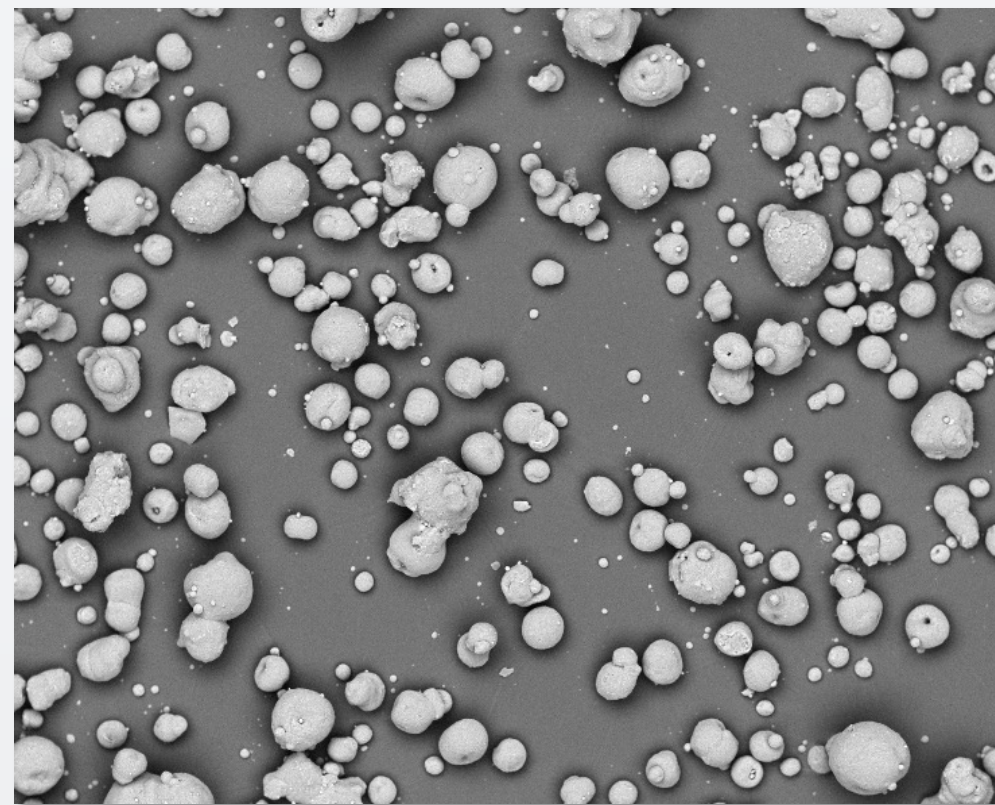
Image Analysis Software

Microstructural Characterization

Simple. Uniquely Powerful.

Microstructural Characterization

Powder → Process → Microstructure → Part



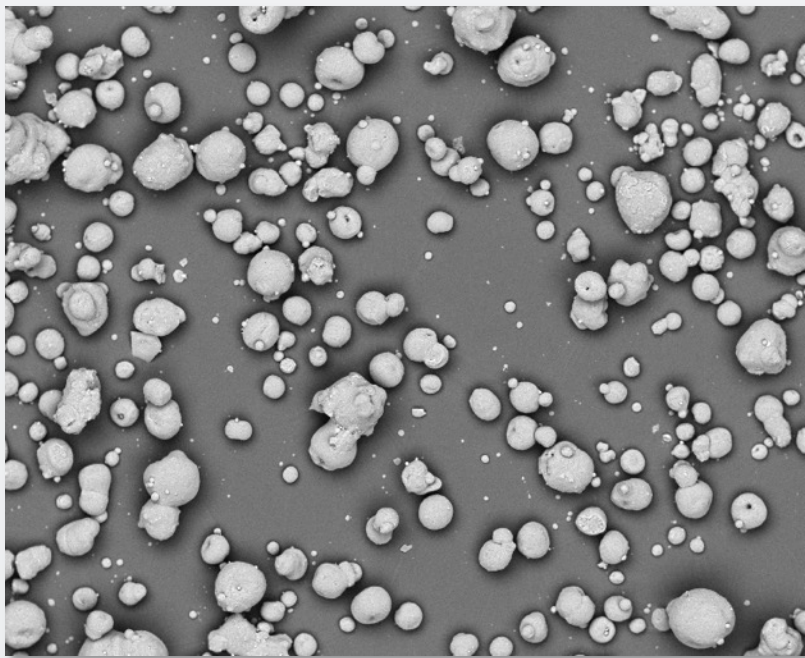
Primary Challenges

Powder → Process → Microstructure → Part

Powder

—

Powder precursor size and shape



Melt Pools

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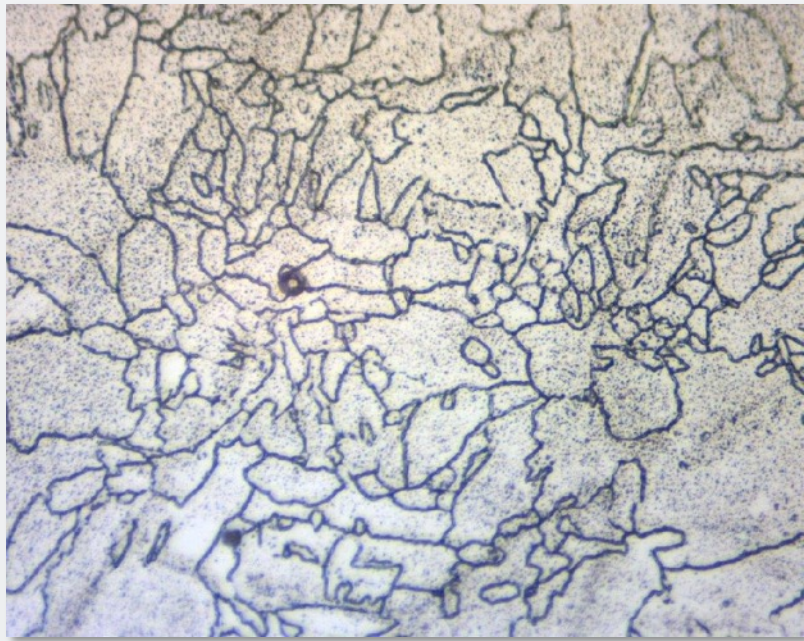
Melt pool dimensions in additive builds



Grains

—

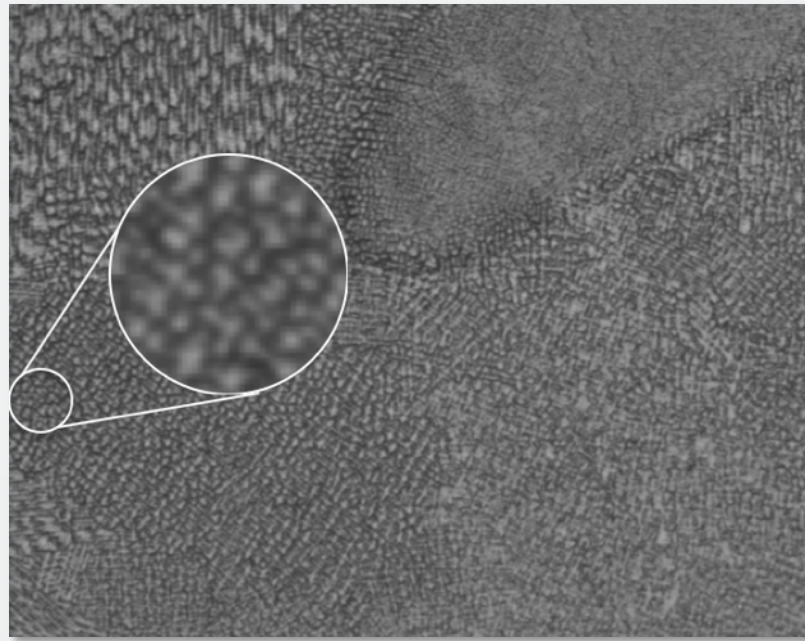
Overall grain size and local banding



Phases

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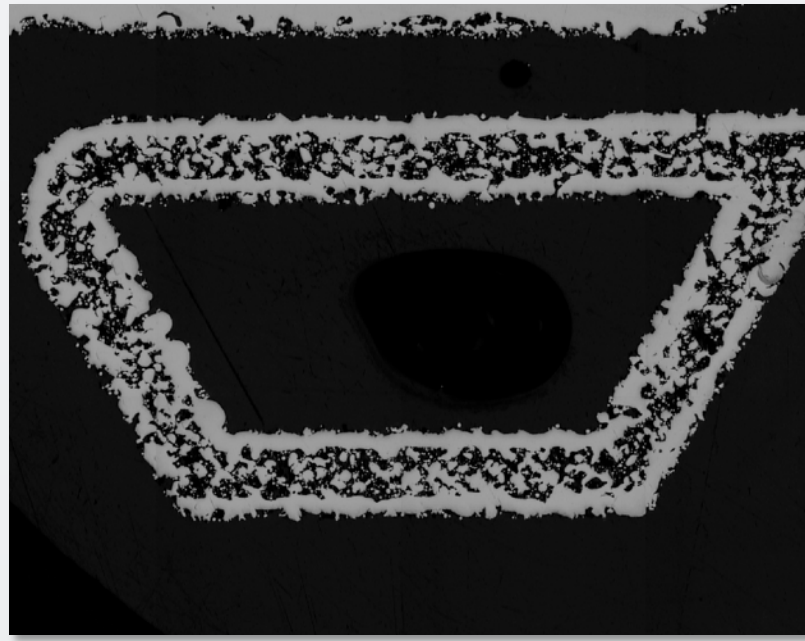
Phase fractions in additive builds



Porosity

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Localized porosity in solid and thin-wall parts



