MIPAR

Image Analysis Software

Metals characterization using deep learning image analysis

Introduction to MIPAR

- ✓ Started in materials science
- ✓ Invented at research university
- ✓ Developed by actual users
- ✓ Spun-out in 2017
- ✓ 100s of schools and companies
- ✓ In over 40 countries

P&G
Honeywell
Pratt & Whitney
A United Technologies Company
EWI
BAYER
NASA
PennState
MIT
Pacific Northwest
NATIONAL LABORATORY
UCSF
Nationwide Children's
ASU
AK Steel
Iowa State University
UofL School of Medicine
Dartmouth
Stevens Institute of Technology
1870
The Innovation University

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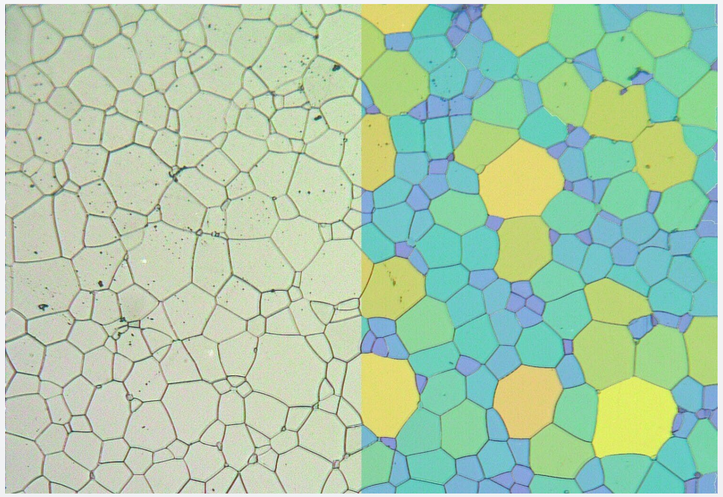
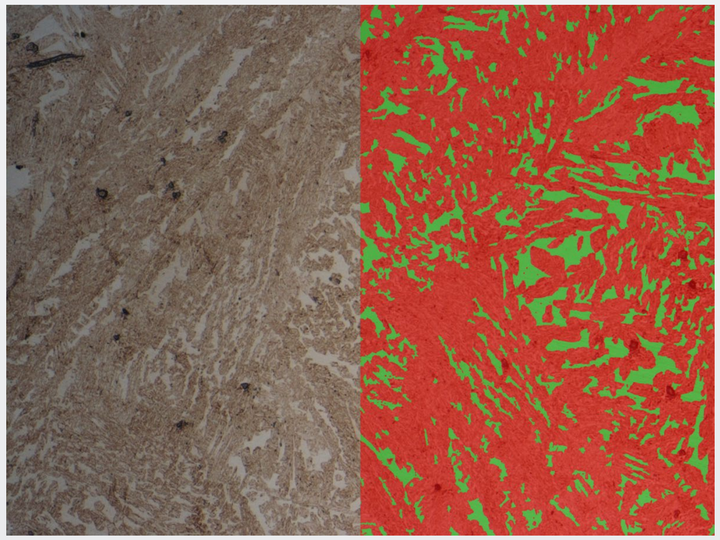
What is possible with Image Analysis for Metals Characterization?

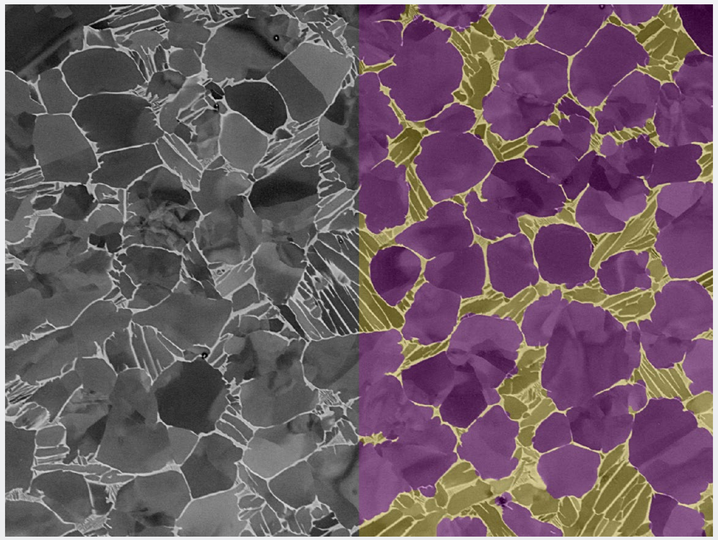
- ✓ Phase Analysis
- ✓ Grain Size Analysis
- ✓ Porosity Analysis
- ✓ Inclusions Analysis
- ✓ Layer Thickness Analysis
- ✓ Particle Analysis
- ✓ Defect Analysis
- ✓ Many more...



Copper alloy grain size measurement following ASTM E-112 standard.



Segments ferrite from surrounding martensite in martensitic stainless steel weld cross-sections.

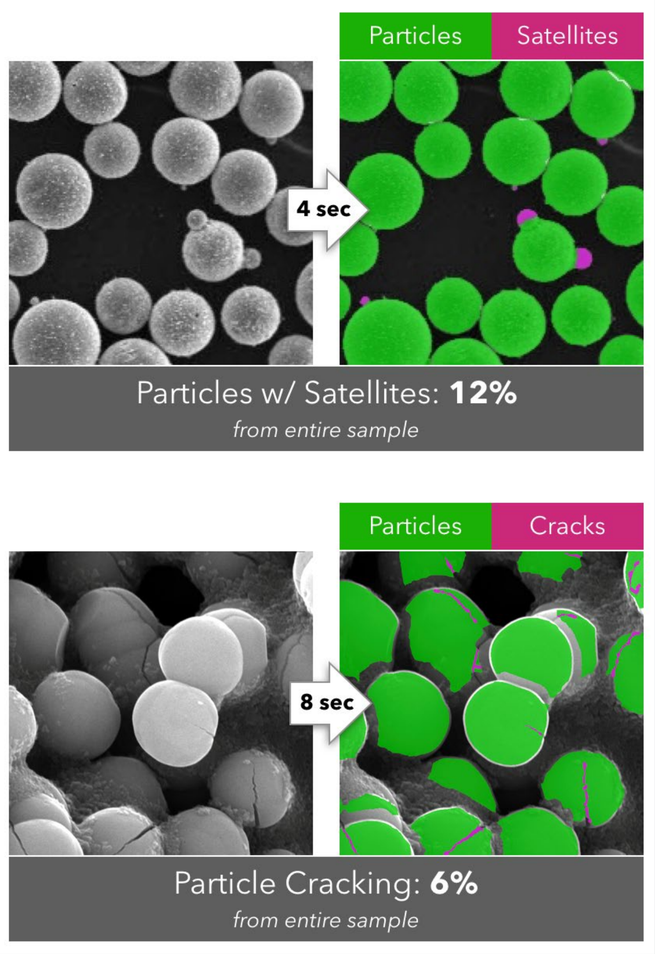


Segments rounder particles from acicular features in [α+β]-processed Ti-alloy microstructures.

Analysis Challenges

Challenges:

- Image analysis expertise
- Operator bias
- Long analysis time
- Low accuracy and reproducibility
- Difficult, complicated images
- Noisy microstructures
- Poor sample prep (scratches)
- Ambiguous feature boundaries
- Wide variety of contrast conditions
- Features of similar grey values
- Poor contrast



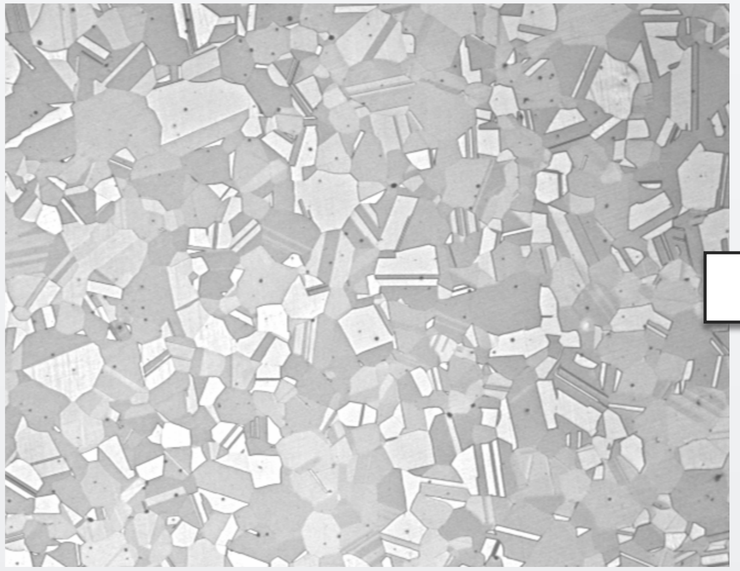
Deep learning addresses all these challenges, it improves image analysis, increases accuracy and throughput, without any image analysis expertise.