Powder: Size and Shape

Powder

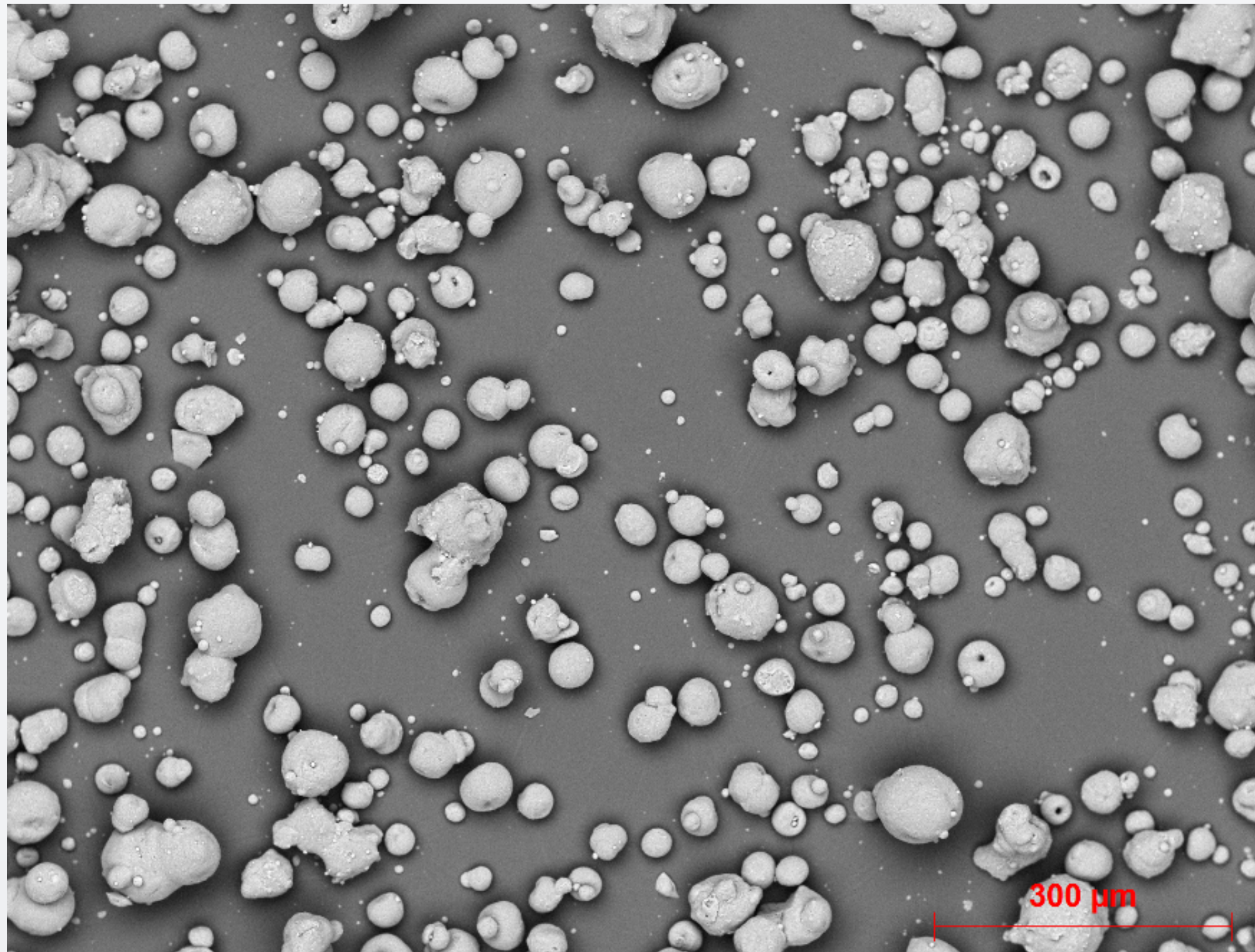
Melt Pools

Grains

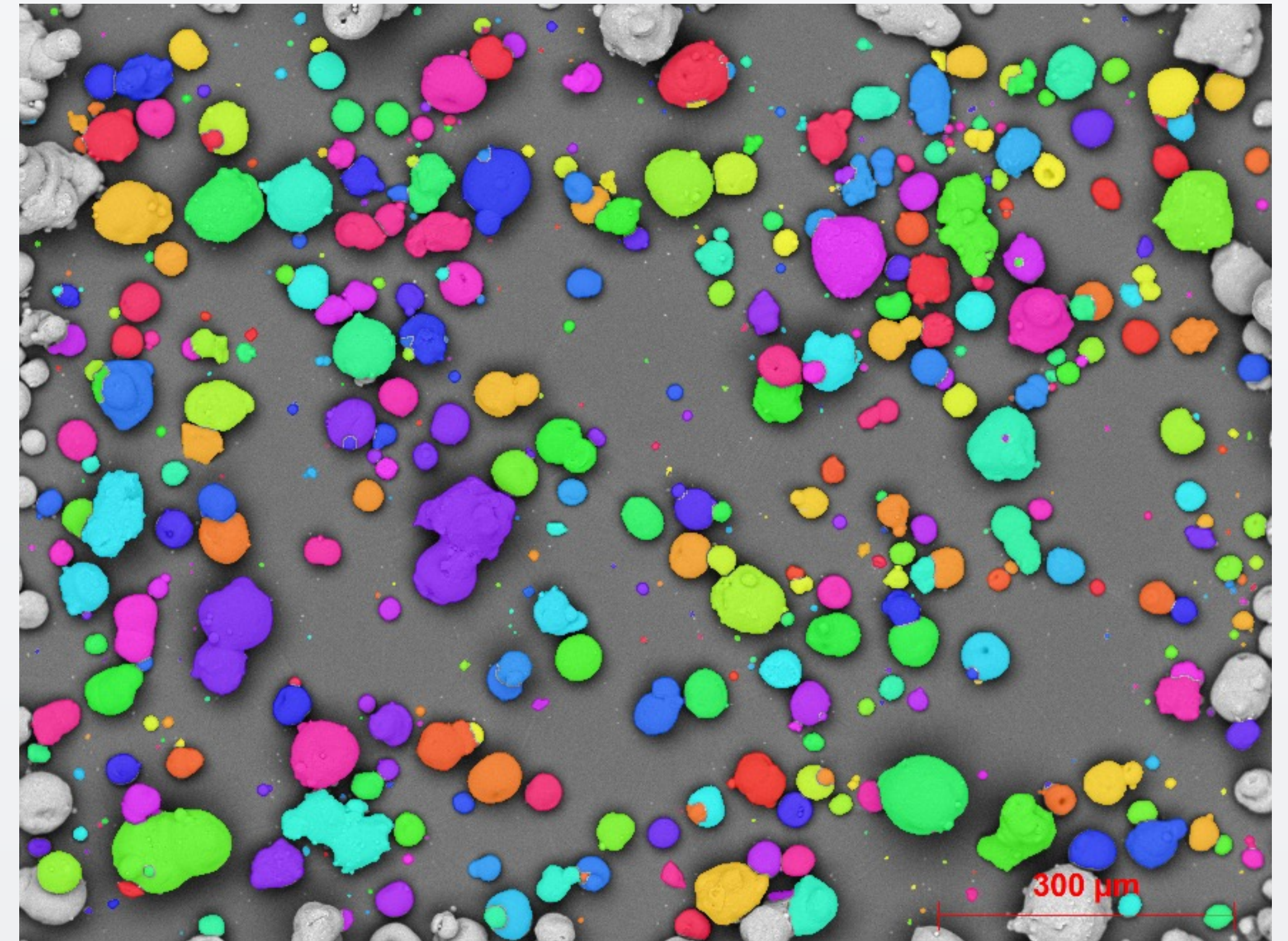
Phases

Porosity

Original



Auto-Detection



Powder: Size and Shape

Powder

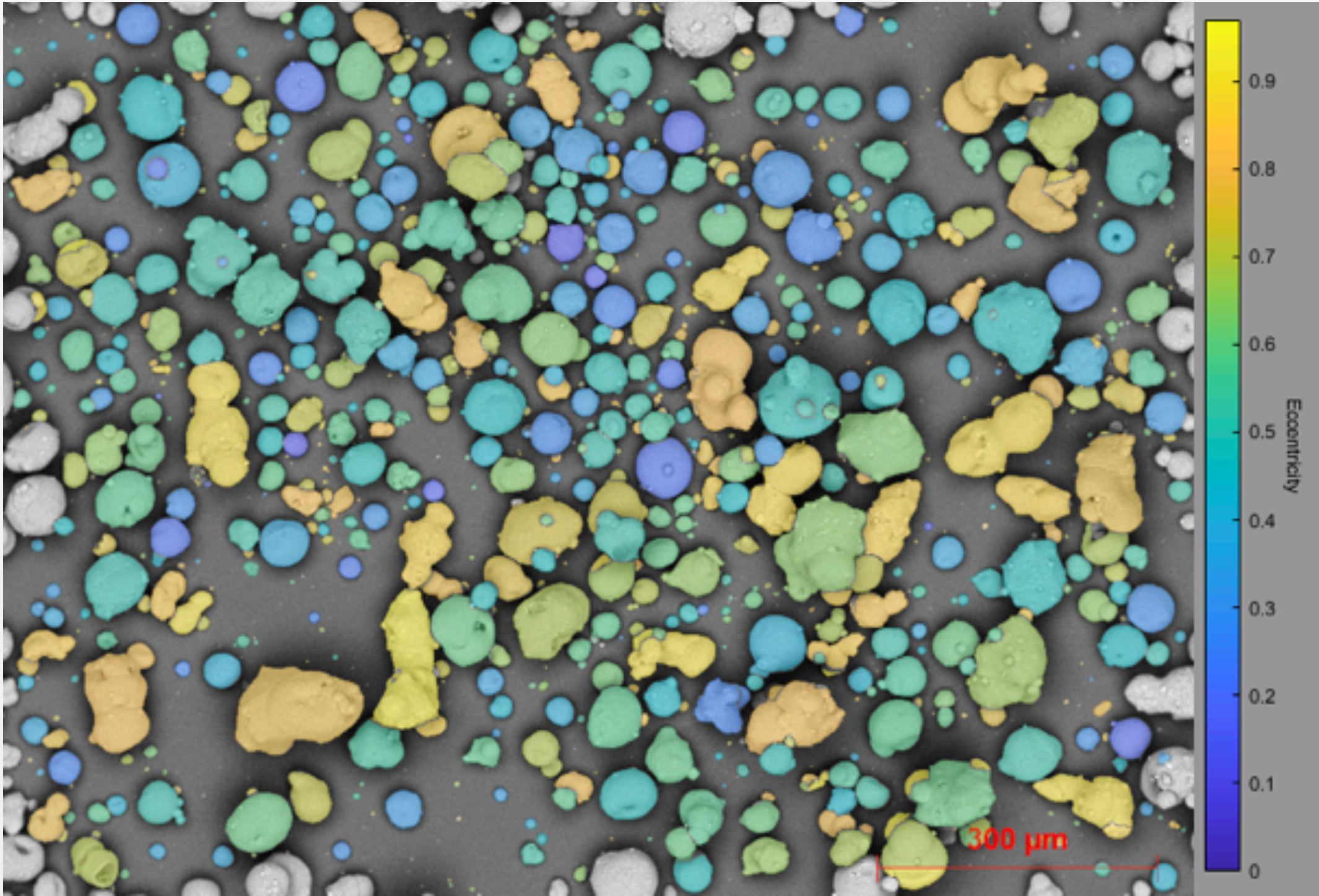
Melt Pools

Grains

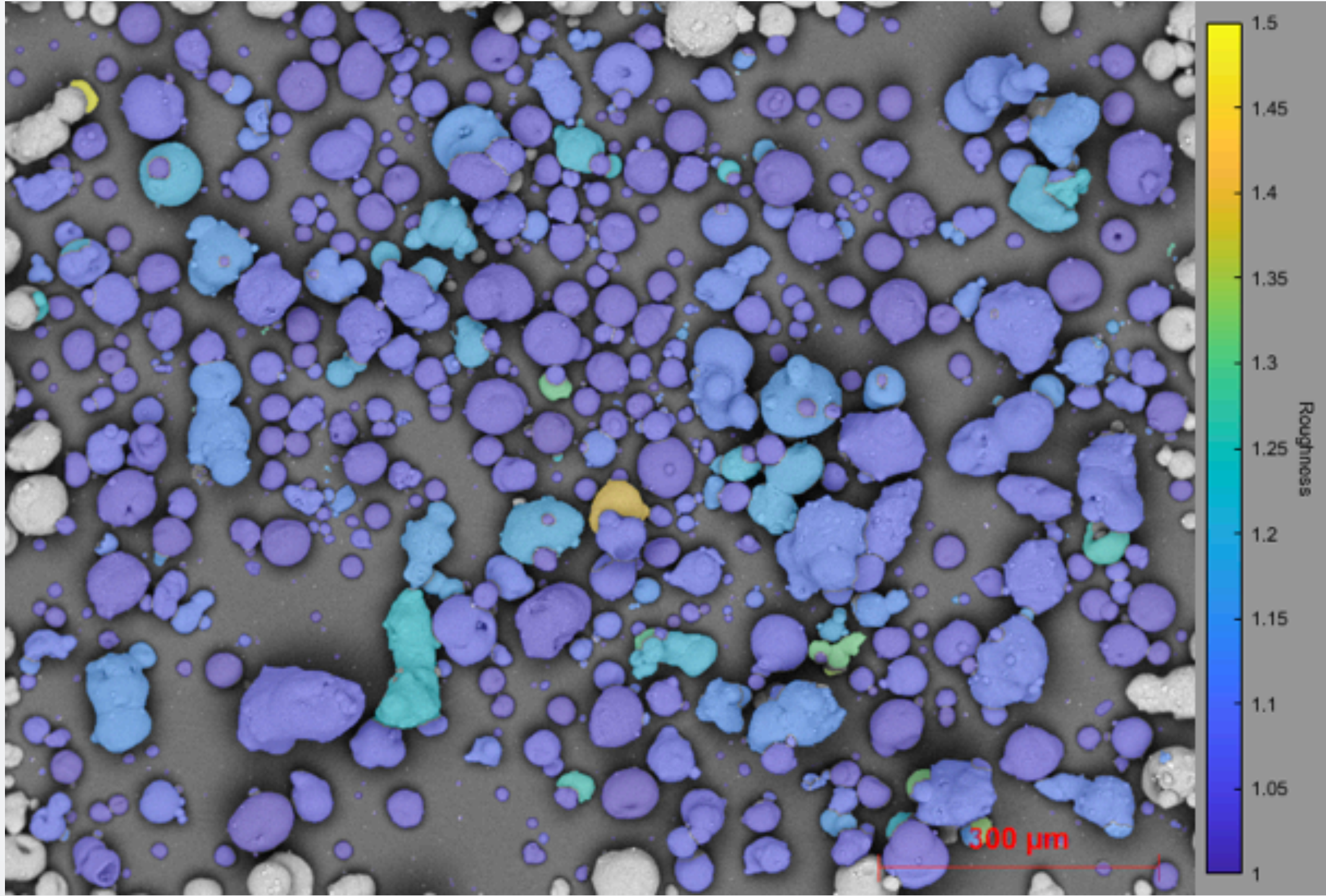
Phases

Porosity

Eccentricity
0 - 1



Roughness
1 - Inf



Melt Pools: Weld Tracks

Powder

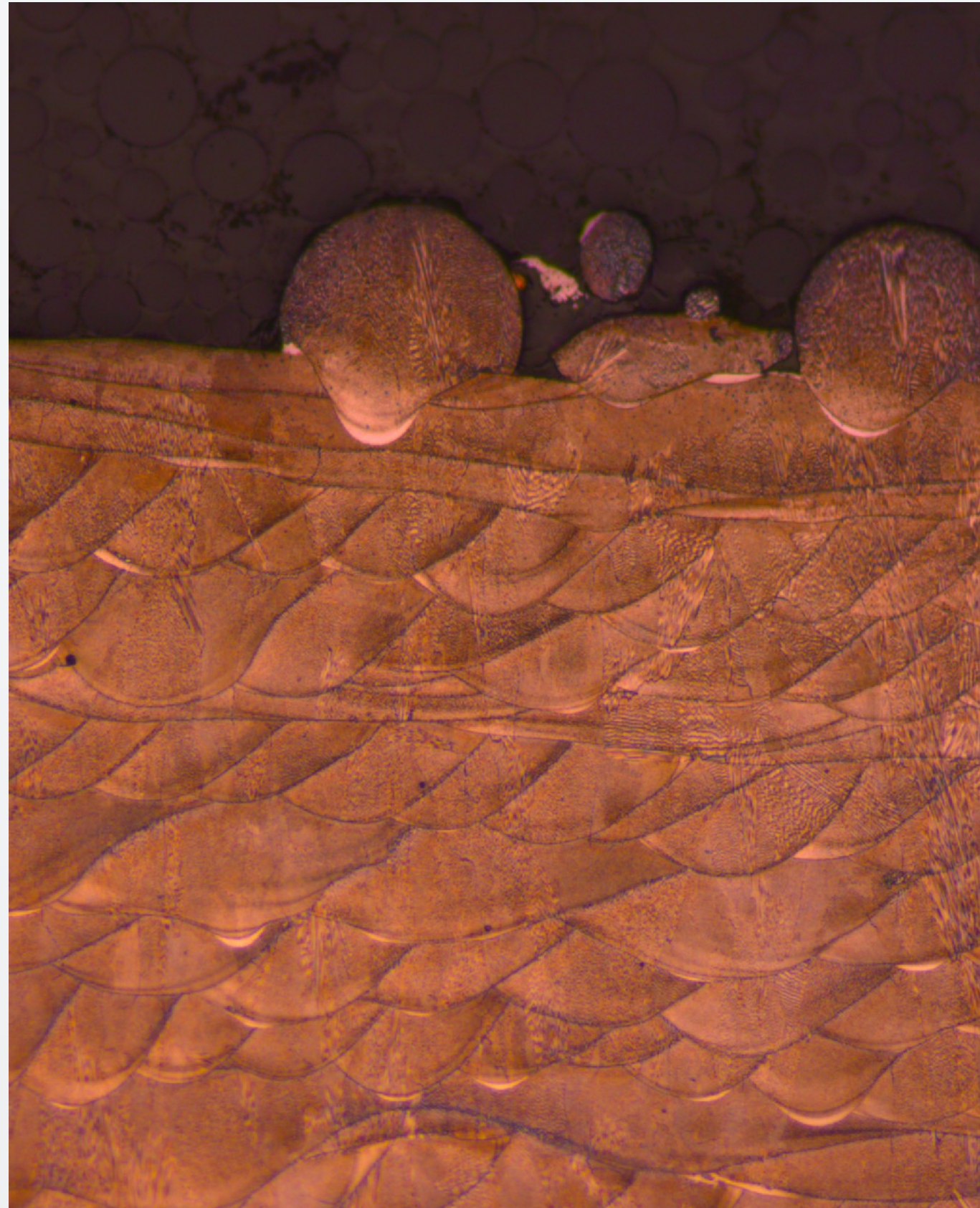
Melt Pools

Grains

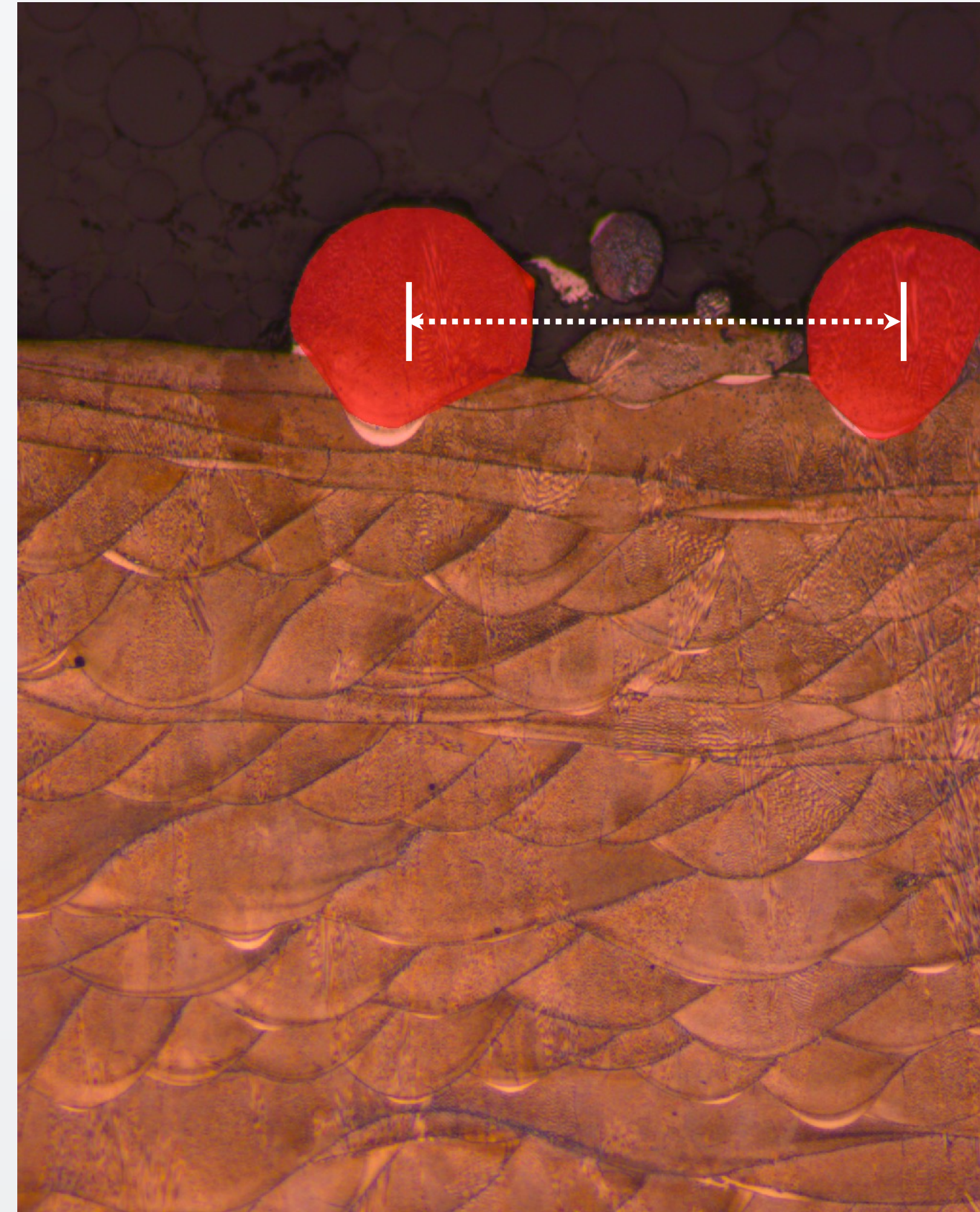
Phases

Porosity

Original

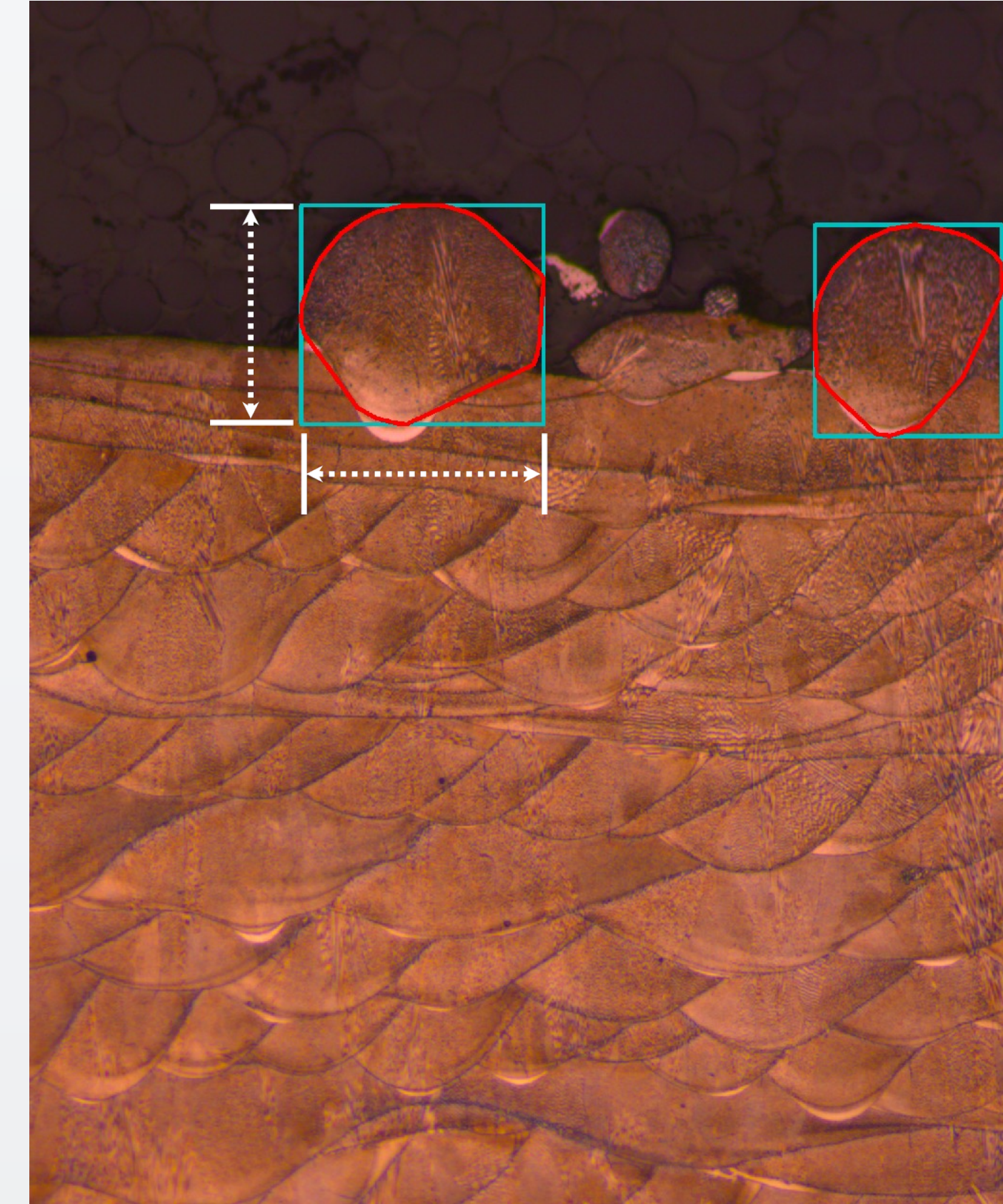


Auto-Detection



Center-to-center distance
can be measured

Bounding Boxes



Melt pool dimensions
can be measured

Melt Pools: Border Region Thickness

Powder

Melt Pools

Grains

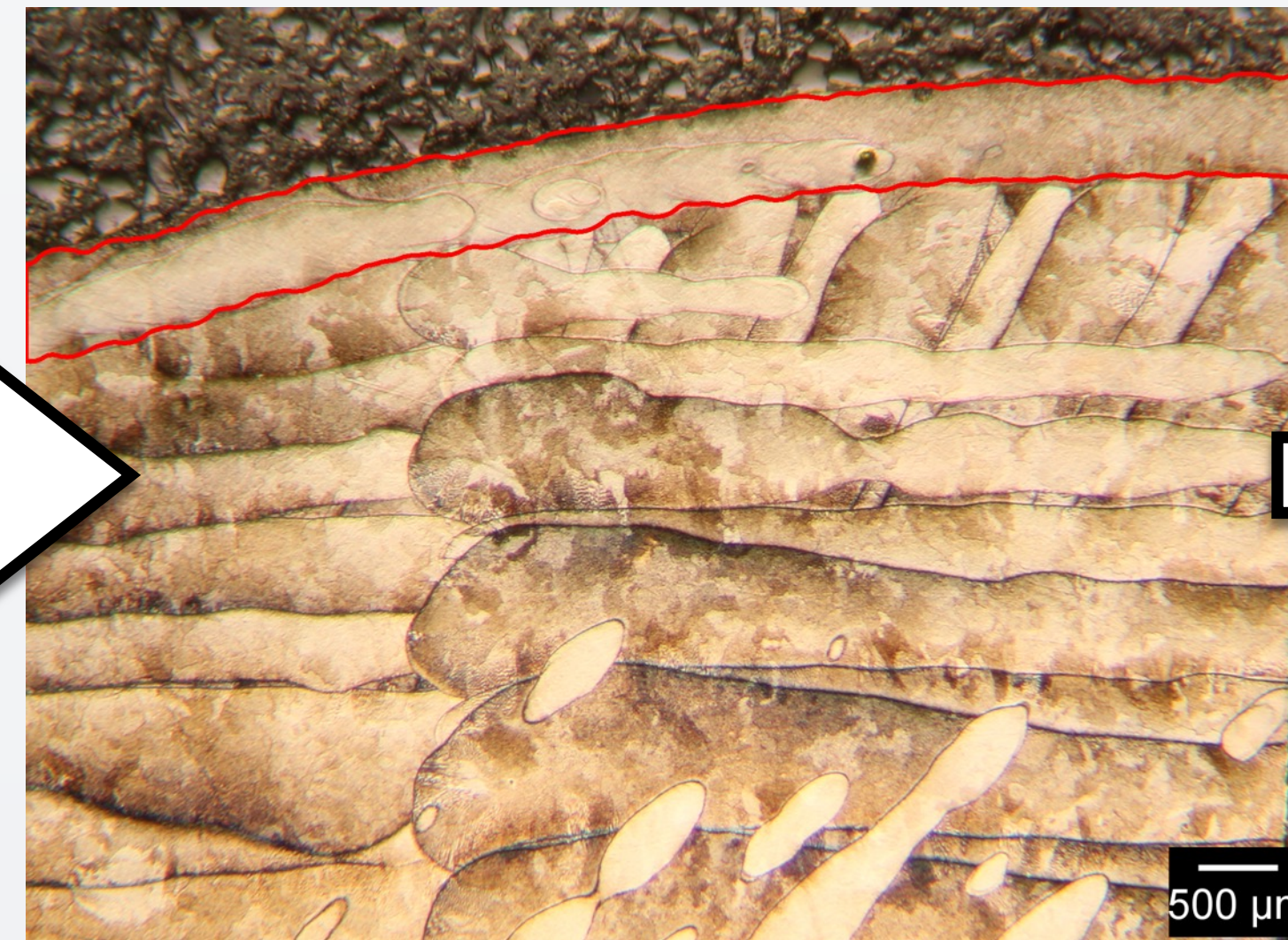
Phases

Porosity

User Traces Inside Region



Border Region "Snapped"



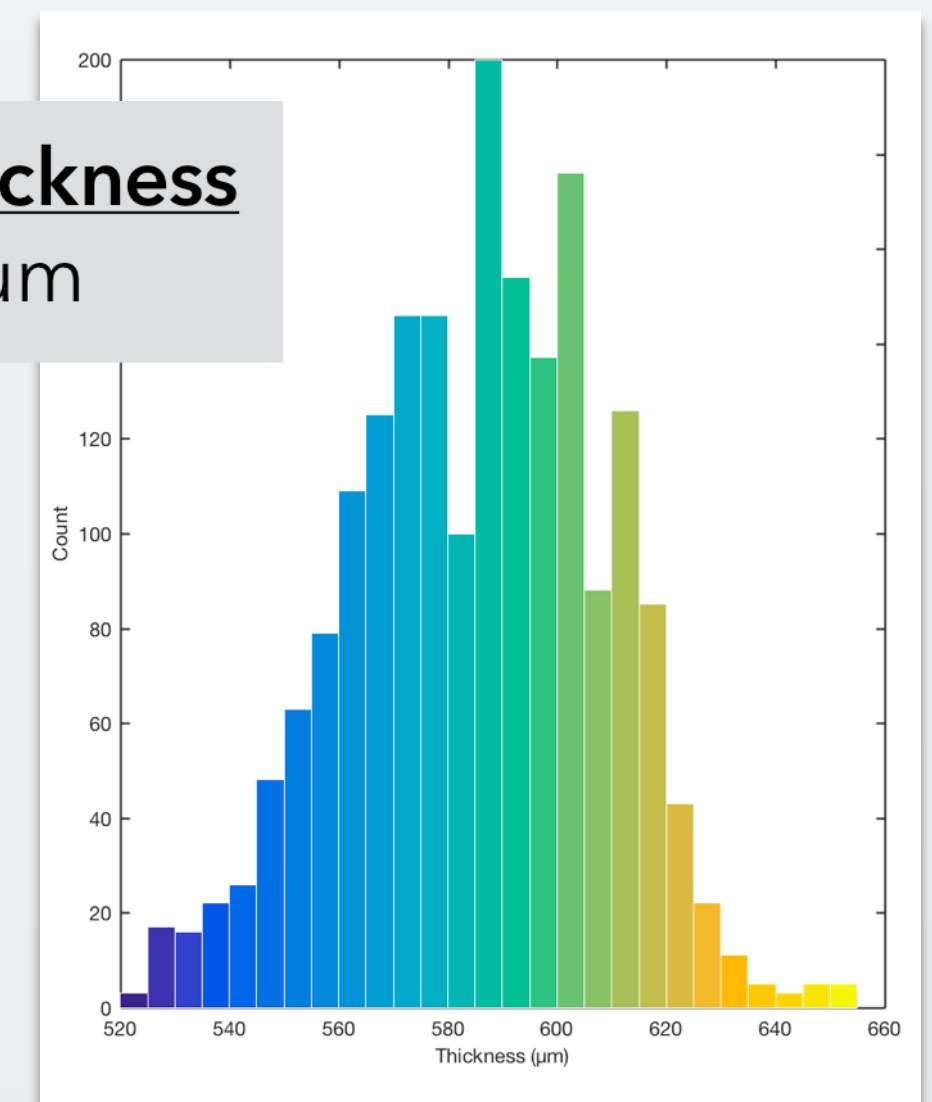
Thickness Measured



- ✓ Border region detected with user oversight
- ✓ Thickness variation measured and visualized

Mean Thickness

585 μm



Melt Pools: Overlap Dimensions

Powder

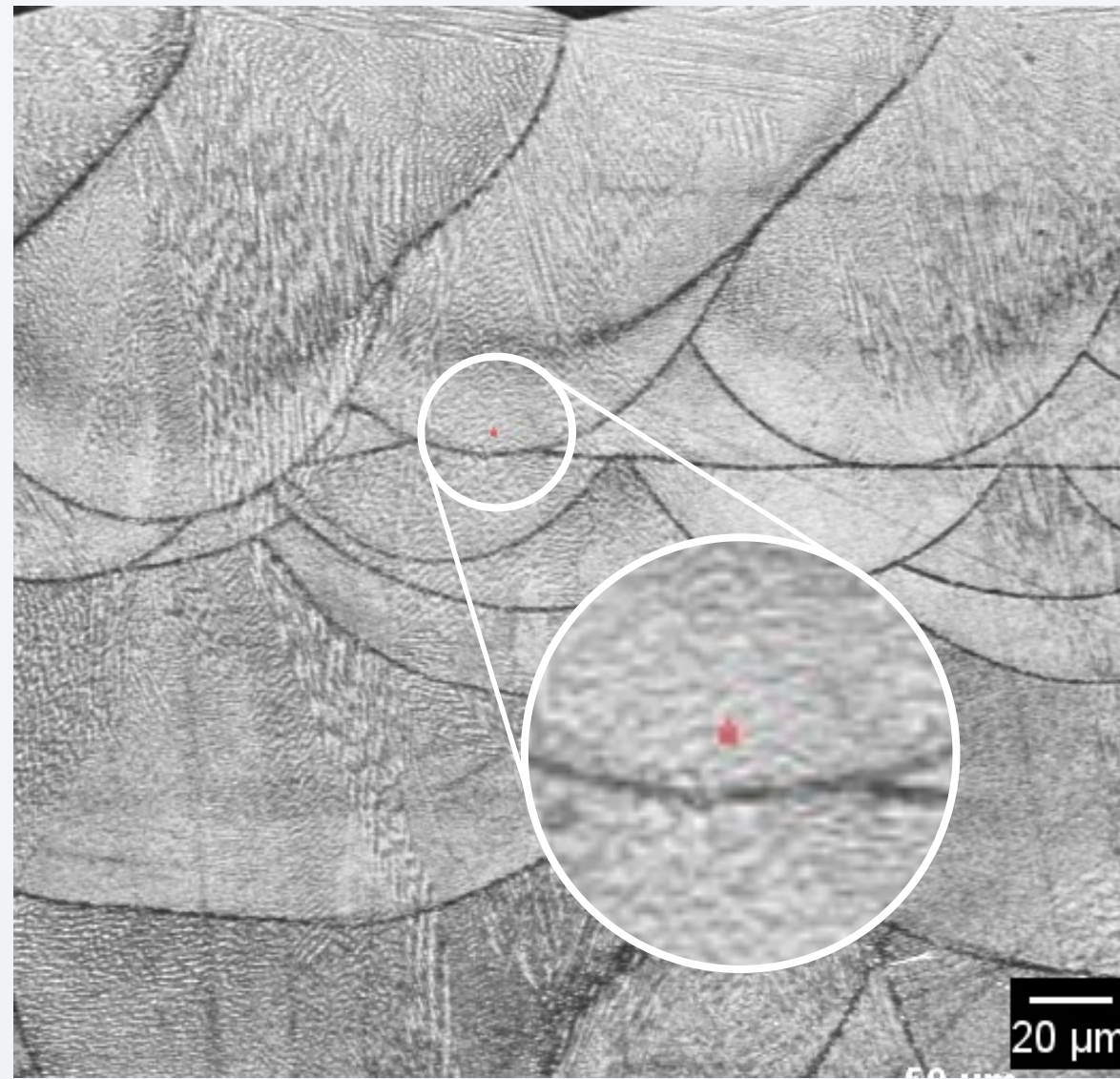
Melt Pools

Grains

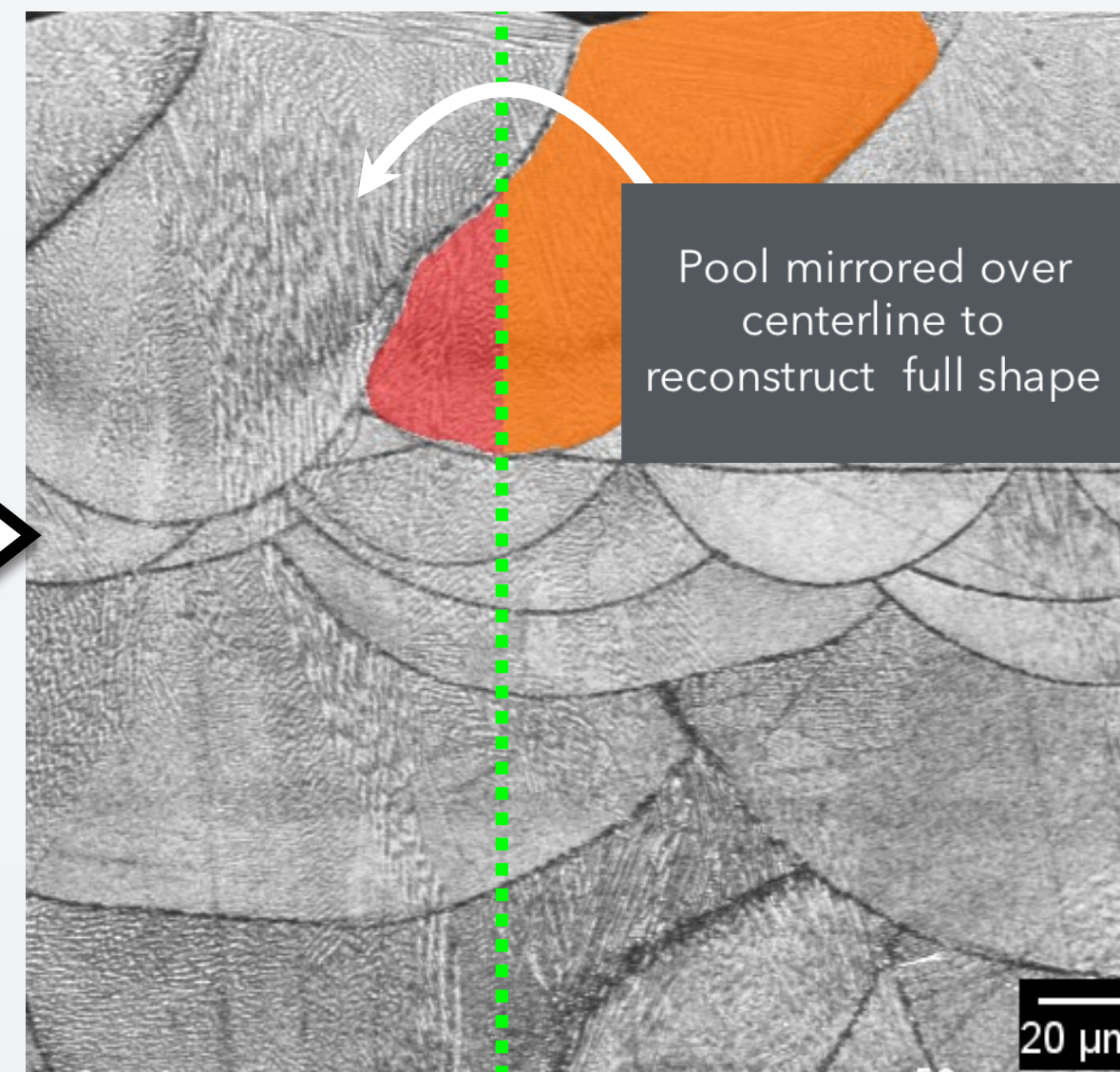
Phases

Porosity

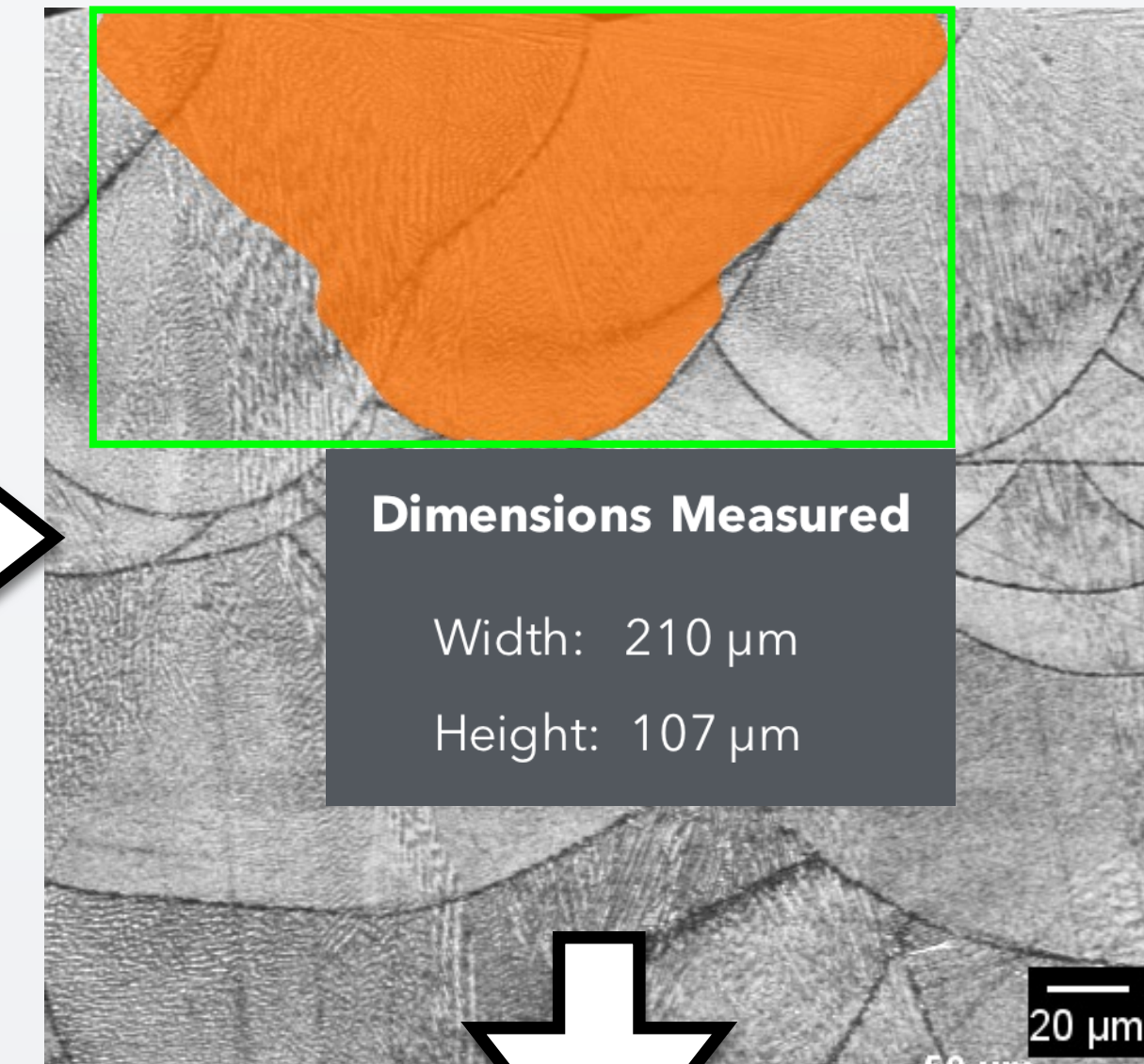
User Marks Above Center



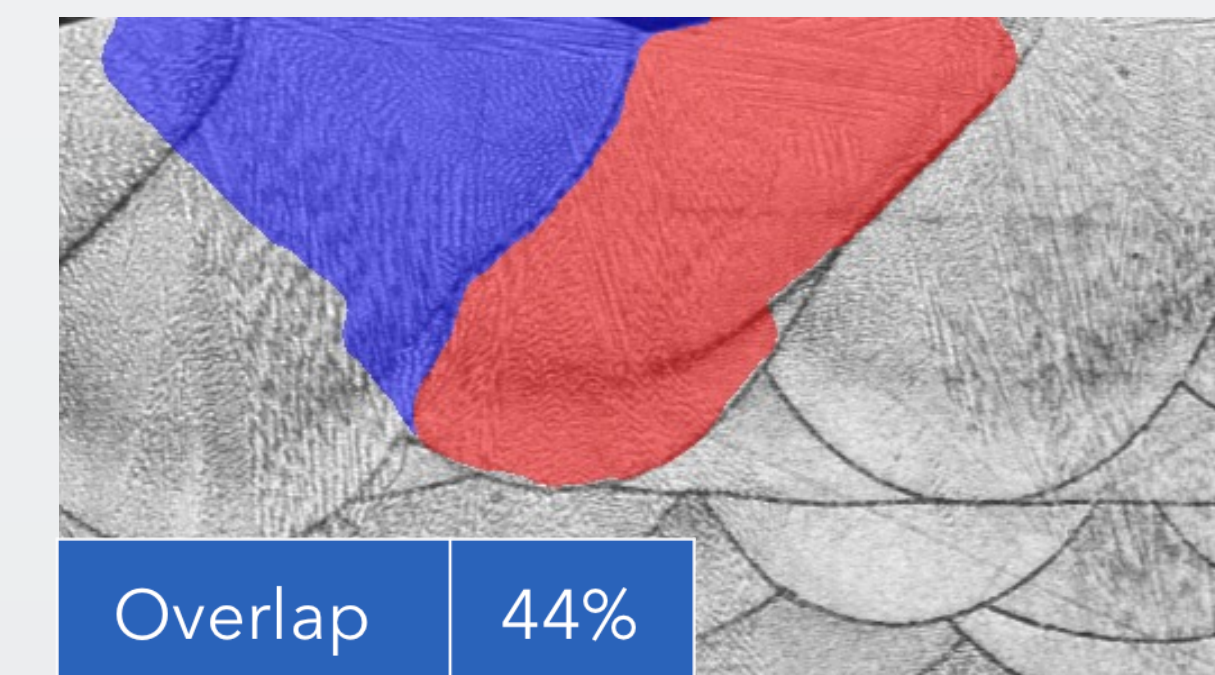
Centerline Auto-Drawn



Pool Reconstructed



Overlap Measured



- ✓ Minimal user interaction, but enough for oversight
- ✓ Melt pool reconstructed for size and overlap measure