MIPAR Image Analysis Software

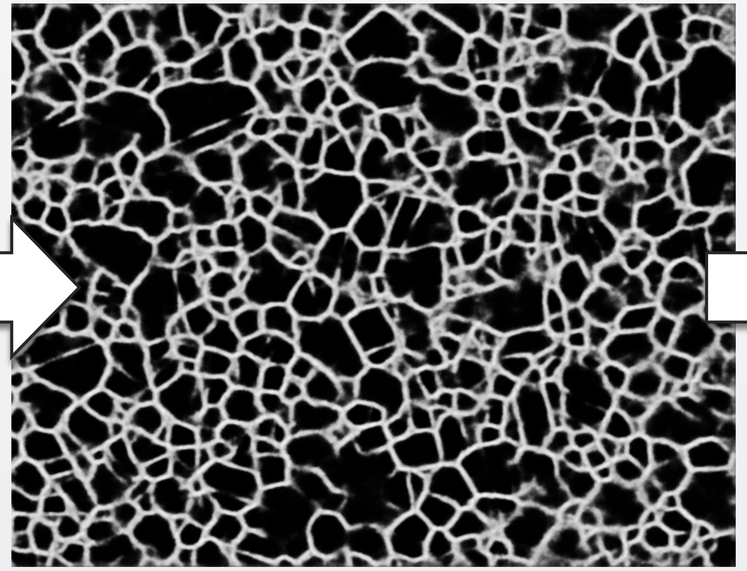
- **Power:** Solve problems others can’t, thanks to powerful **Recipes**
- **Speed:** Solve problems faster with **intuitive design** and **batch processing**
- **Versatility:** Solve problems across **many application areas**
- **Objectivity:** Reduce subjectivity in analysis using the **Optimization Engine**
- **Expertise:** Call on experts to rapidly deliver custom solutions

Grain Analysis - Twinned Grains in Brass

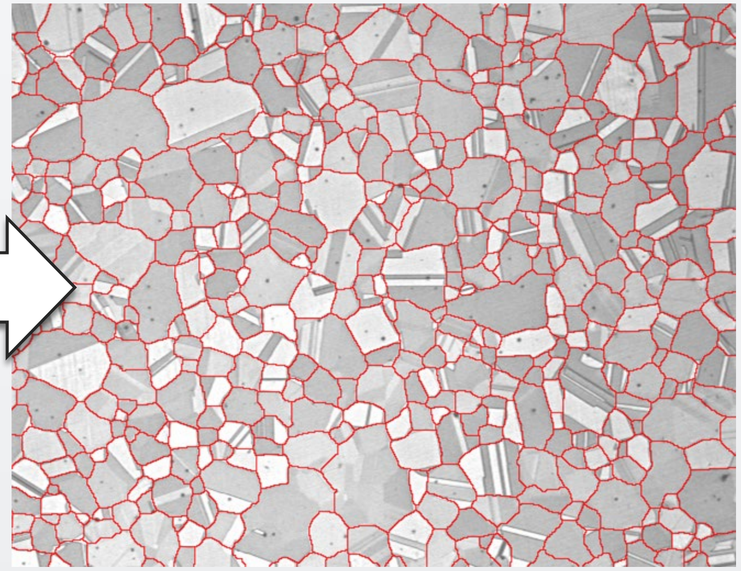
Original Image



Deep Learning Applied



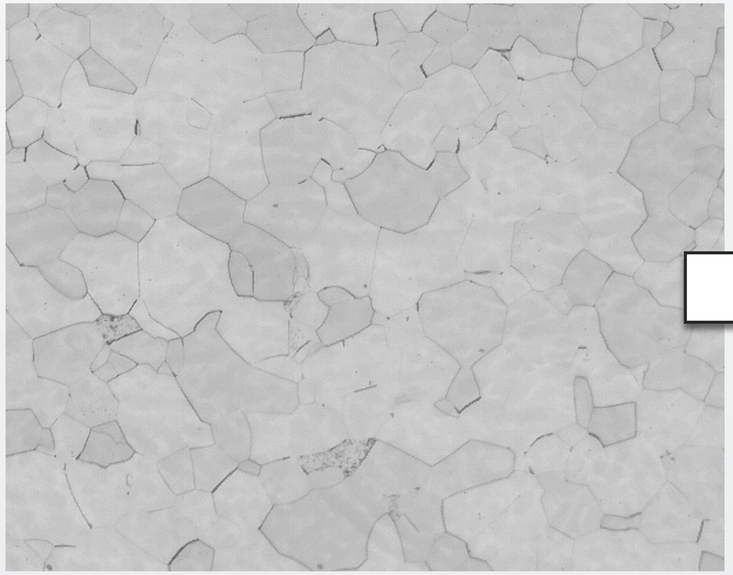
Final Segmentation



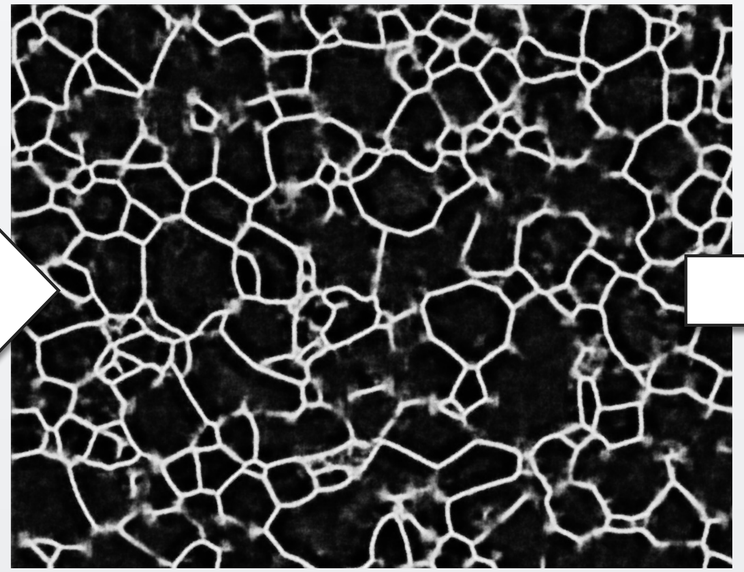
- ✓ Automated measurement of complex grains despite poor contrast
- ✓ Replace manual tracing
- ✓ Deep learning enables highly complex classification

Grain Analysis – Beta grains in Titanium

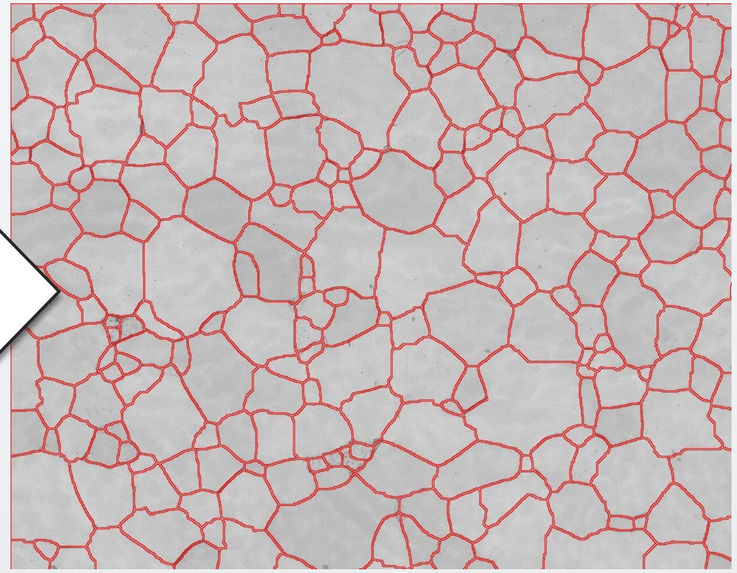
Original Image



Deep Learning Applied



Final Segmentation

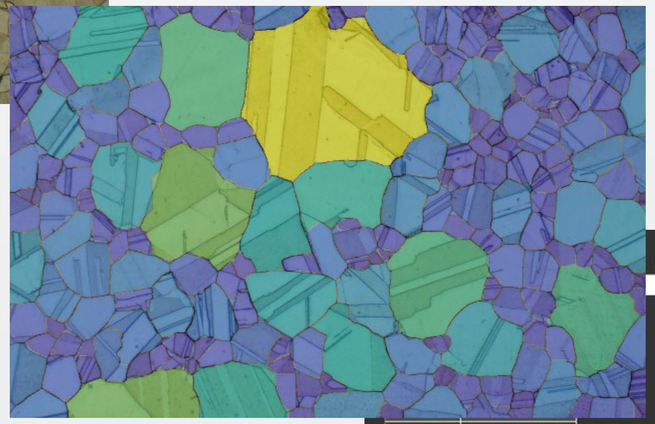


- ✓ Accurately detects beta grains despite very faint contrast
- ✓ Grain mean size and distribution measurements possible