Grains: Size Analysis

Powder

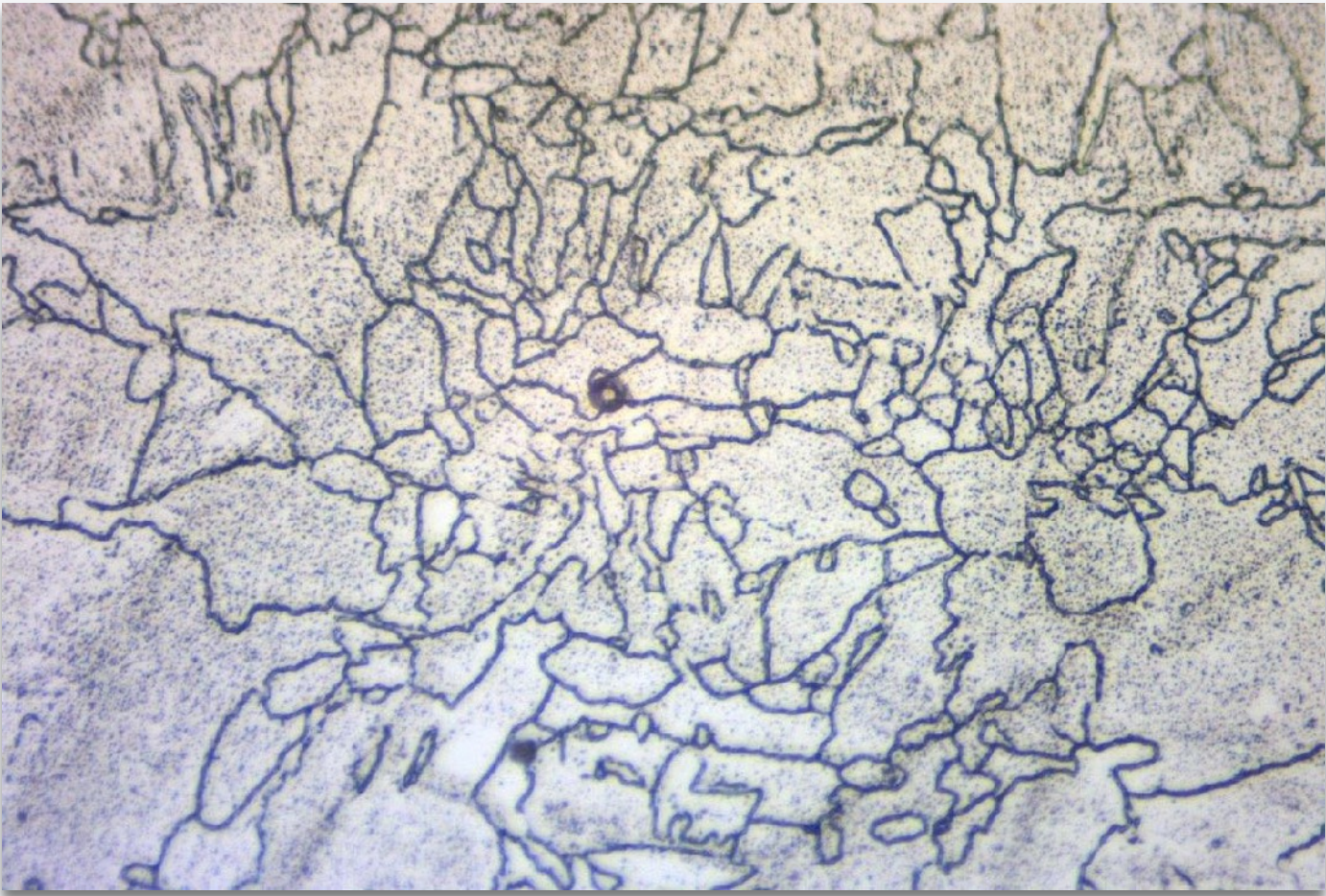
Melt Pools

Grains

Phases

Porosity

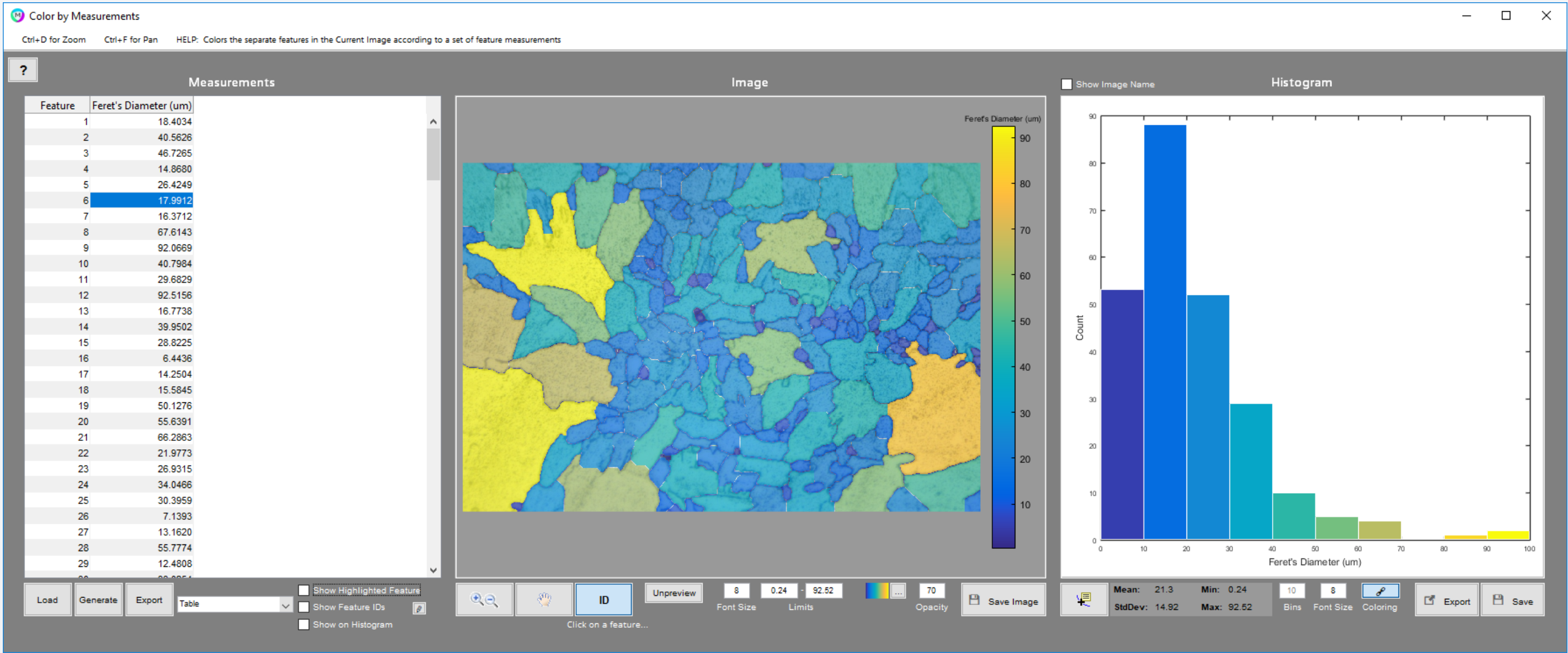
Original



Detection



Grain Size Analysis



Grain size statistics and histogram



Powerful visualization: grains colored by size

Grains: Band Identification

Powder

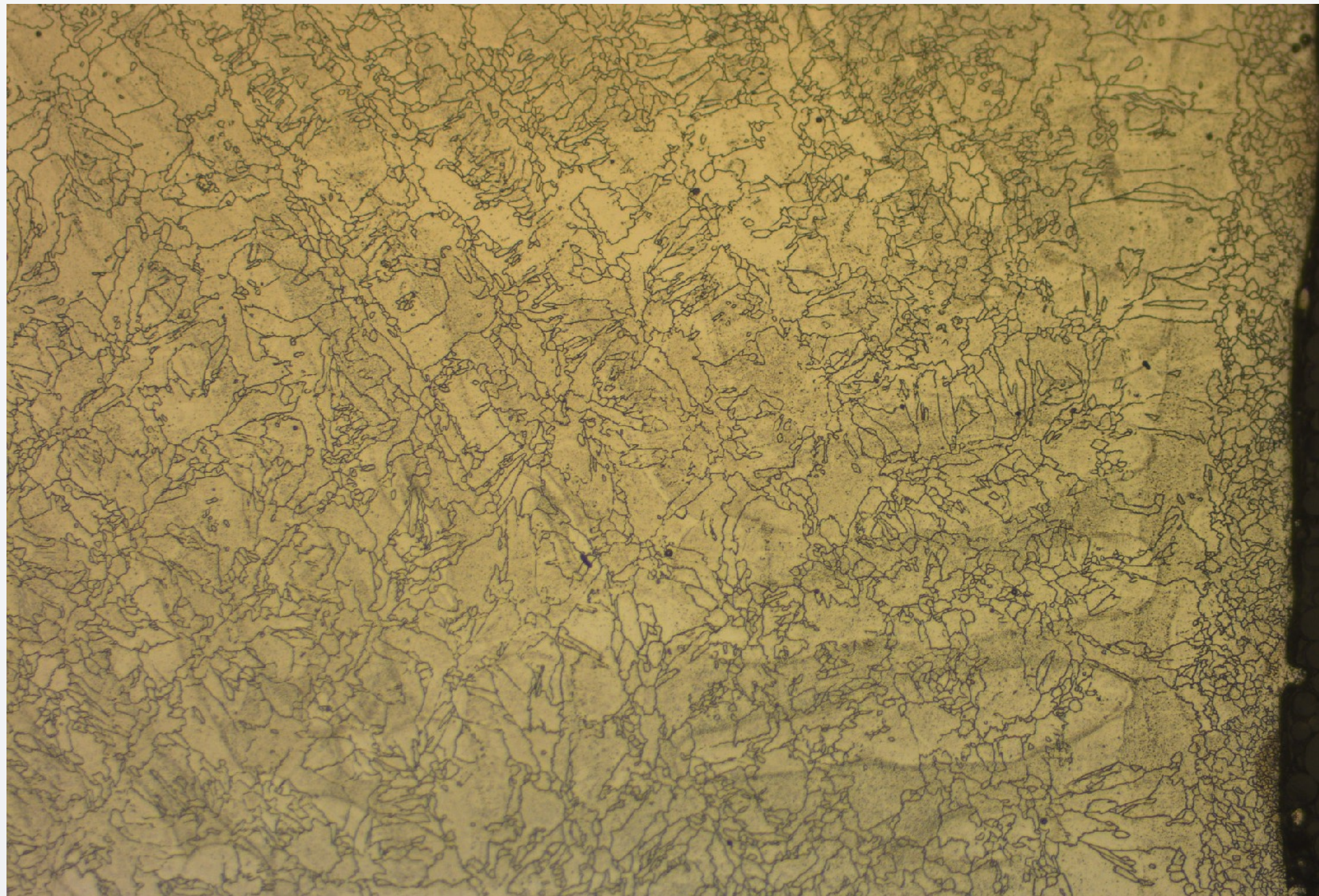
Melt Pools

Grains

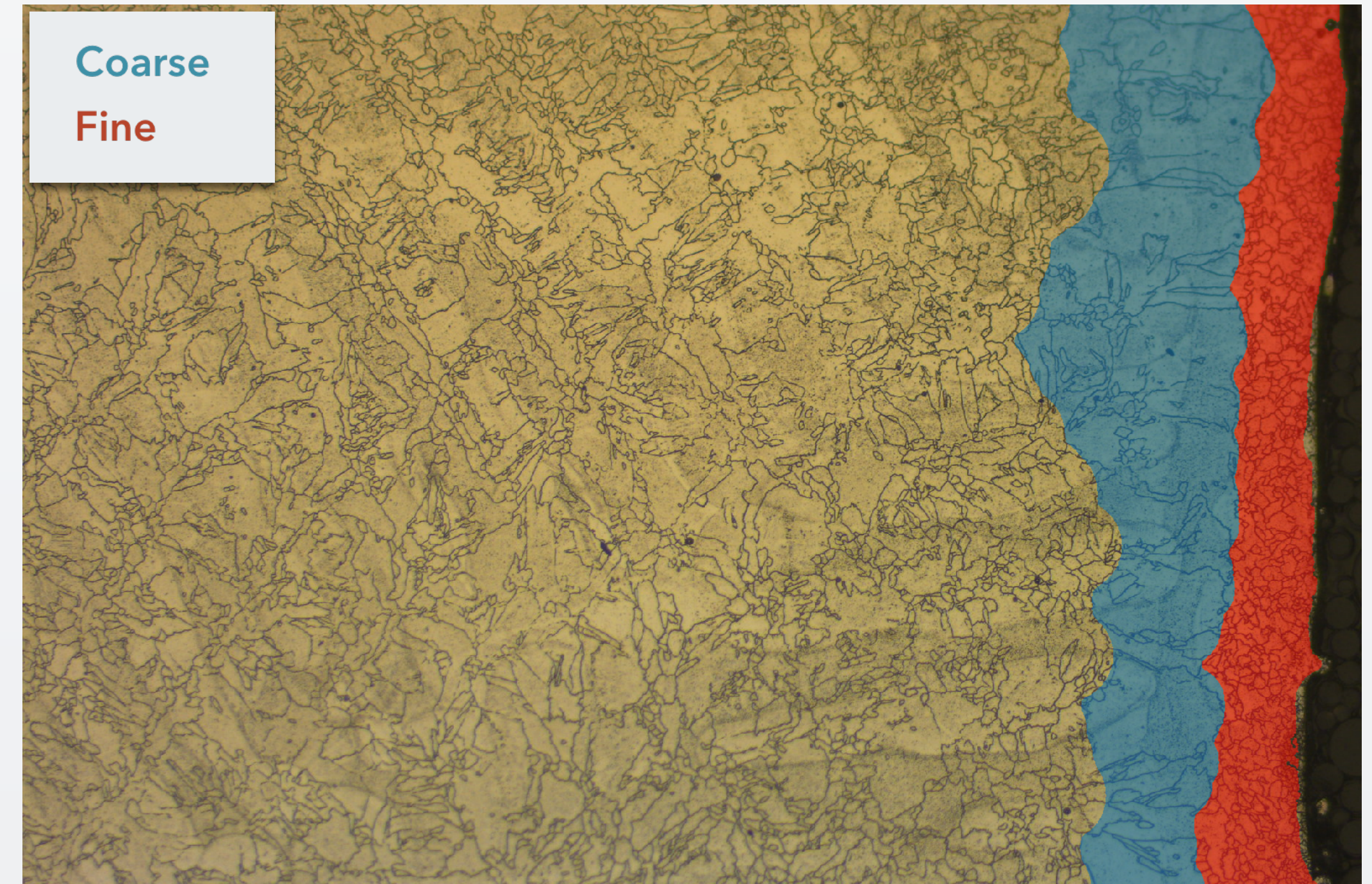
Phases

Porosity

Original



Grain-Band Identification



✓ Band widths can be measured

Phases: Laves in Inconel

Powder

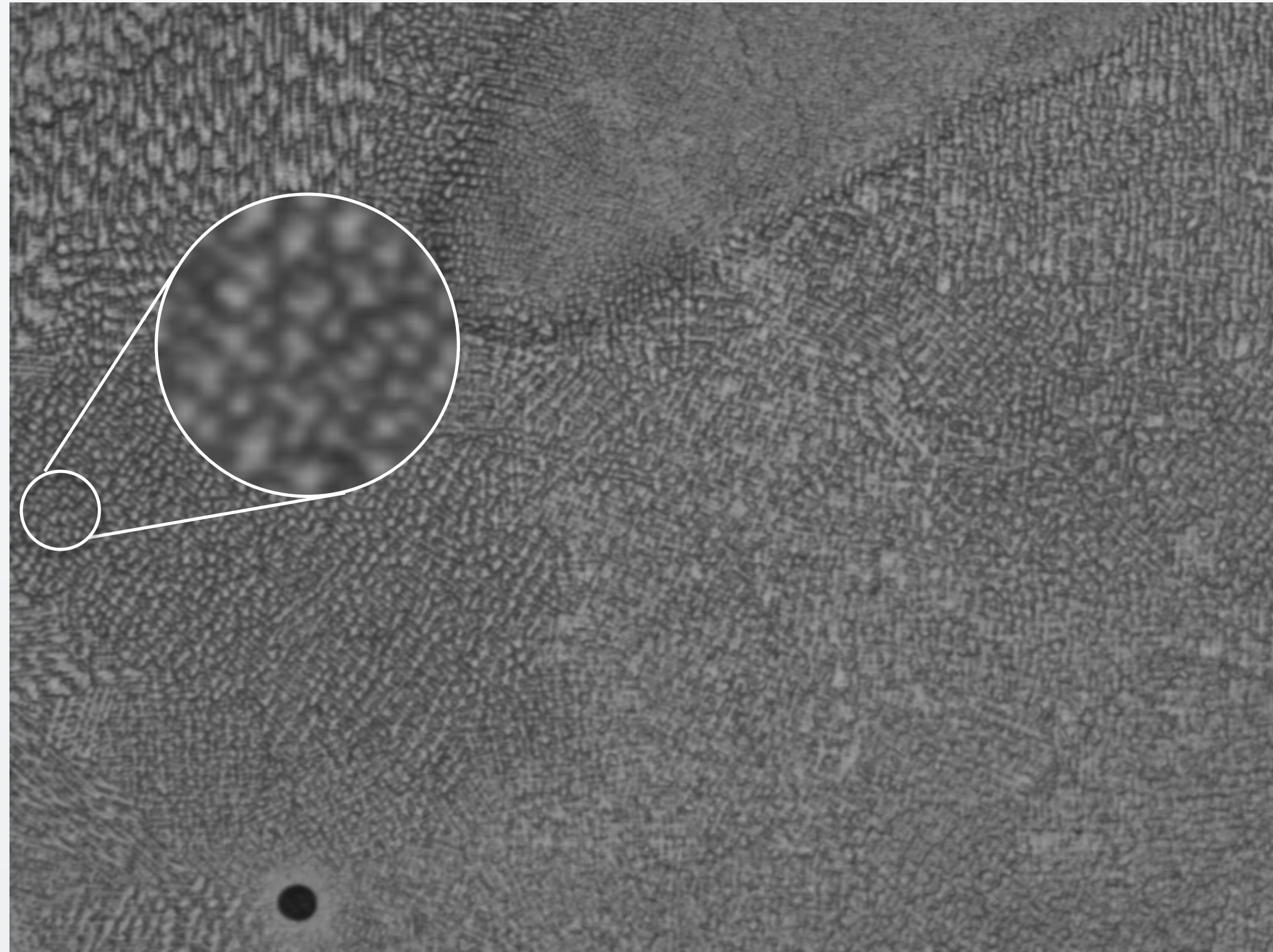
Melt Pools

Grains

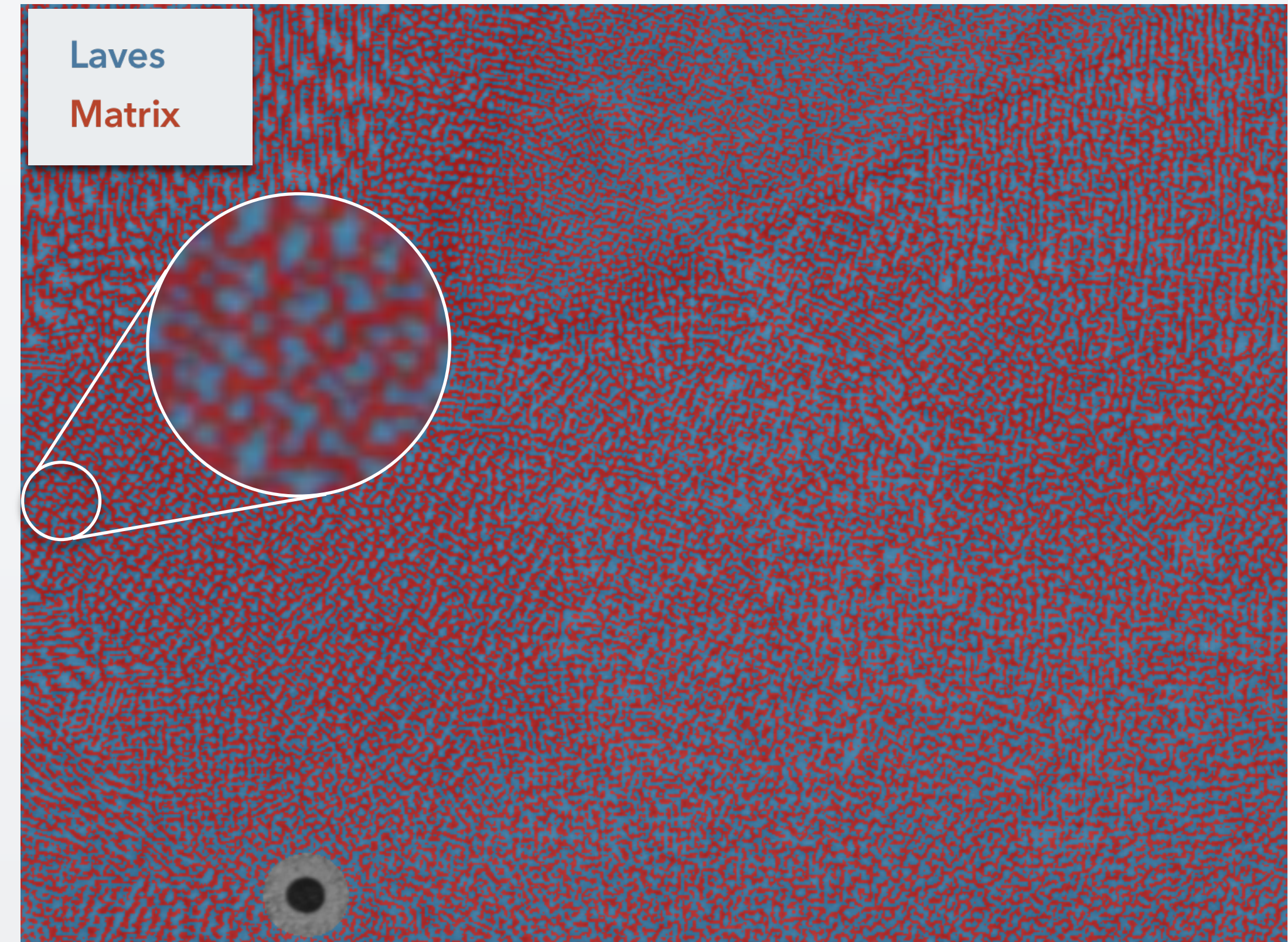