Grain Analysis – Copper Alloy

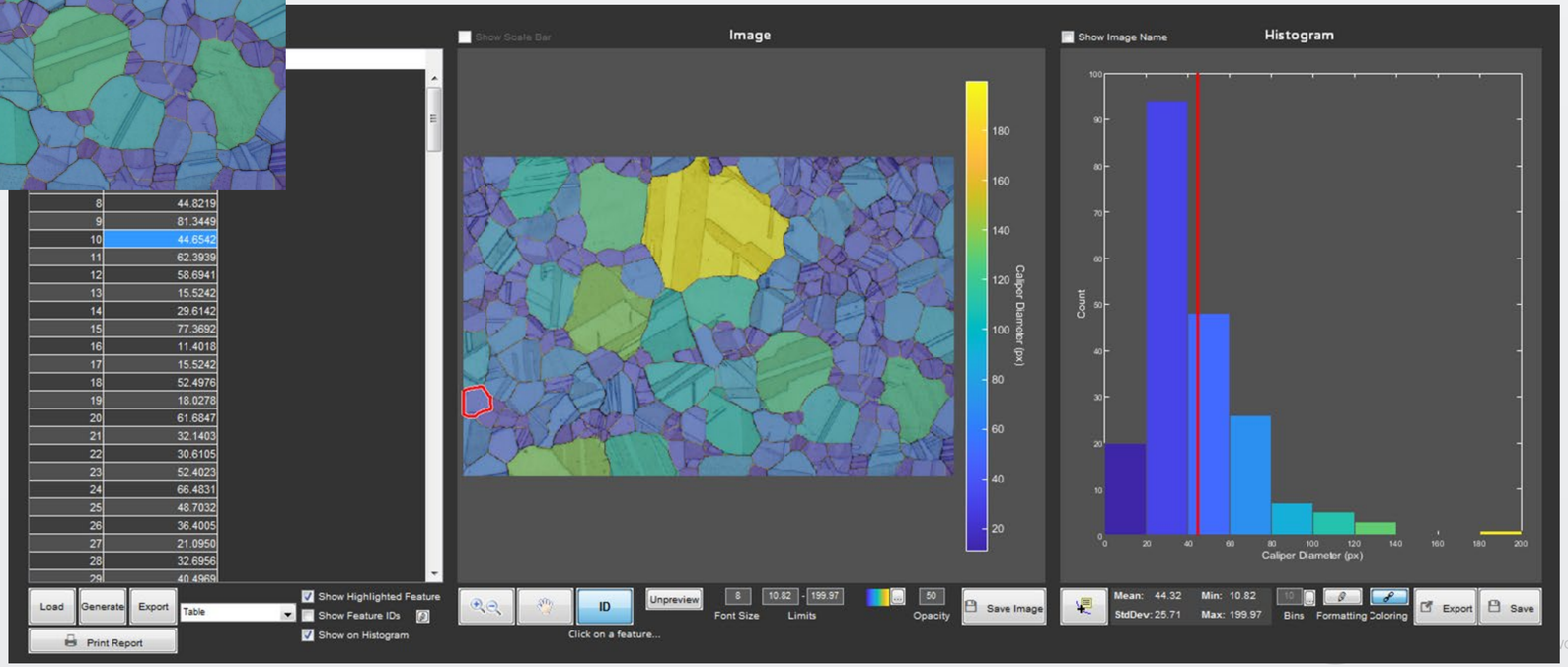
Original

Identified Grains



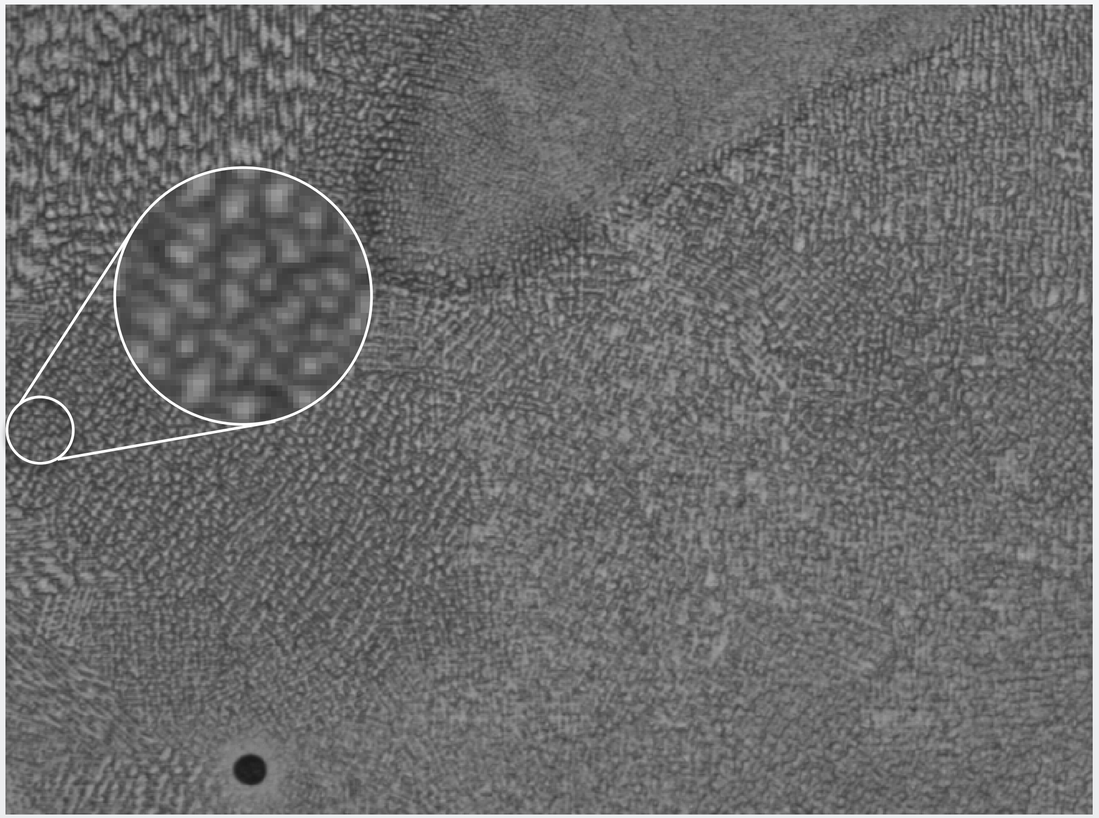
- ✓ Measurements meet ASTM-E112 grain size guidelines
- ✓ Automated, unbiased results

Grain Size Measurements

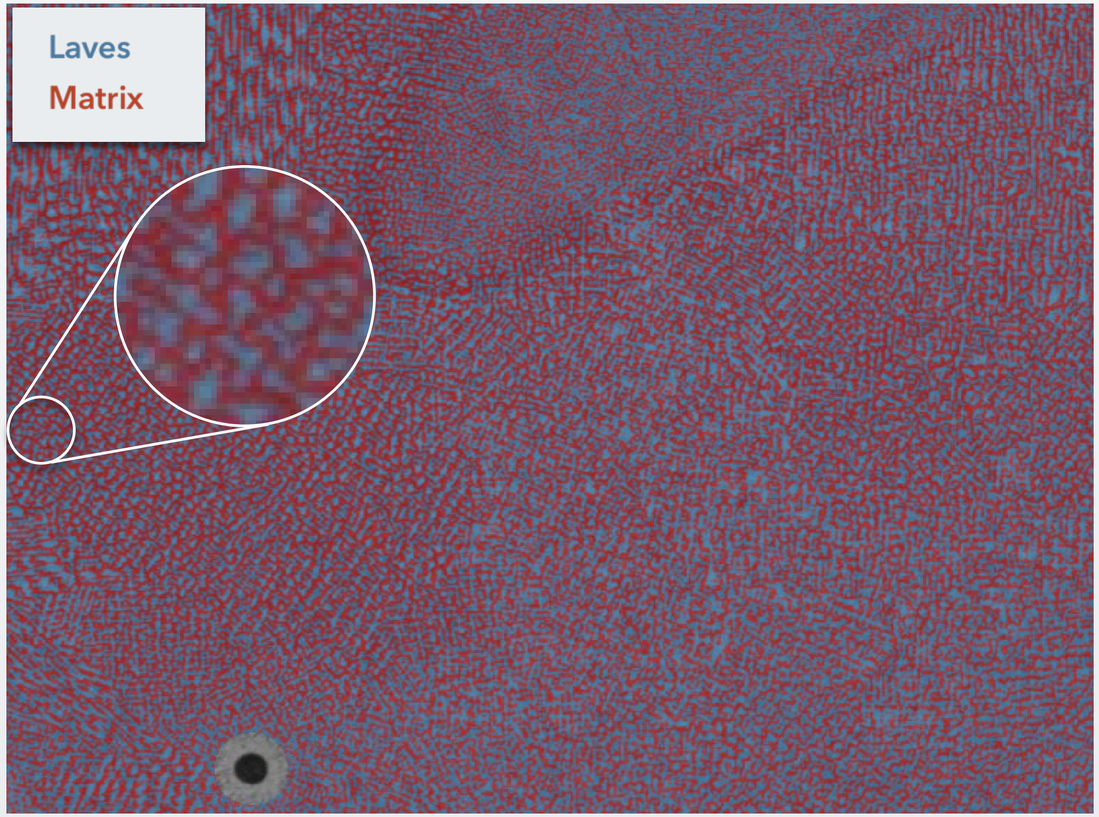


Phase Analysis – Laves in Inconel

Original



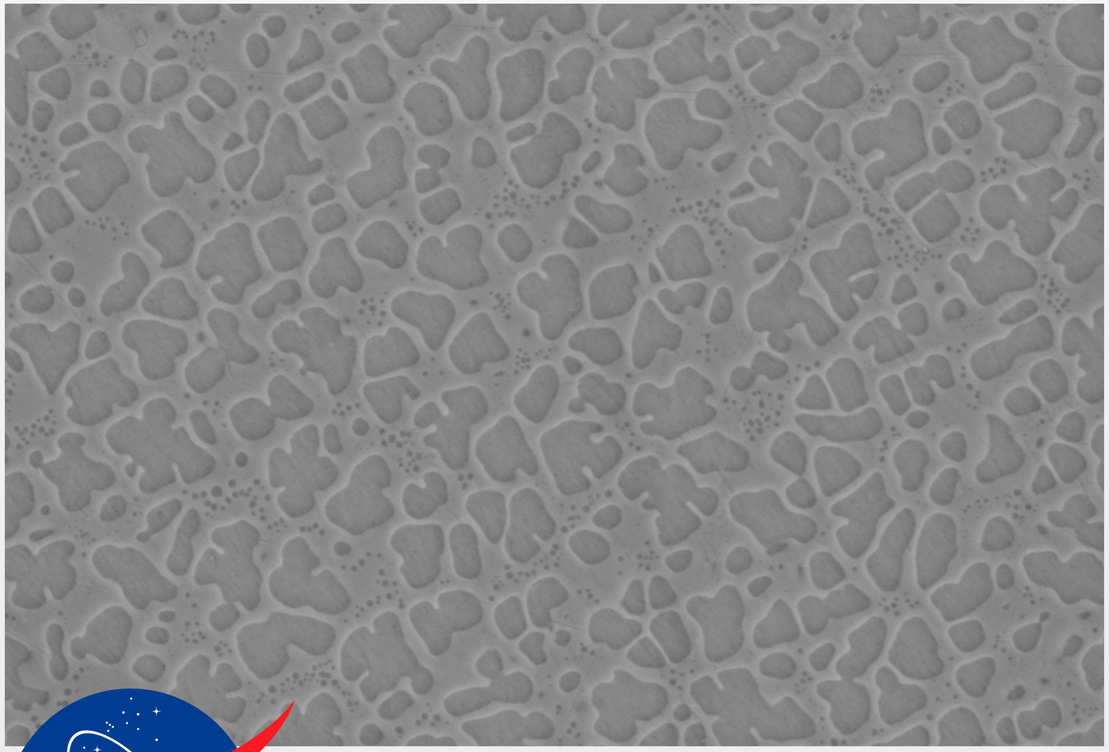
Phase Detection



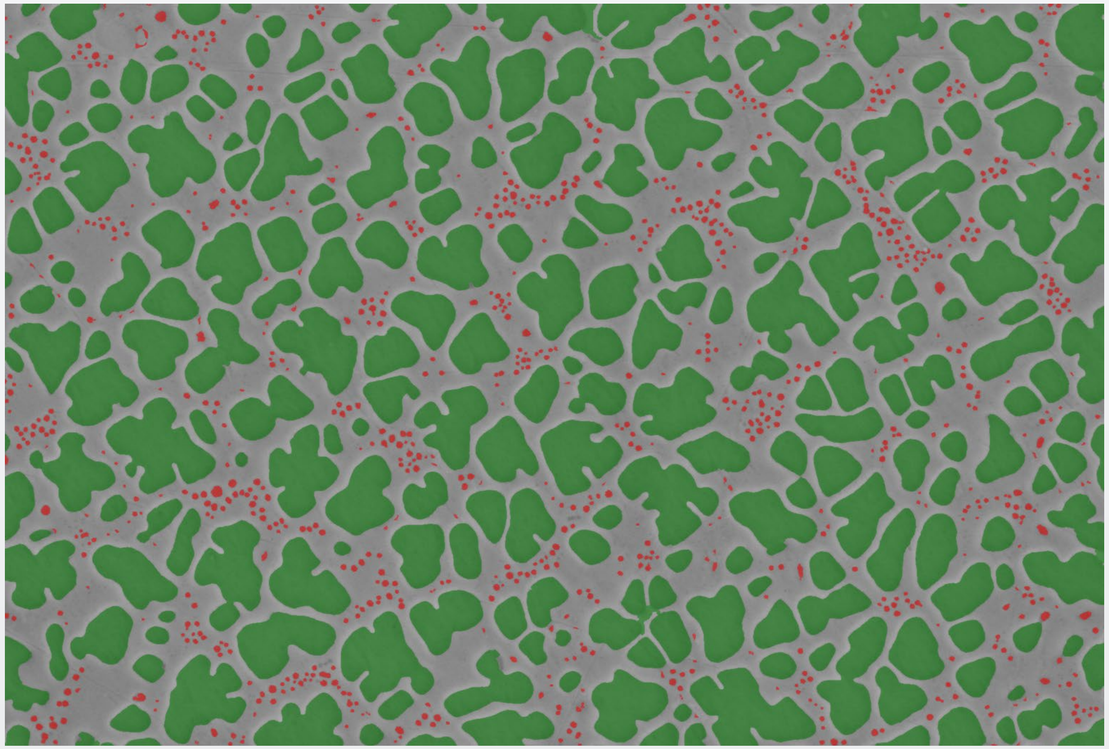
- ✓ Phase fraction can be measured
- ✓ Challenging ultra-fine laves phase detected
- ✓ Robust recipe ignores pores and defects

Phase Analysis – Particles in Nickel-base Superalloy

Original



Particle detection



- ✓ Area fraction can be measured
- ✓ Tough to distinguish particles segmented
- ✓ Fully automated workflow

T.M. Smith, P. Bonacuse, J. Sosa, M. Kulis, L. Evans, *A quantifiable and automated volume fraction characterization technique for secondary and tertiary γ′ precipitates in Ni-based superalloys*, Materials Characterization, Volume 140, 2018, Pages 86-94

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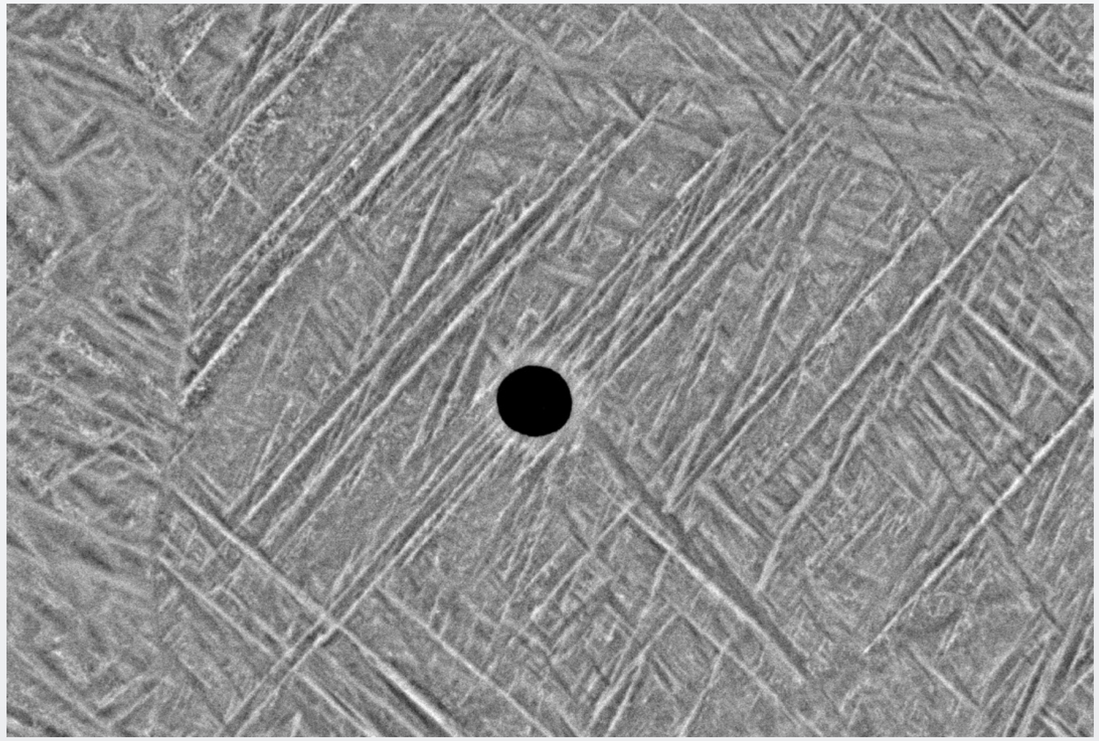
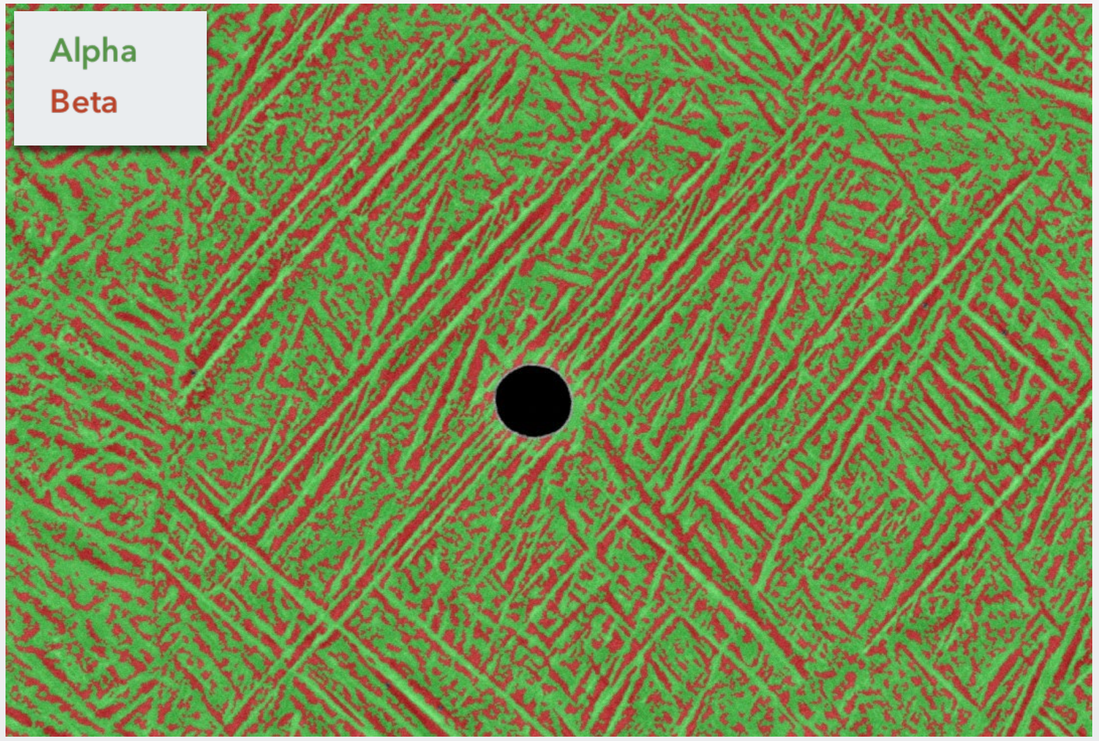
Phase Analysis – Alpha and Beta in Titanium