Phases

Porosity

Original



Phase Detection



- ✓ Phase fraction can be measured
- ✓ Challenging ultra-fine laves phase detected
- ✓ Robust recipe ignores pores and defects

Porosity: Thin-Wall Parts

Powder

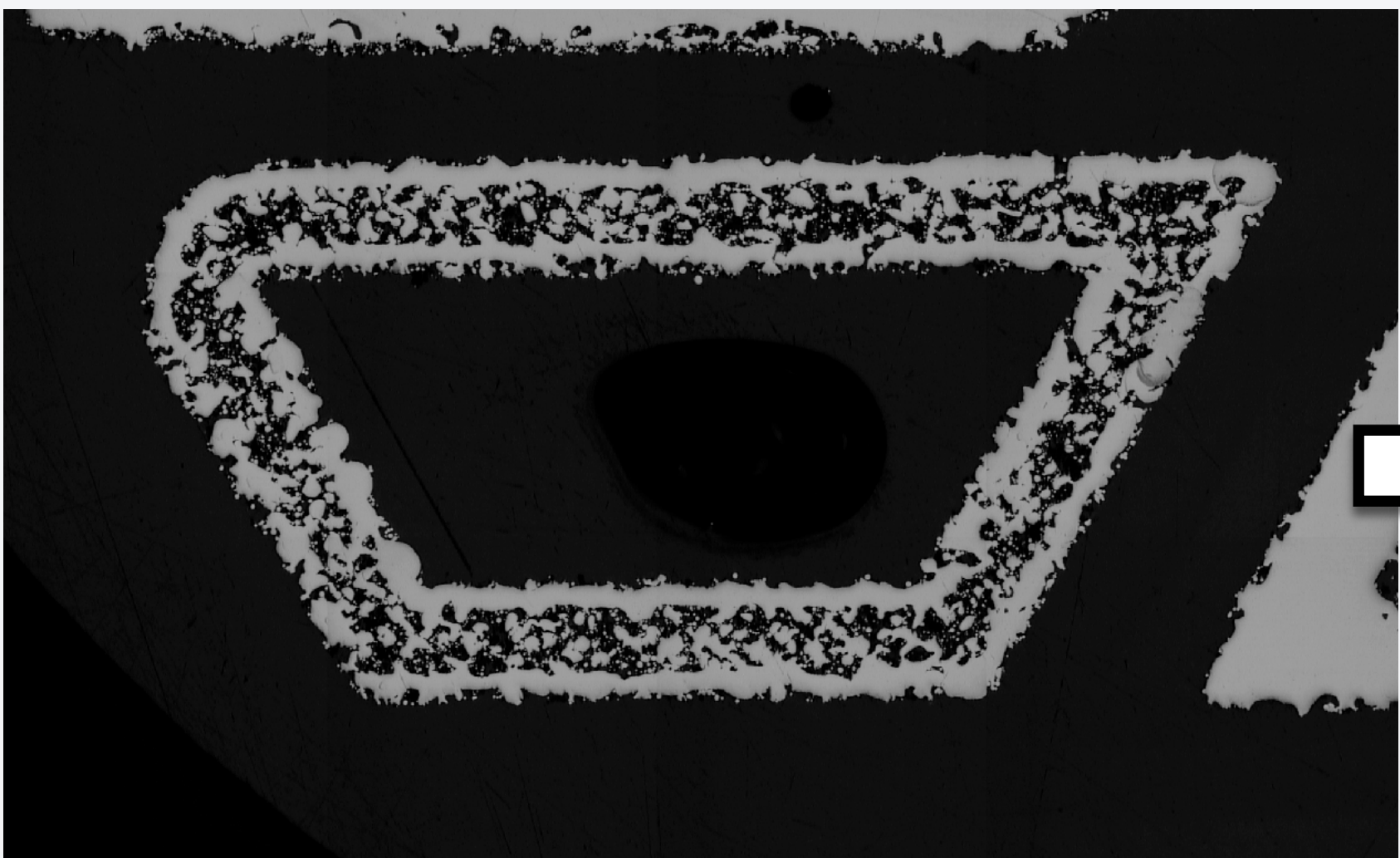
Melt Pools

Grains

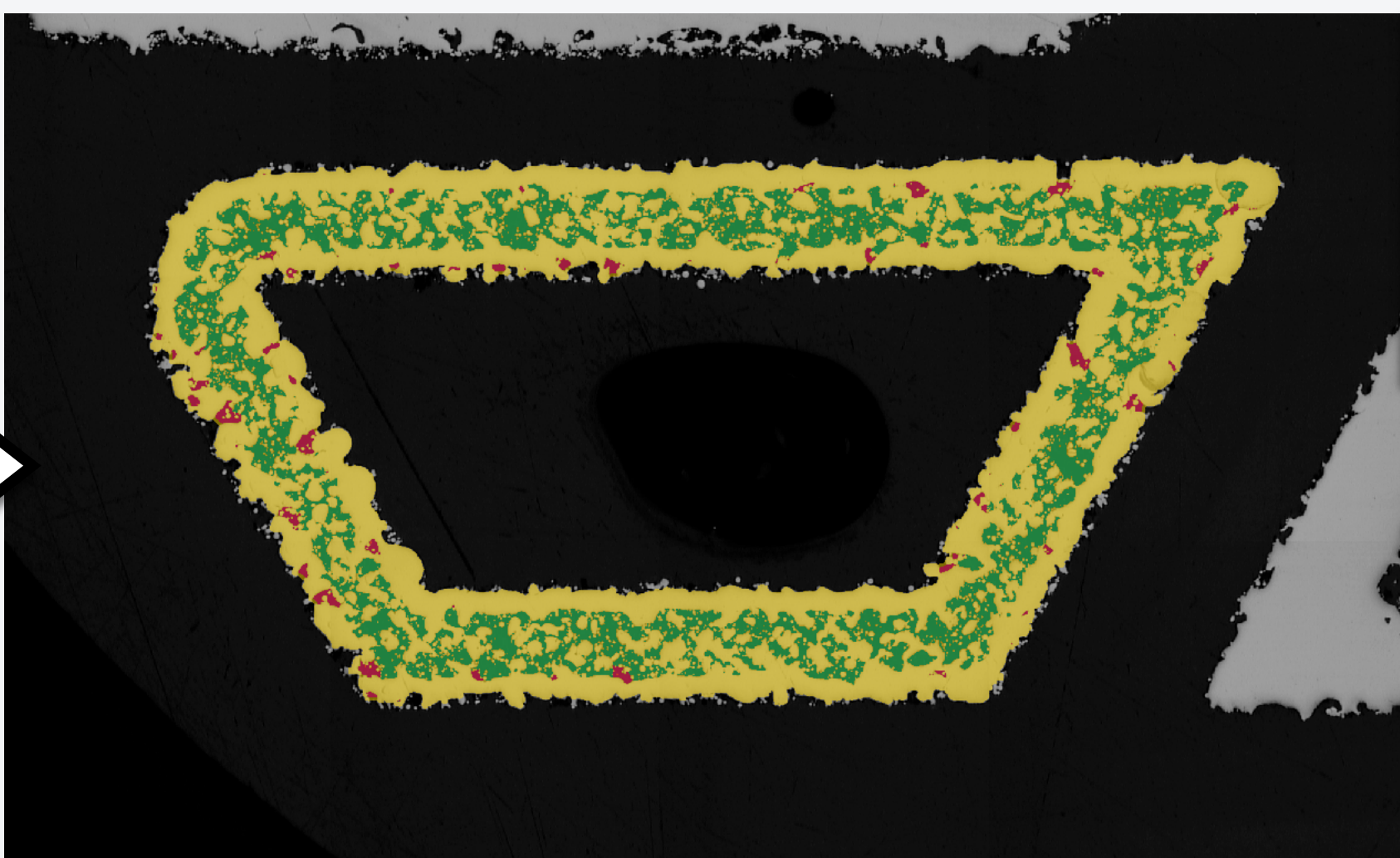
Phases

Porosity

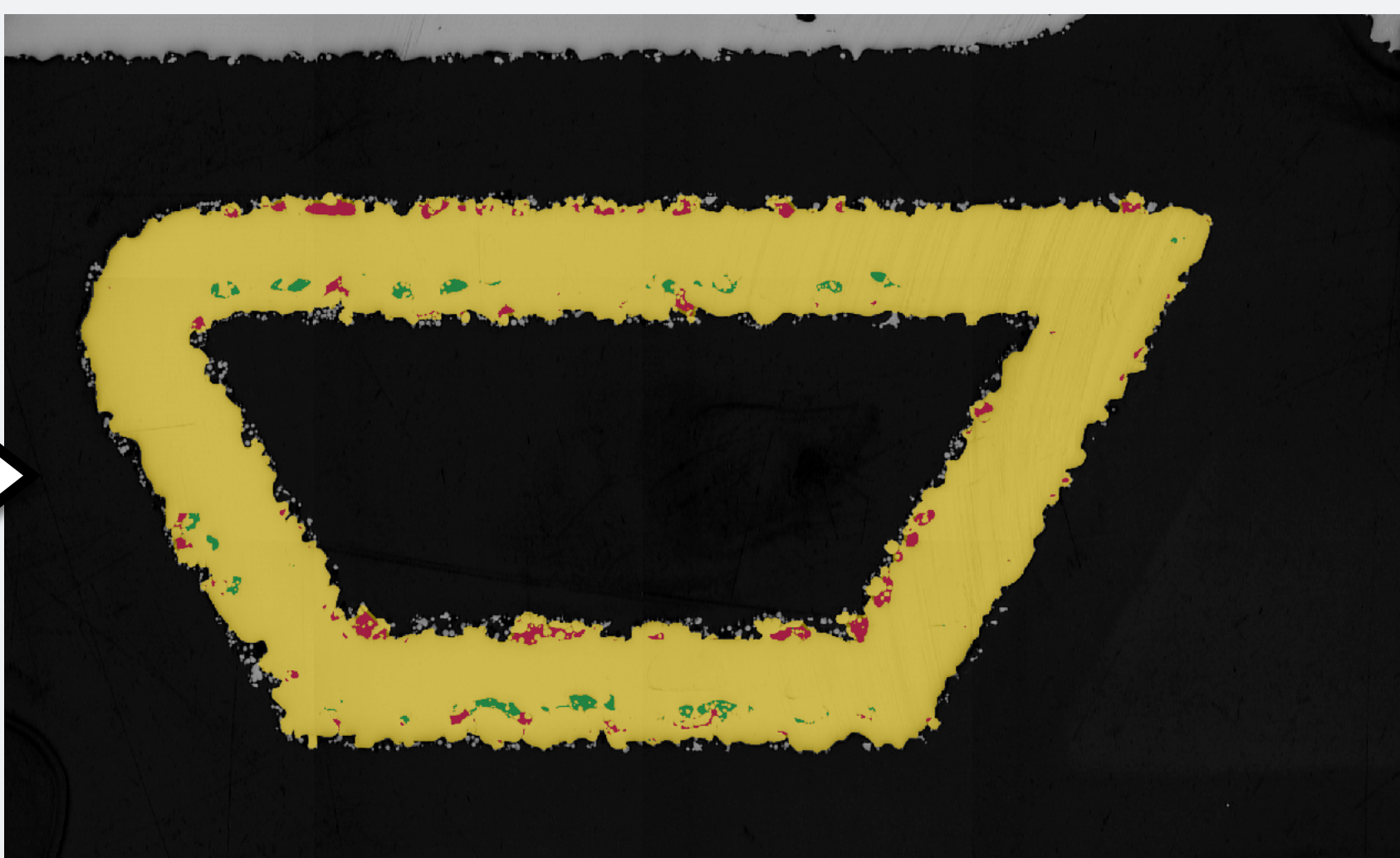
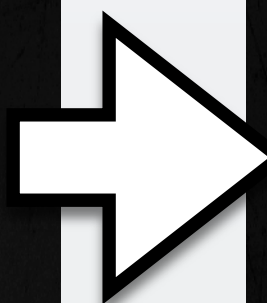
Original



Thin-Wall Porosity



	Layer	Area Fraction (%)
	Part	100
	Border Pores	3.9620
	Bulk Pores	41.5850
	All Pores	25.6360



	Layer	Area Fraction (%)
	Part	100
	Border Pores	4.8840
	Bulk Pores	1.8670
	All Pores	3.0970