Original



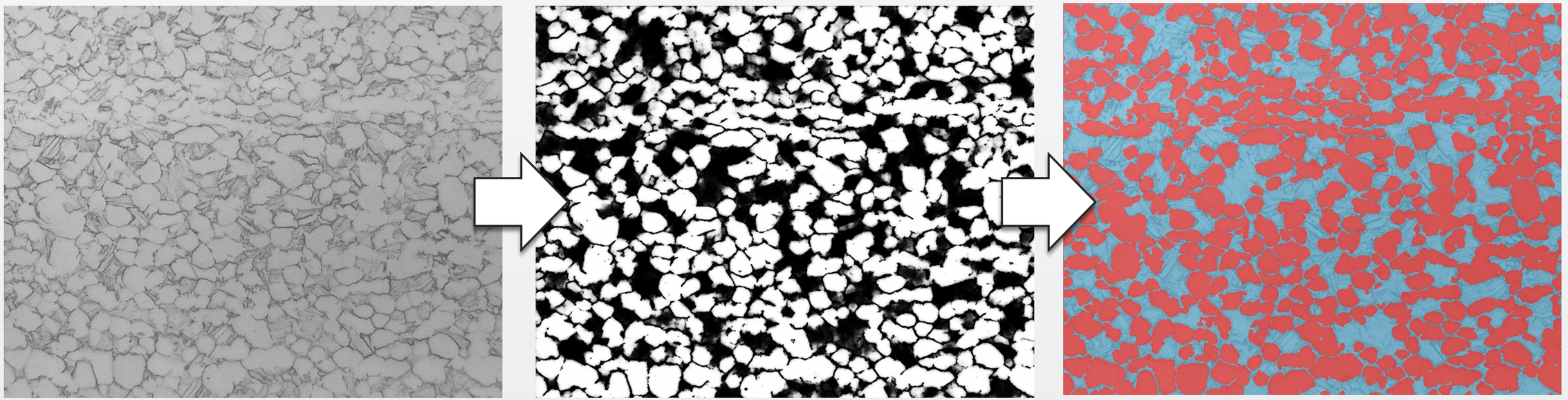
Phase Detection



- ✓ Phase fraction can be measured
- ✓ Complex alpha and beta phases detected
- ✓ Robust recipe ignores pores and defects

Morphology Classification - Globular Alpha

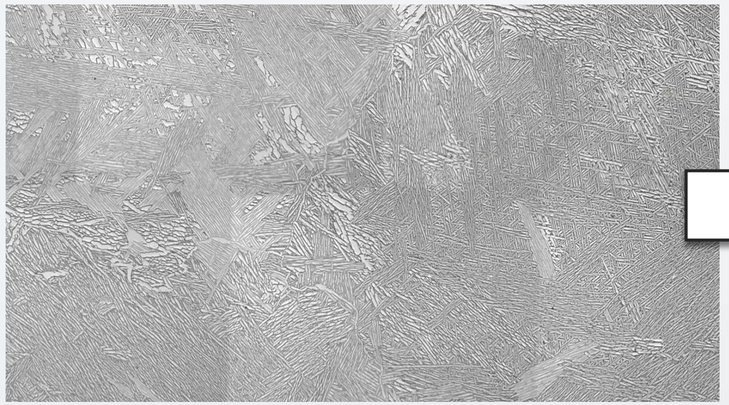
Original Image | **Deep Learning Applied** | **Final Segmentation**



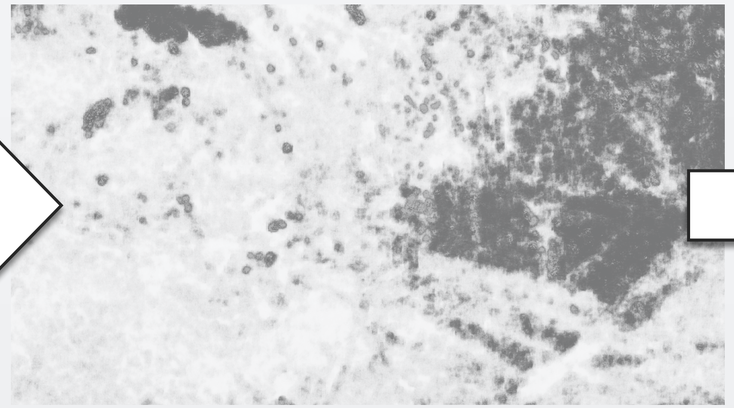
- ✓ Accurately and automatically measure globular alpha fraction
- ✓ Replace heavy amounts of manual correction
- ✓ Globular percentage and size measurements possible

Morphology Classification – Colony vs. Basketweave

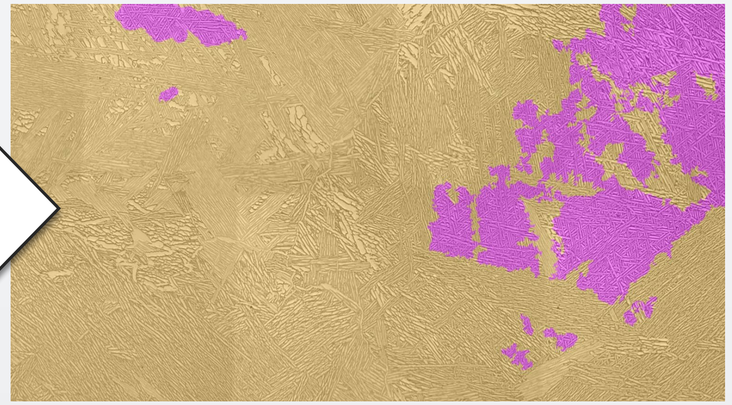
Original Image



Deep Learning Applied



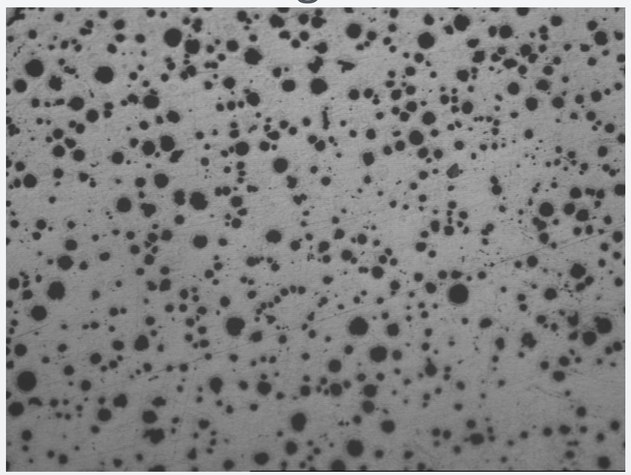
Final Segmentation



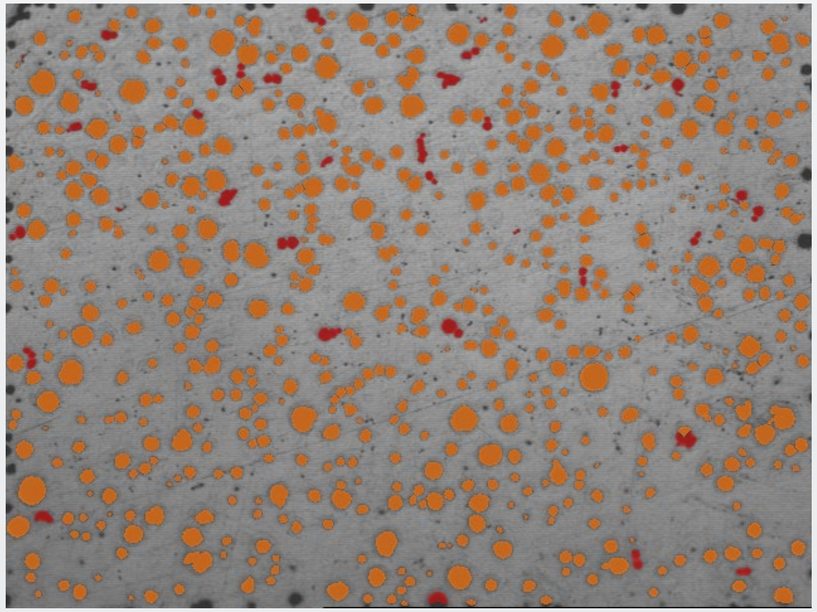
- ✓ Automated classification of morphologies based on image texture
- ✓ Replace tedious point-counting and user bias
- ✓ Deep learning enables highly complex classification

Steel Inclusions

Original



Identified and Classified



Non-nodular Graphite

Nodular Graphite

- ✓ Measurements meet ASTM-A247 graphite characterization in steel guidelines
- ✓ Tailored recipes to internal standards

Nodularity Measurement

Measurements

Layer	Area Fraction (%)
ASTM Nodularity Percentage	94.4780

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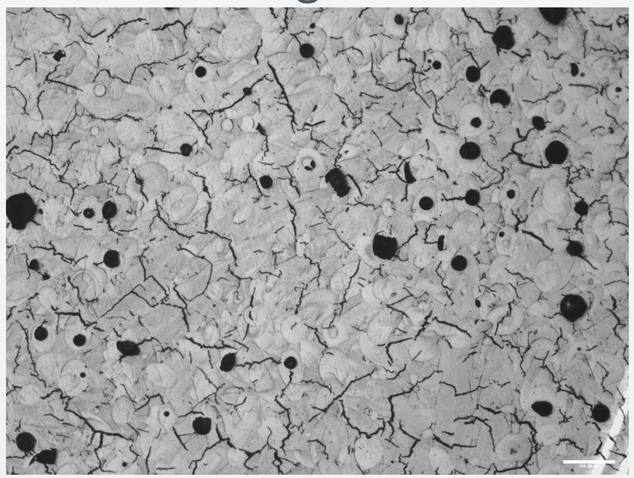
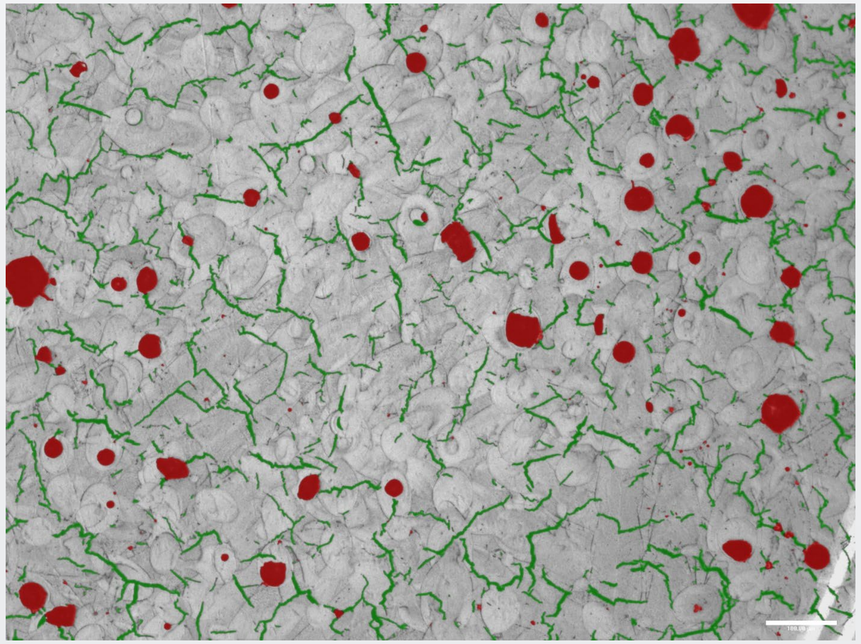
Defects Analysis – Additive Manufacturing

Original



Identified and Classified



Pores

Cracks

- ✓ Calibrate recipe to match existing techniques
- ✓ Facilitates workflow integration

Crack + Pore Measurement

Measurements

Layer	Area Fraction (%)	Number Density (features/µm^2)
Pores	3.7940	1.4408e-04
Cracks	5.9420	9.5184e-04

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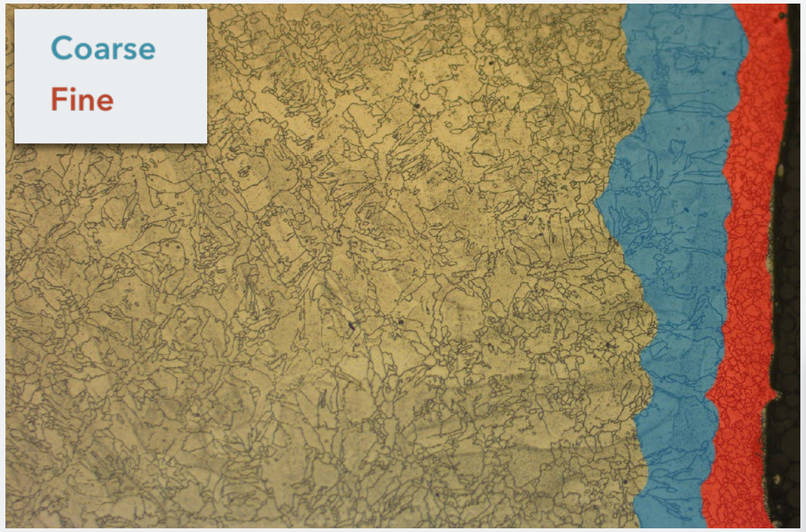
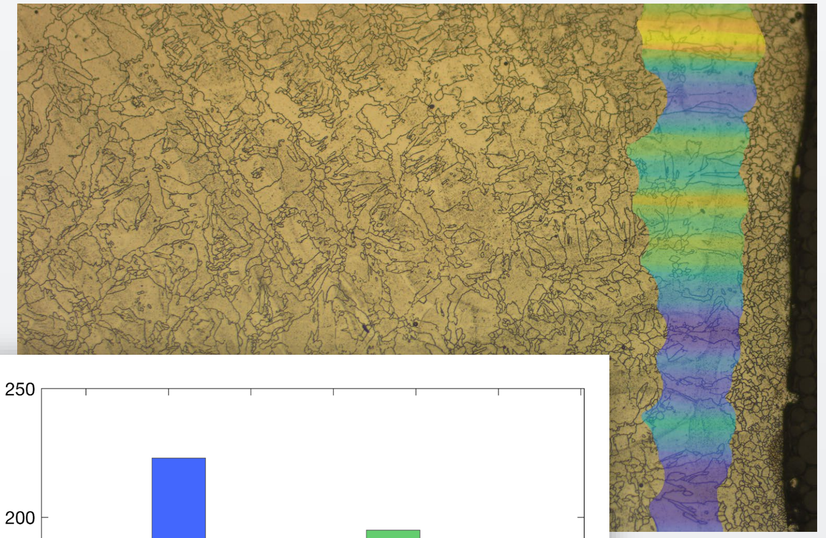
Layer Thickness Analysis – Grain-Band Identification