Single recipe accurately measures porosity at each extreme



Perform analysis in batch

Porosity: Solid Parts

Powder

Melt Pools

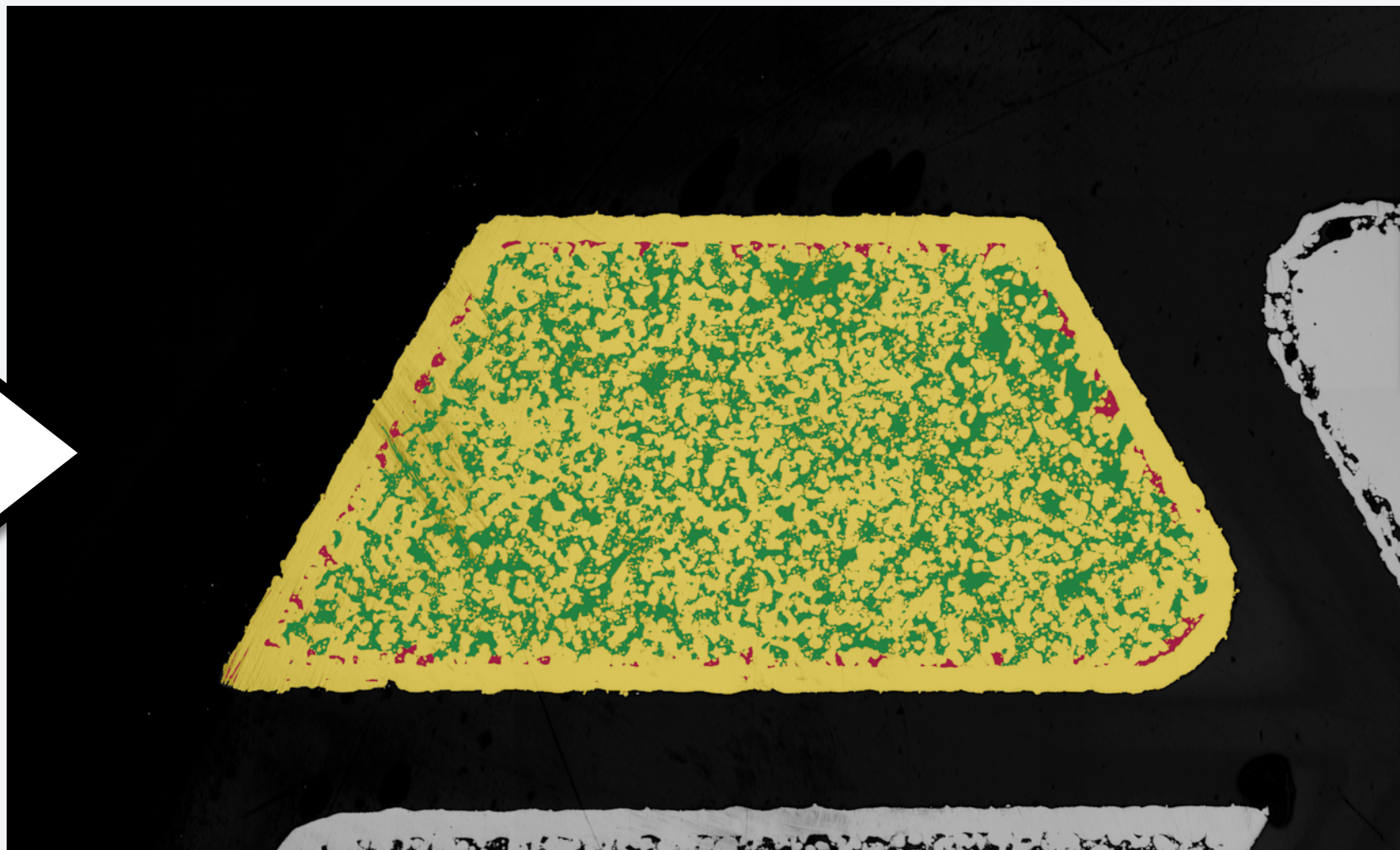
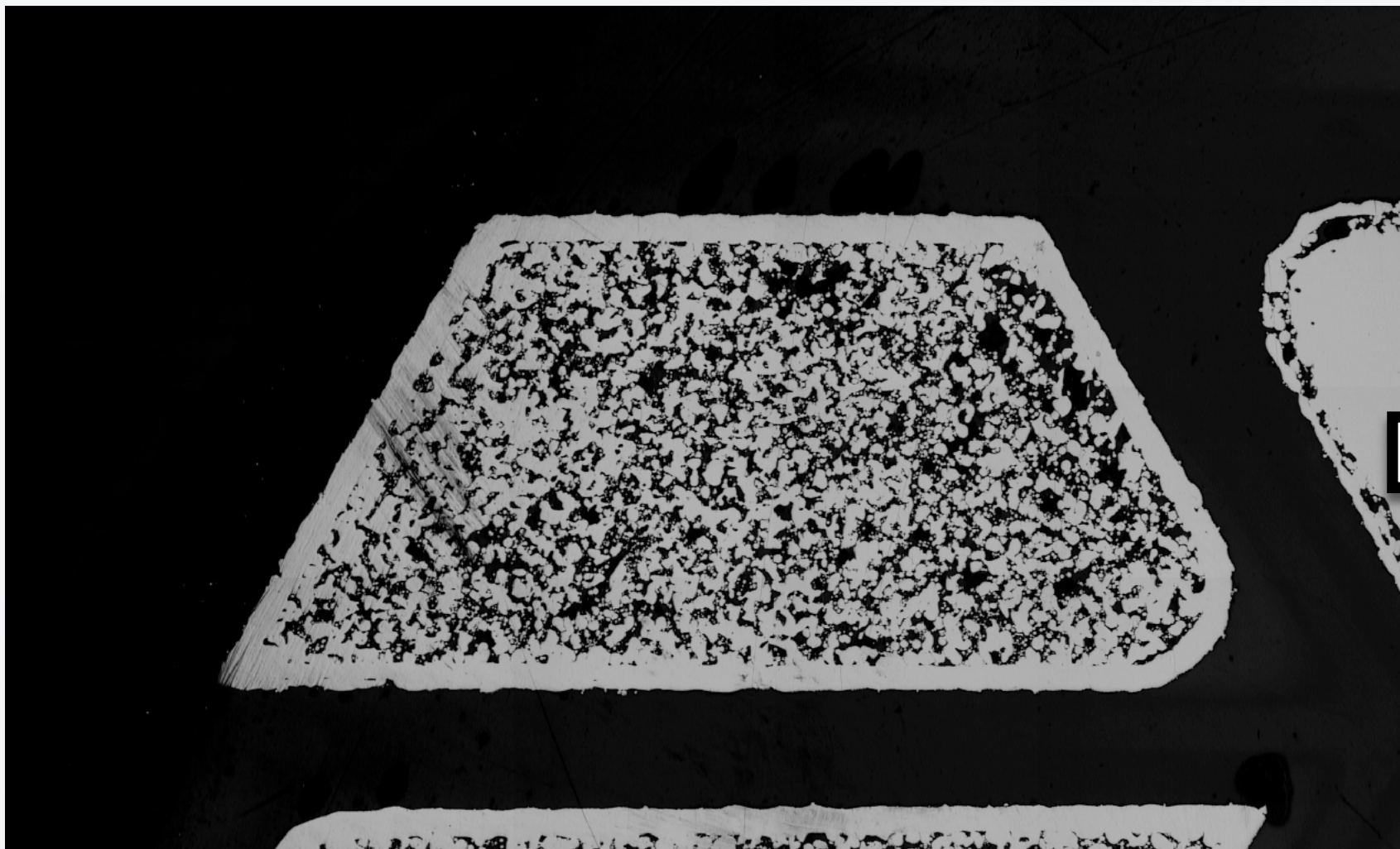
Grains

Phases

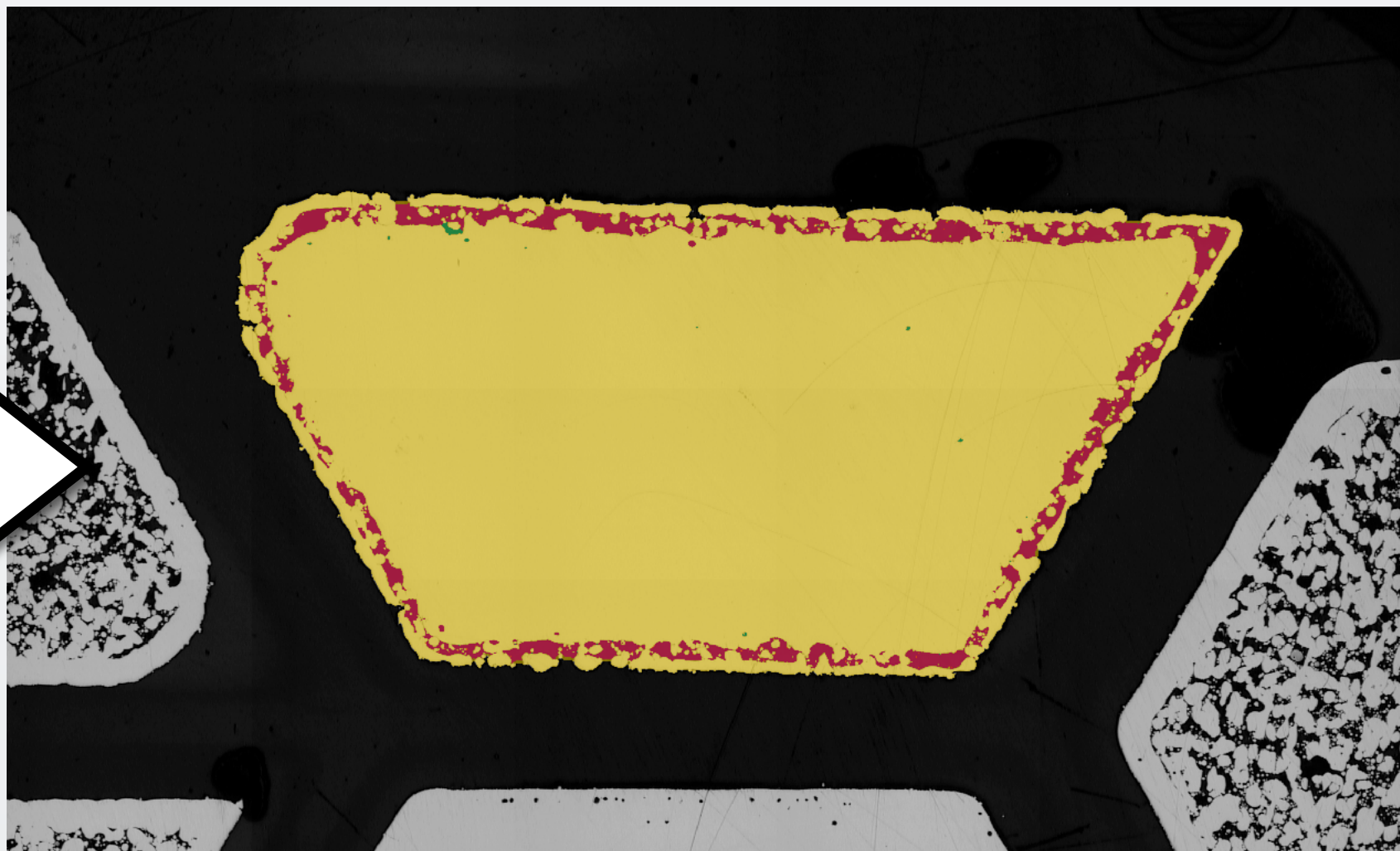
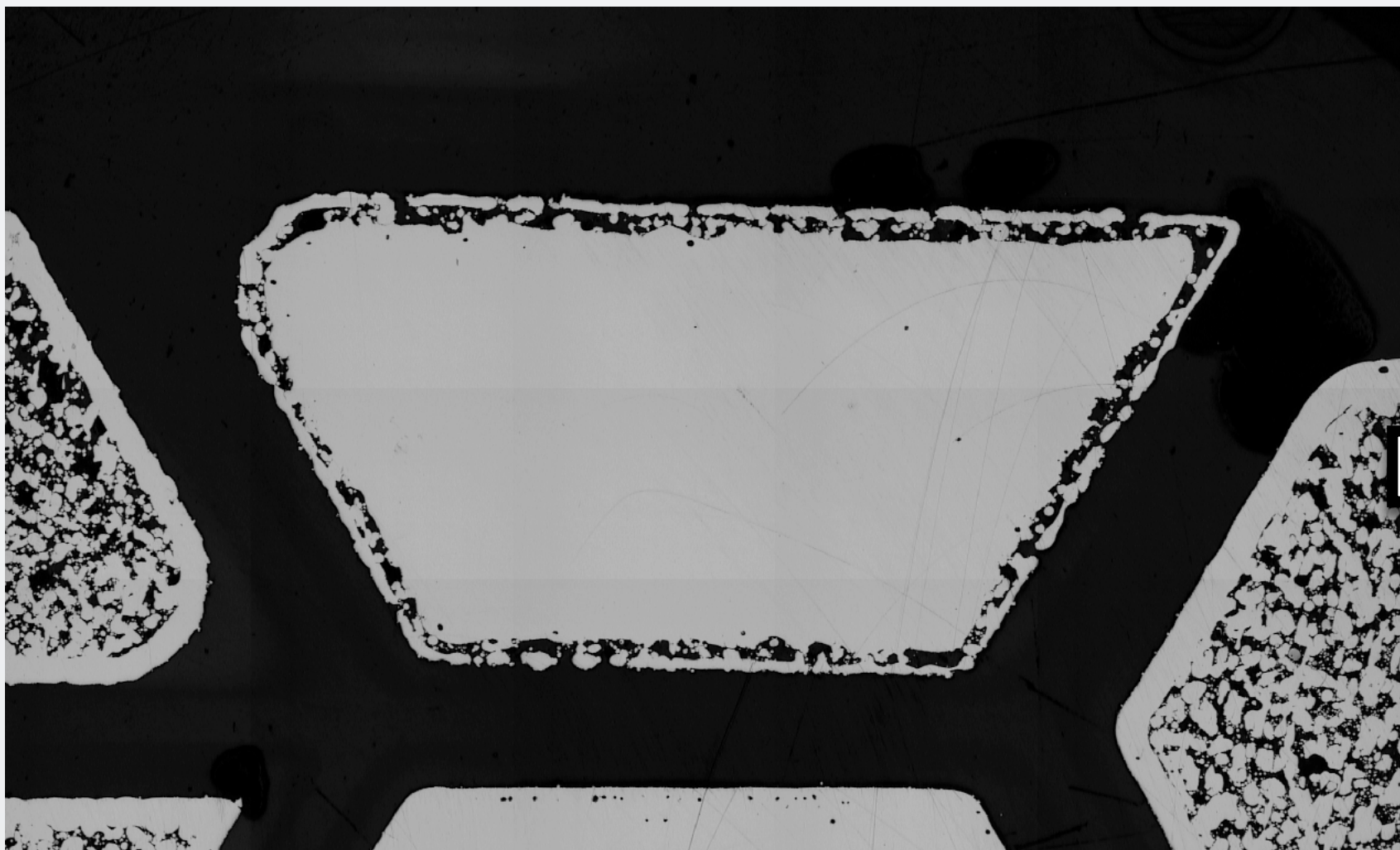
Porosity

Original

Solid Porosity



	Layer	Area Fraction (%)
	Part	100
	Border Pores	5.6770
	Bulk Pores	31.9670
	All Pores	26.0900



	Layer	Area Fraction (%)
	Part	100
	Border Pores	26.3390
	Bulk Pores	0.0742
	All Pores	6.2600



Single recipe accurately measures porosity at each extreme



Perform analysis in batch

Porosity: Pore Assignment Options

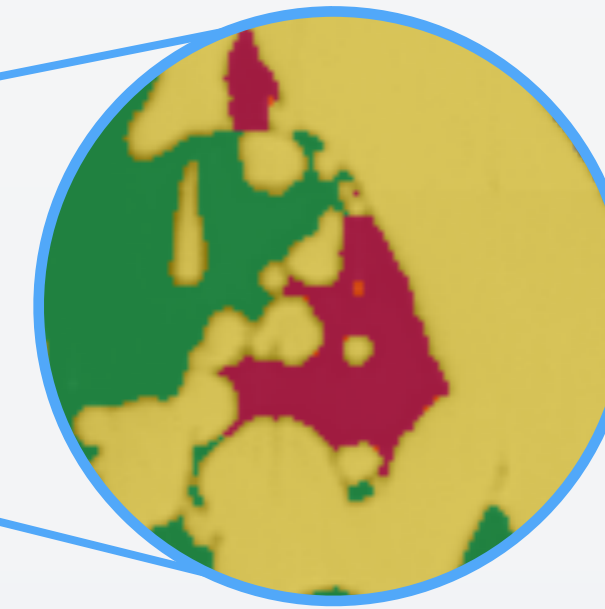
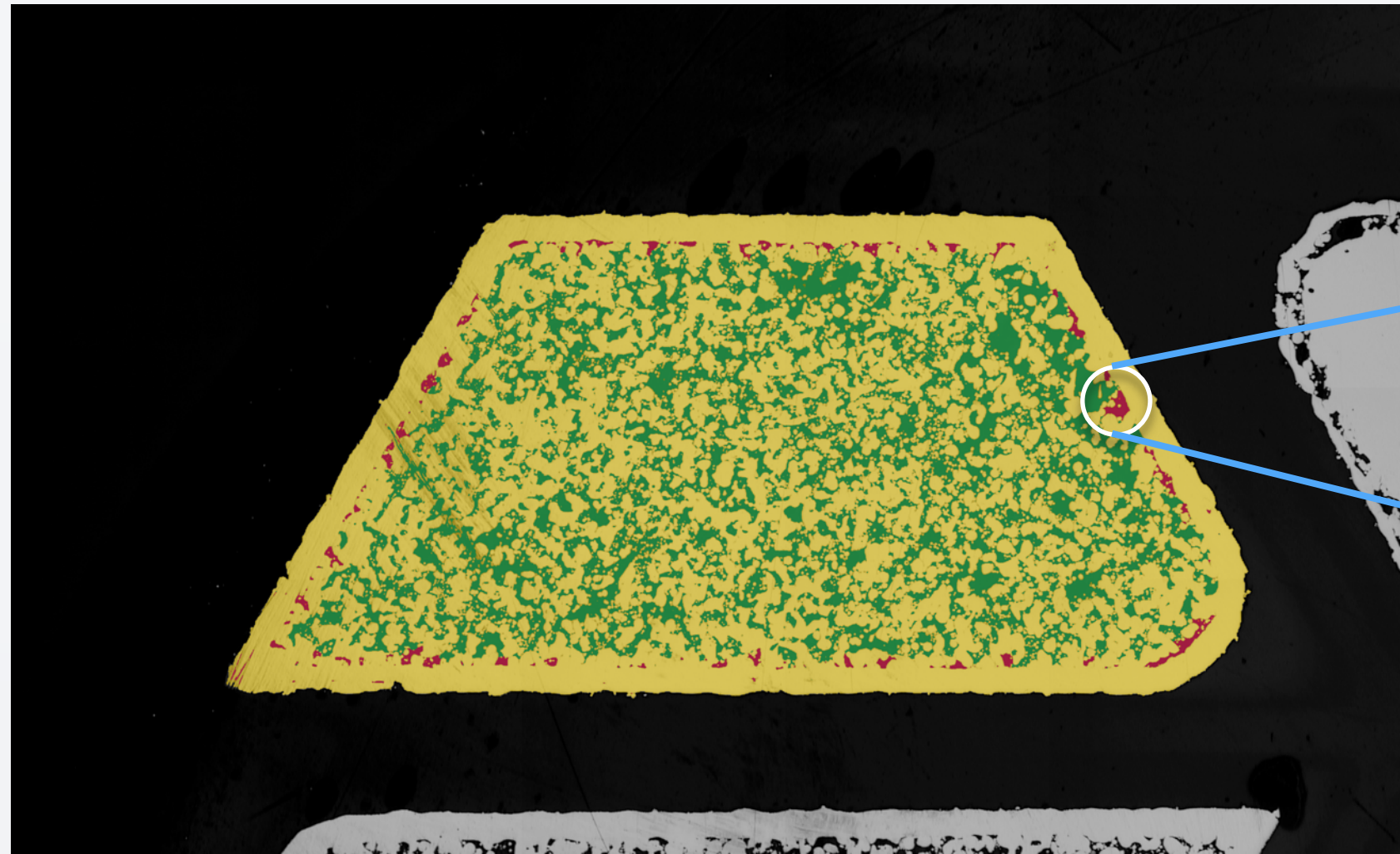
Powder