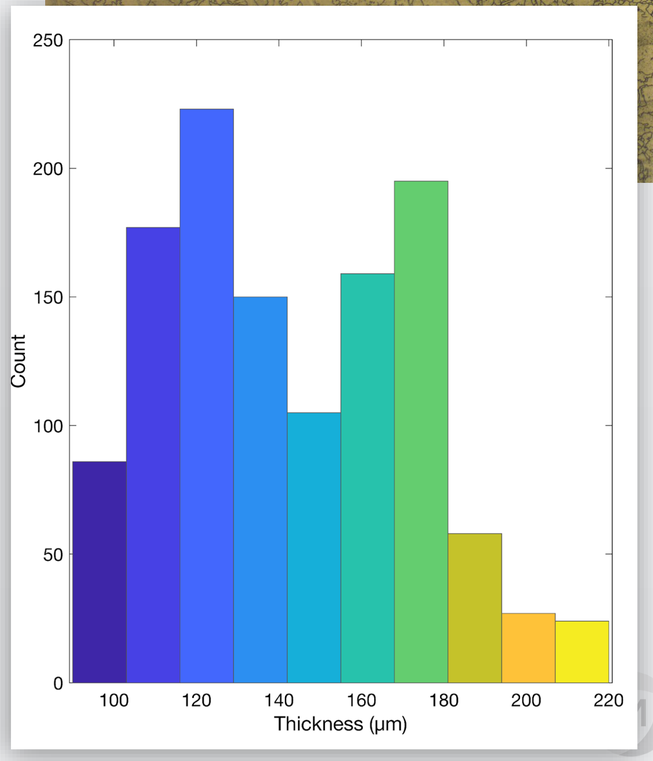
Original

Grain-Band Identification



Thickness Measurement

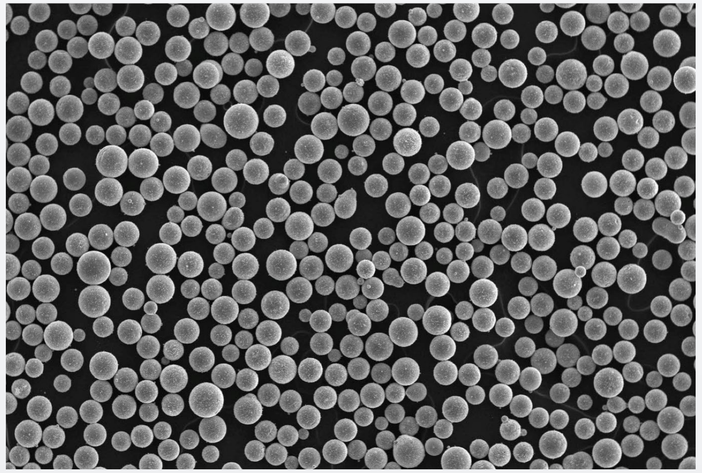




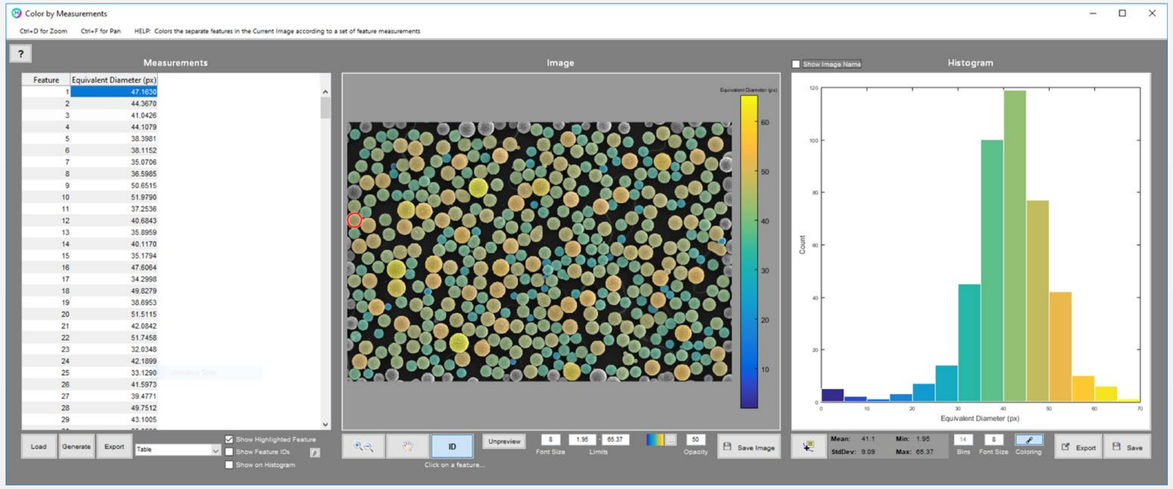
✓ Band widths can be measured

Powder particles – Size and Shape Measurements

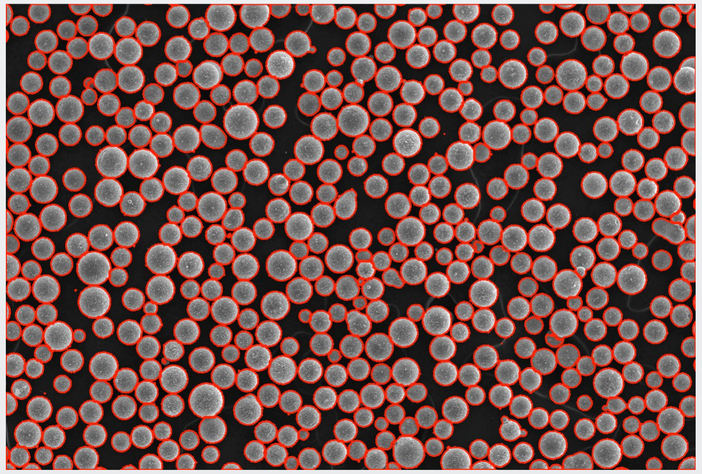
Original



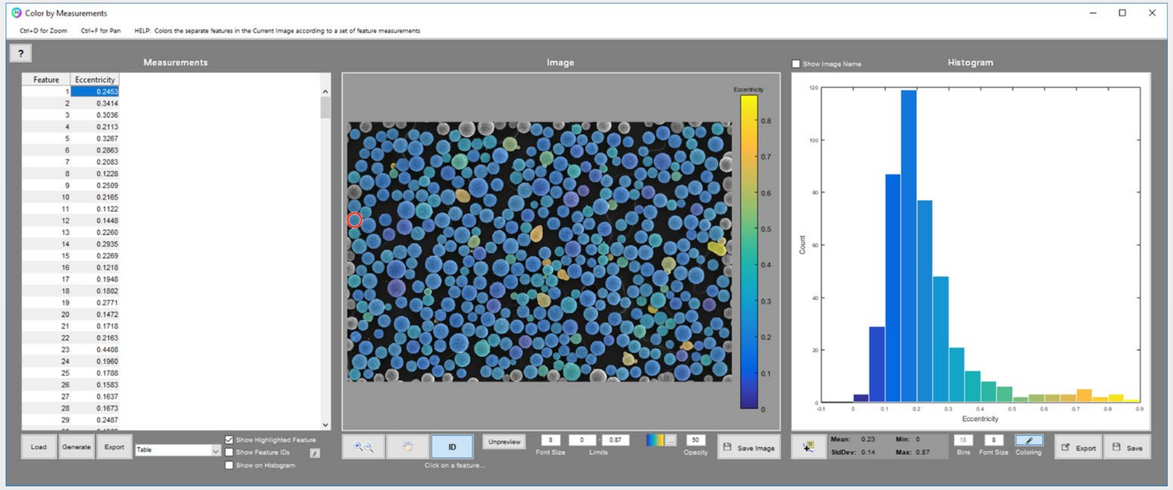
Size Measurement



Identified Particles



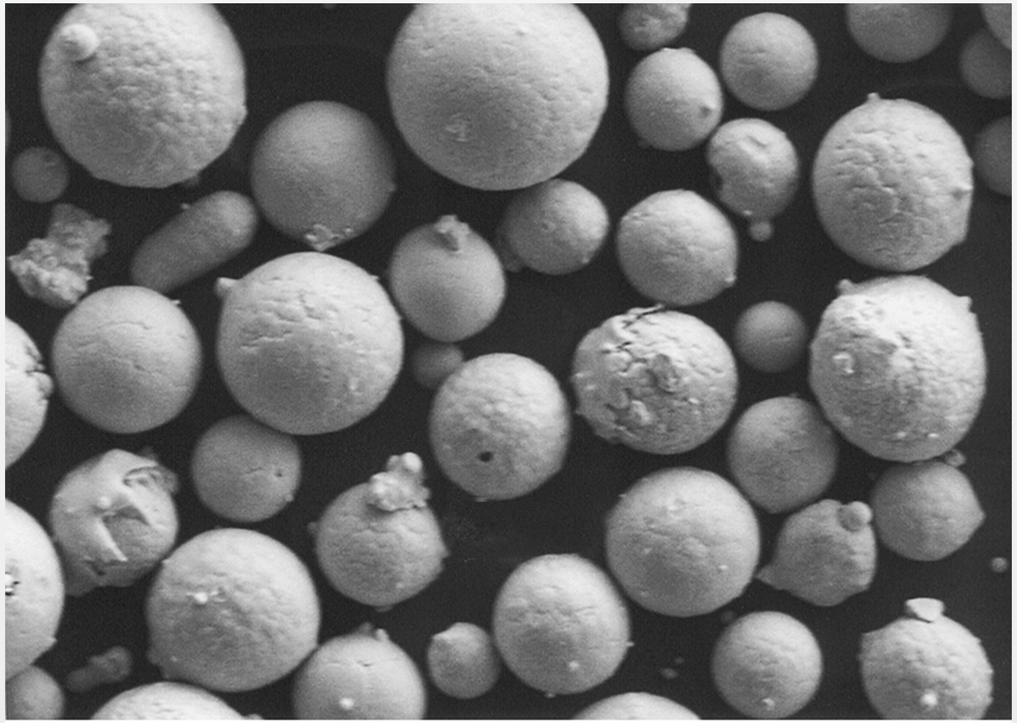
Shape Measurement



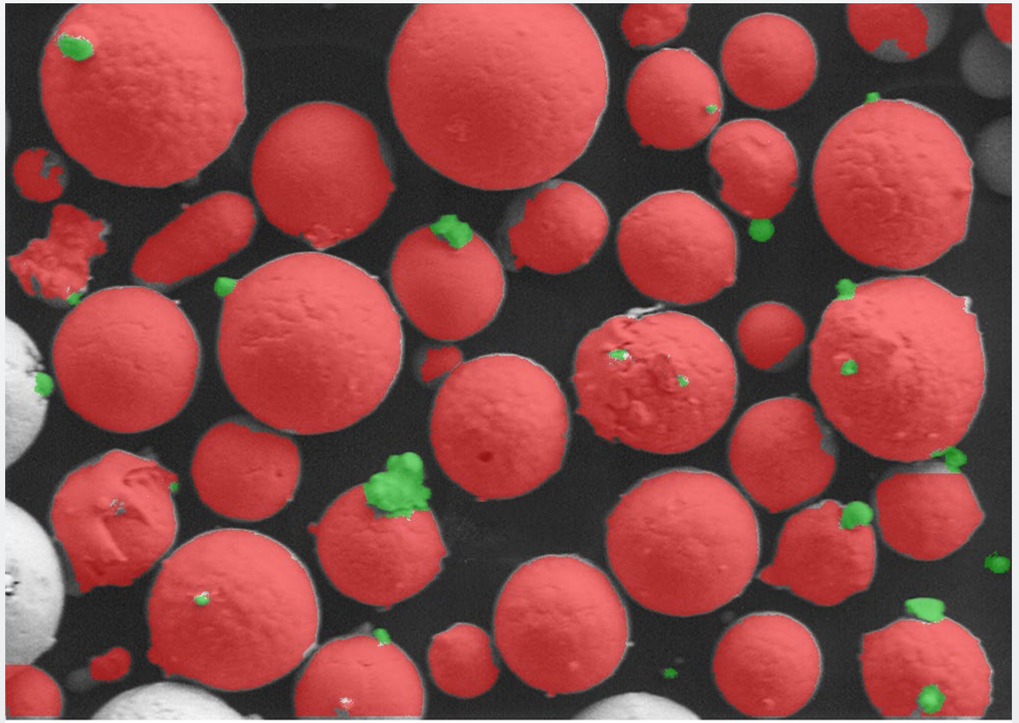
SEM Image of Particles is Segmented and Characterized by Size (Diameter) and Shape (Eccentricity)