Melt Pools

Grains

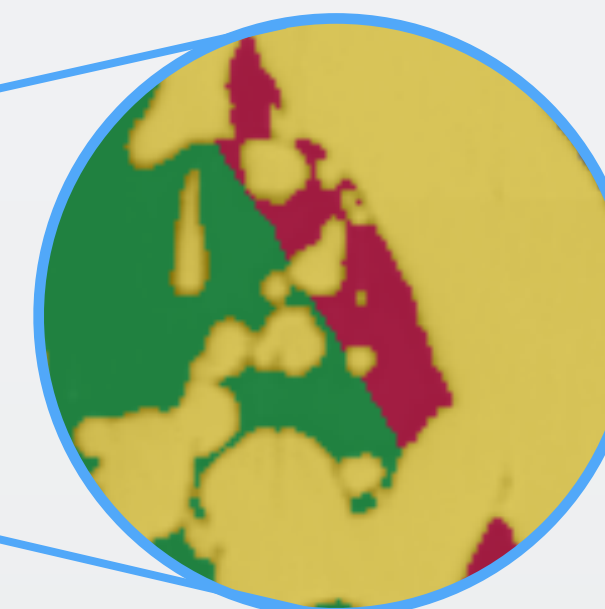
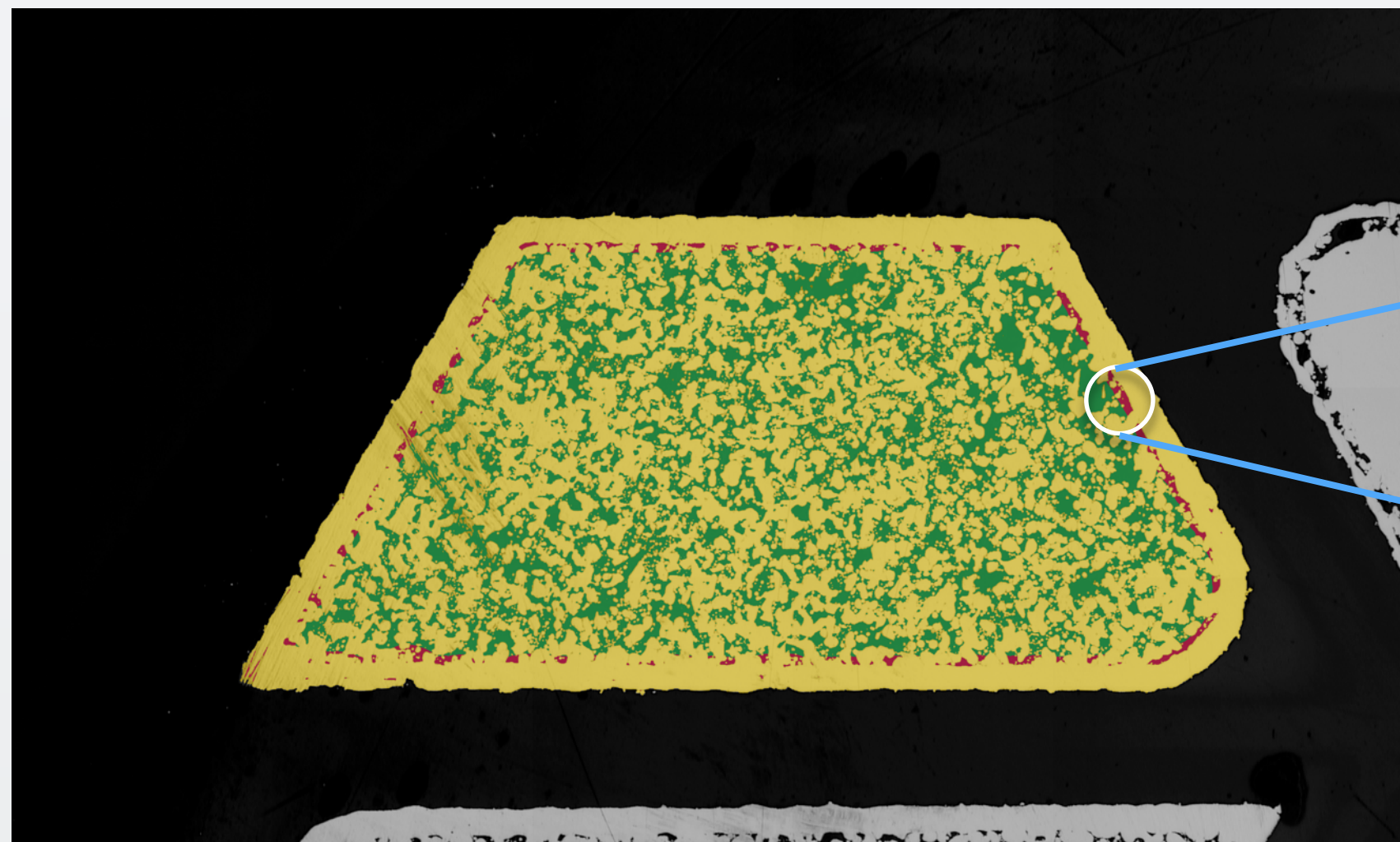
Phases

Porosity



Majority Assignment

Pores assigned to border or bulk based on which they most belong to



Split Assignment

Pores assigned to border or bulk based on simple region intersection

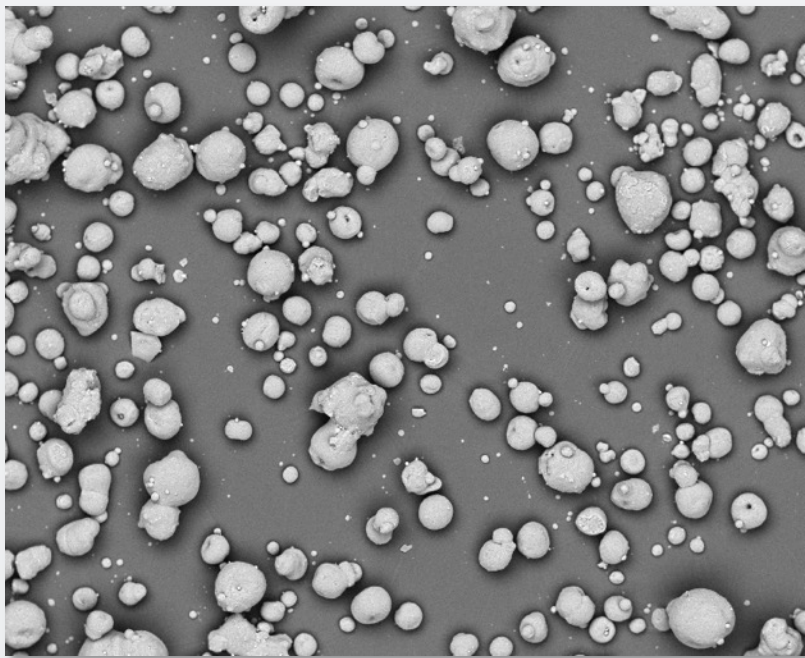
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Melt Pools

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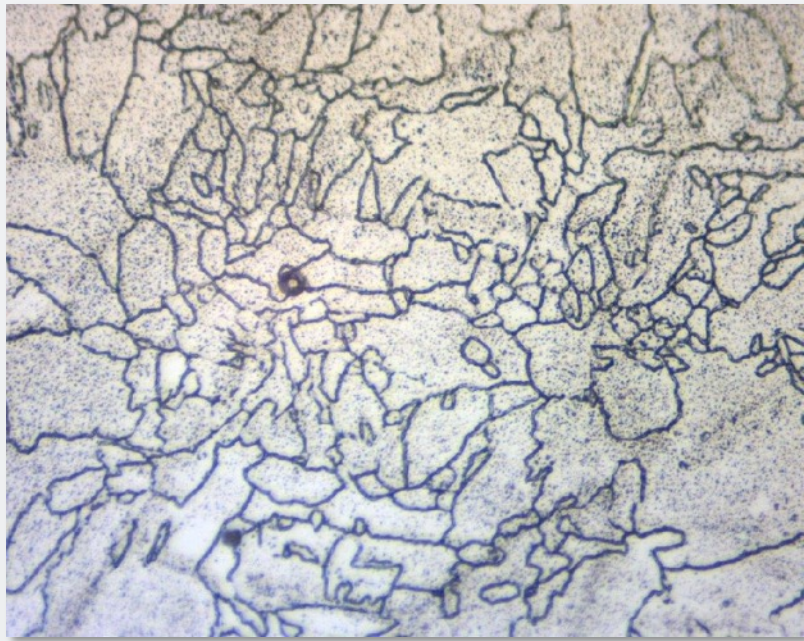
Melt pool dimensions in additive builds



Grains

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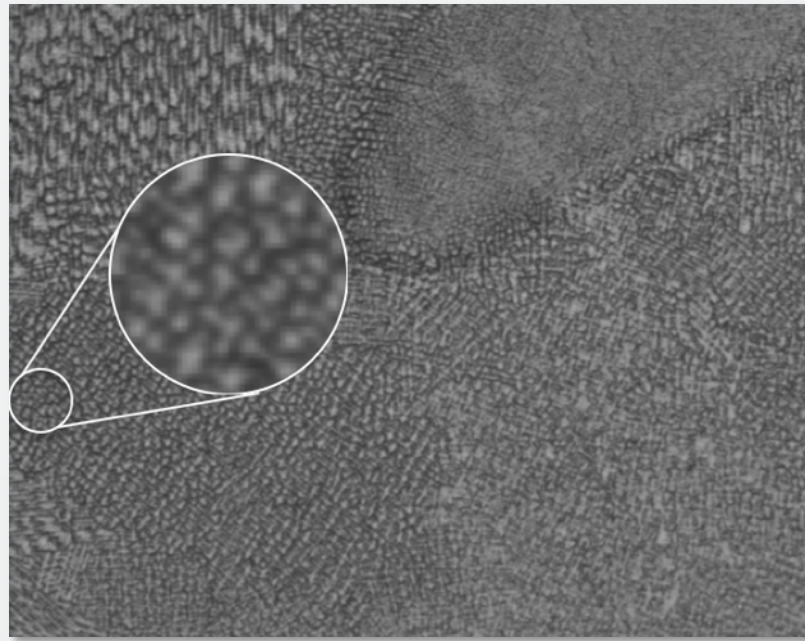
Overall grain size and local banding



Phases

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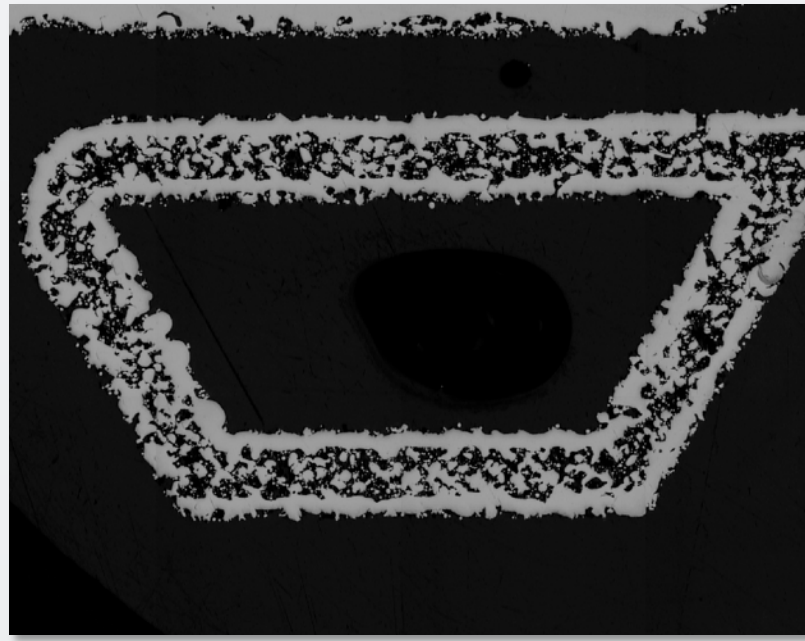
Phase fractions in additive builds



Porosity

—

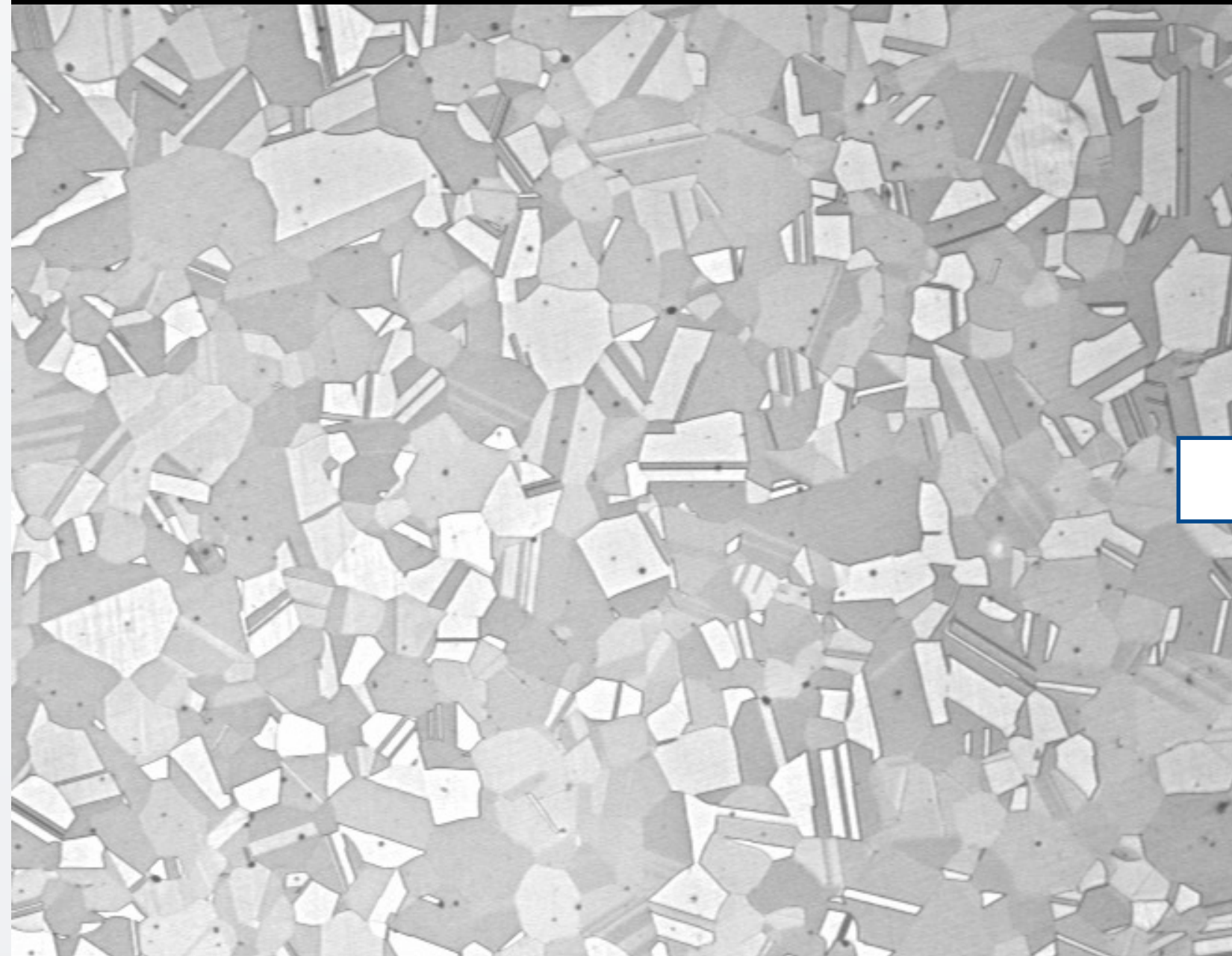
Localized porosity in solid and thin-wall parts



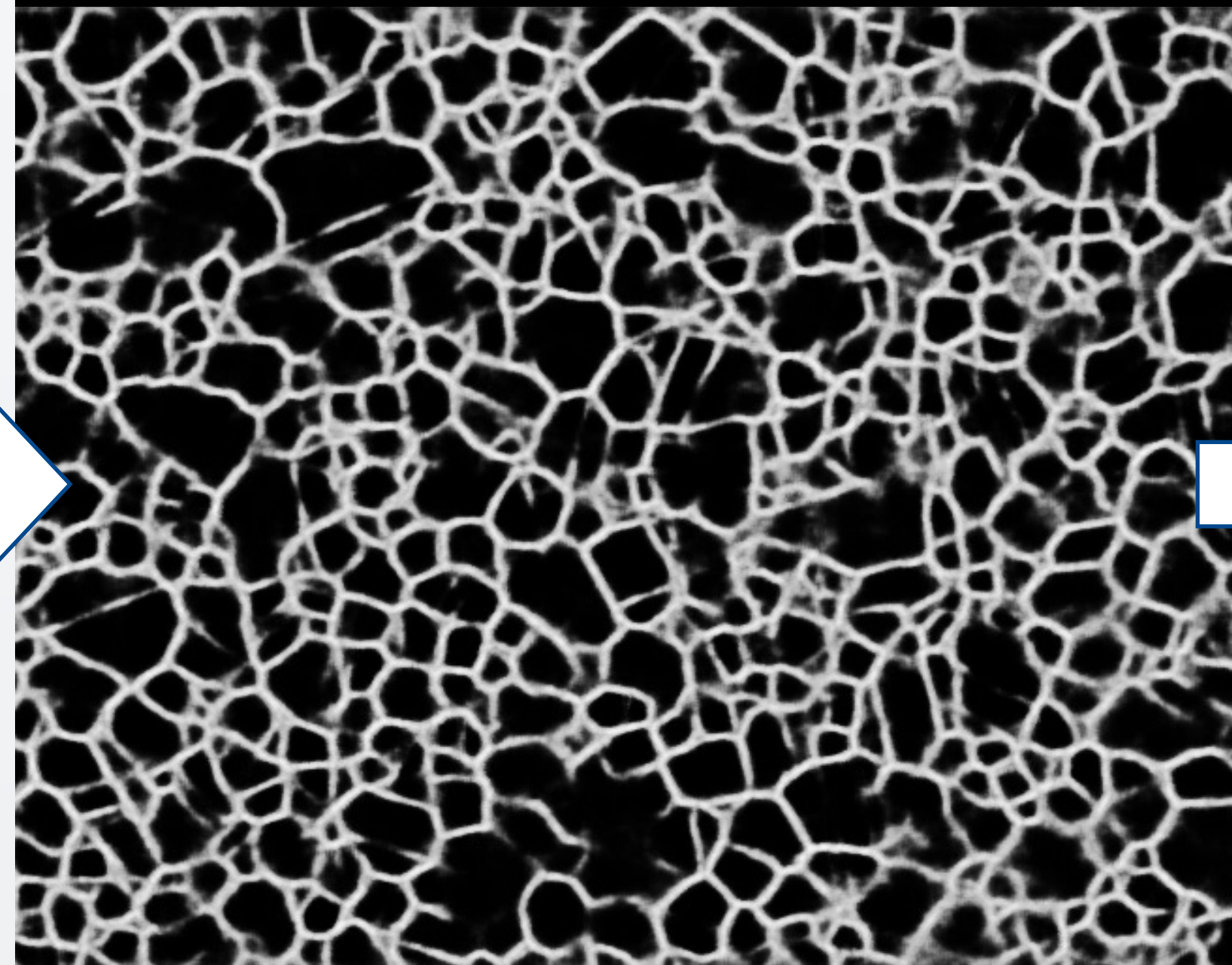
Automating the Impossible: Grains with *Many* Twins

Powder

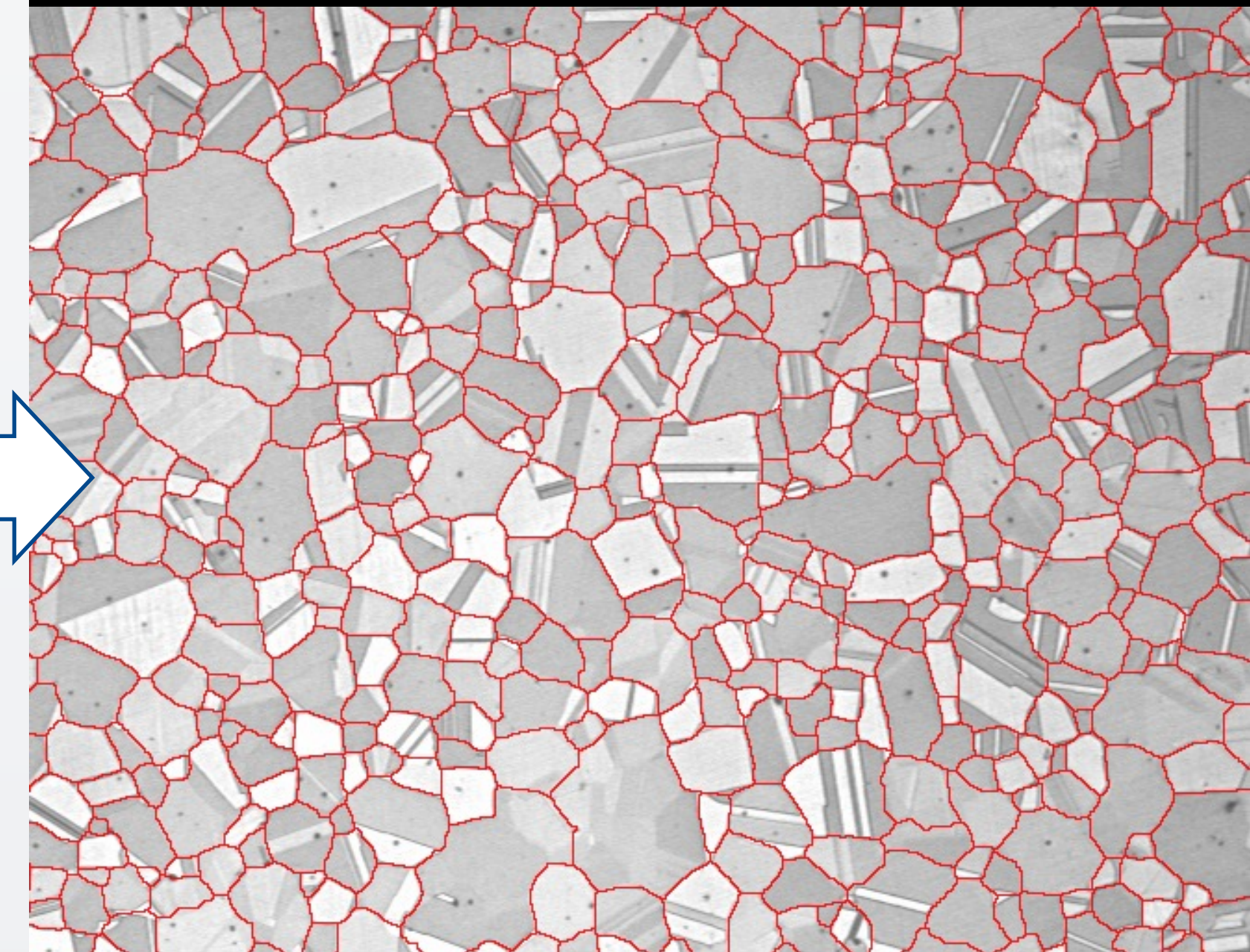
Grains with Twins



Deep Learning Applied



Grain Detection



Model trained on 25 sub-images in 40 minutes on a GPU.

Model applied to new image in 2 seconds.

Melt Pools

Grains

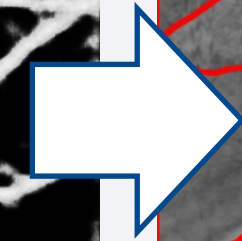
Automating the Impossible: Melt Pools with Minimal Contrast

Powder

Melt Pools

Deep Learning Applied

Melt Pool Detection



Model trained on 16 sub-images in 60 minutes on a GPU.

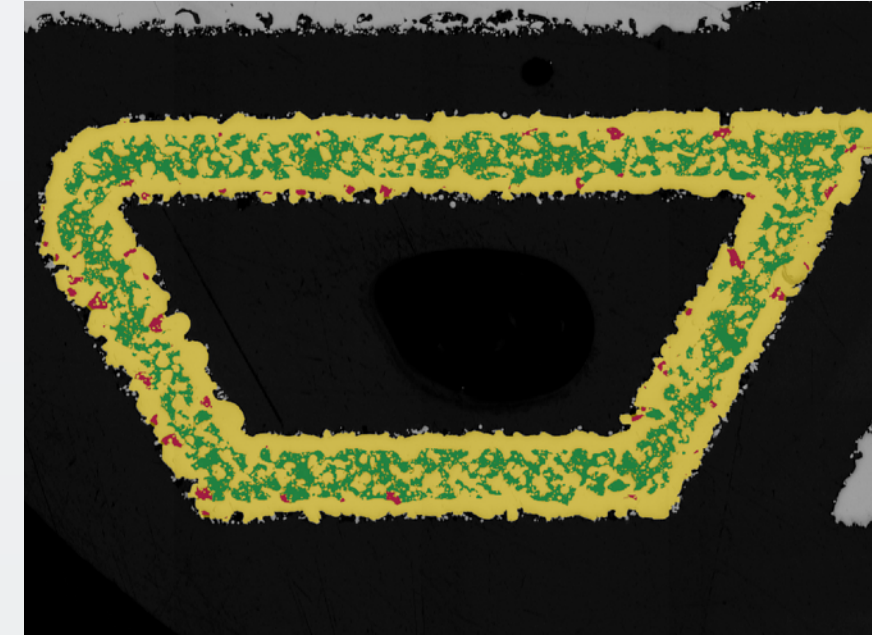
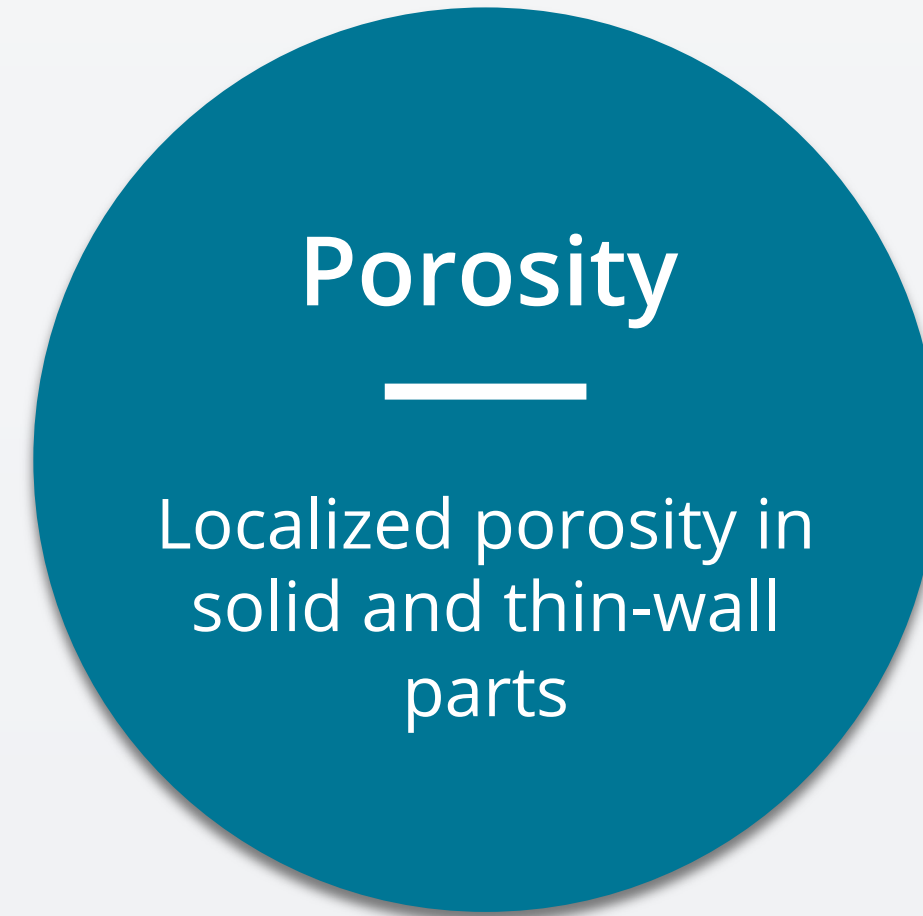
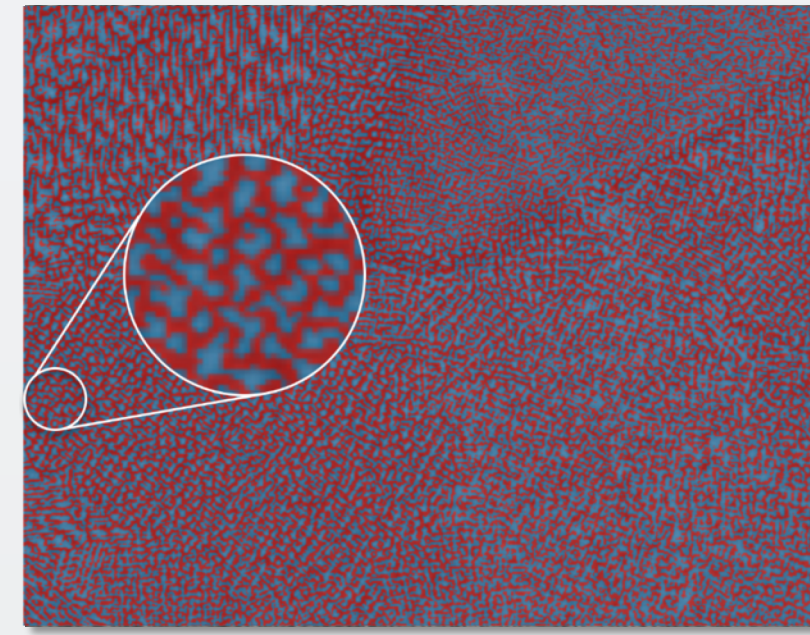
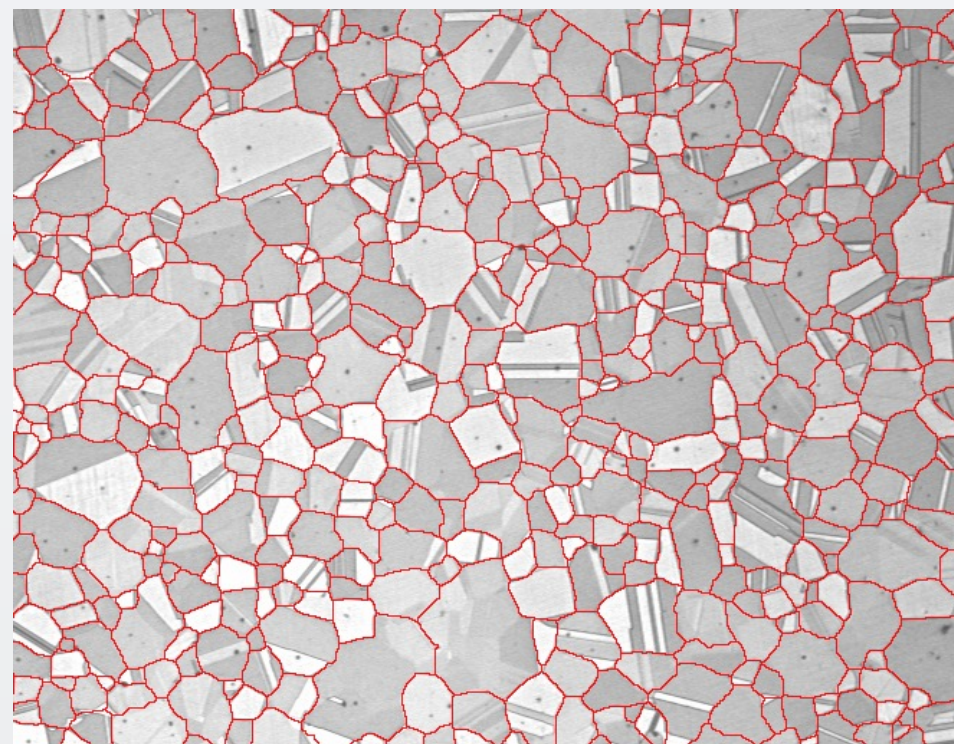
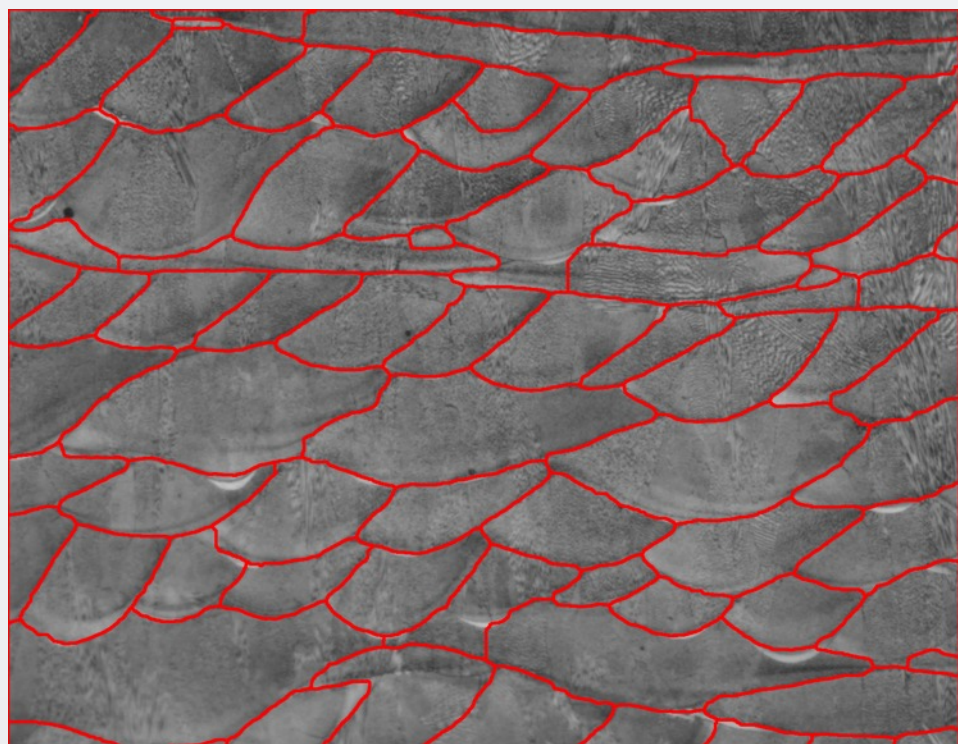
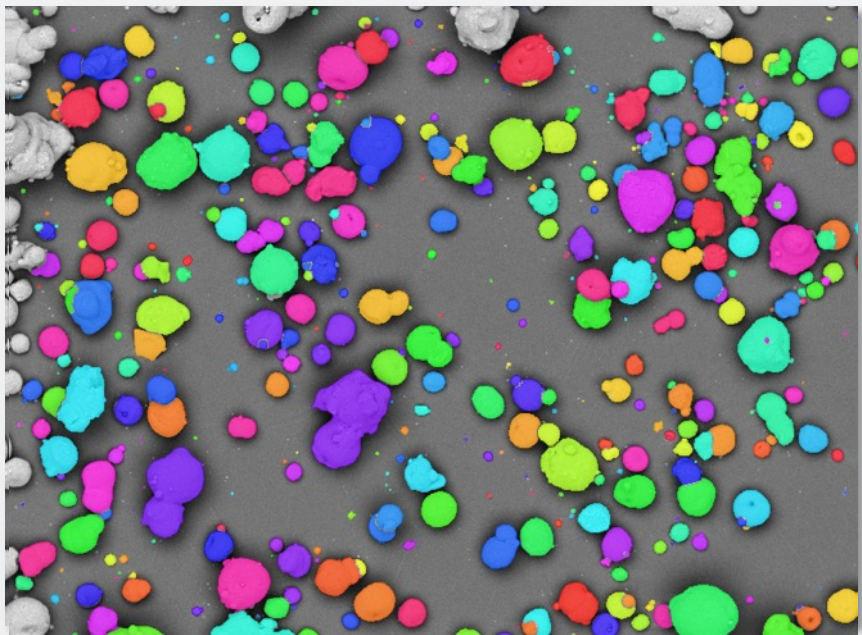
Model applied to new image in 3 seconds.

Melt Pools

Grains

Primary Challenges

Powder → Process → Microstructure → Part



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