Powder particles – Satellite Analysis

Original



Particle detection

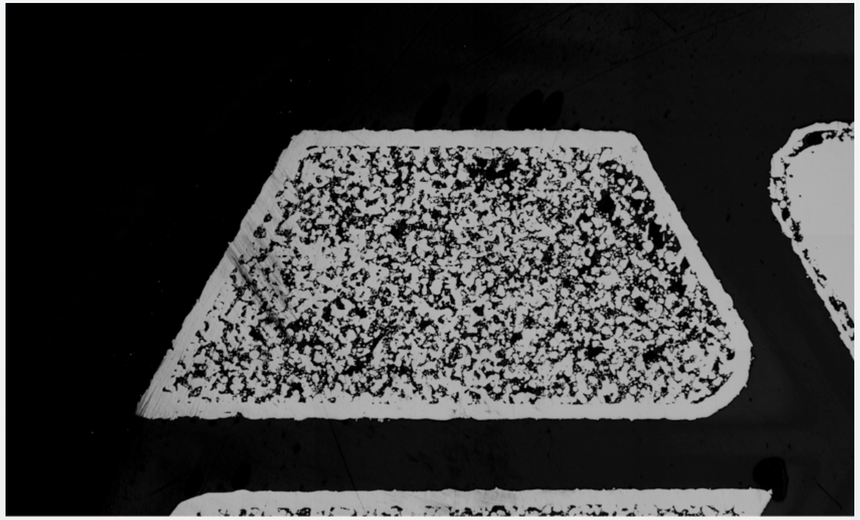


- ✓ Diameter of particles can be measured
- ✓ Fully automated satellite detection

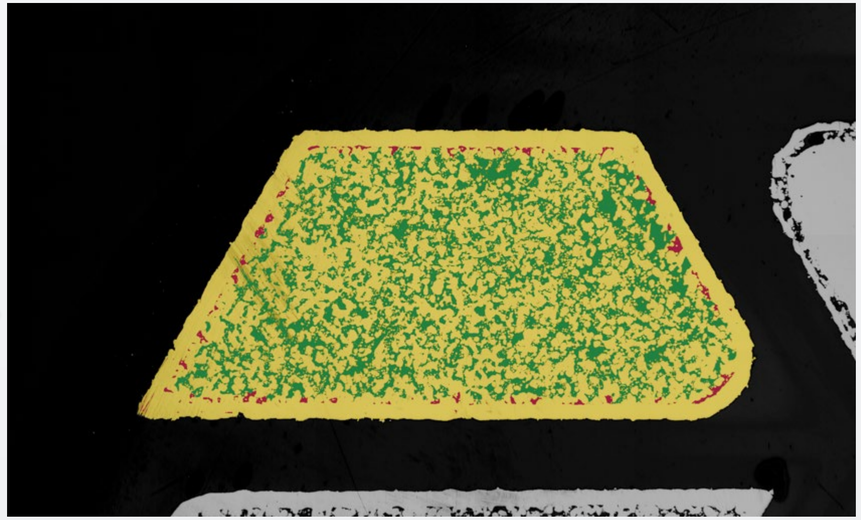
Porosity Analysis – Additive Manufactured Parts

Original

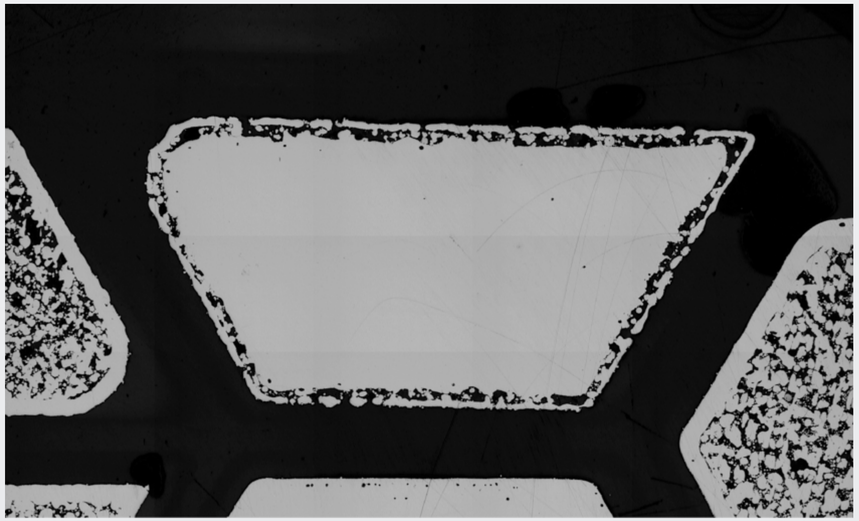
Solid Porosity



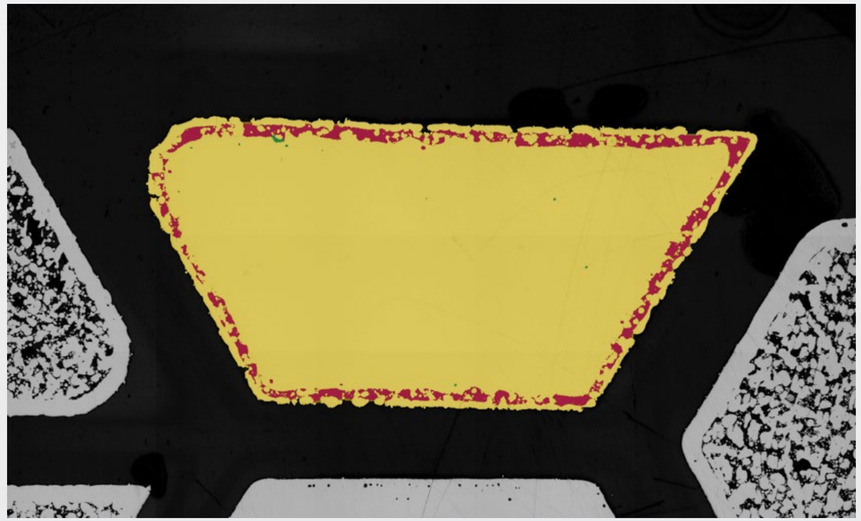
15 sec



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



15 sec



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

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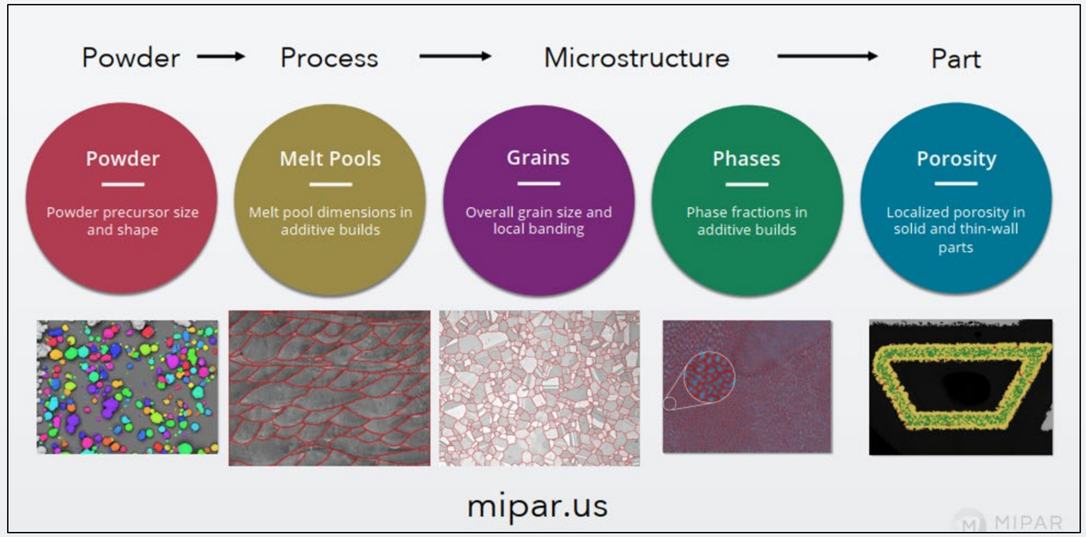
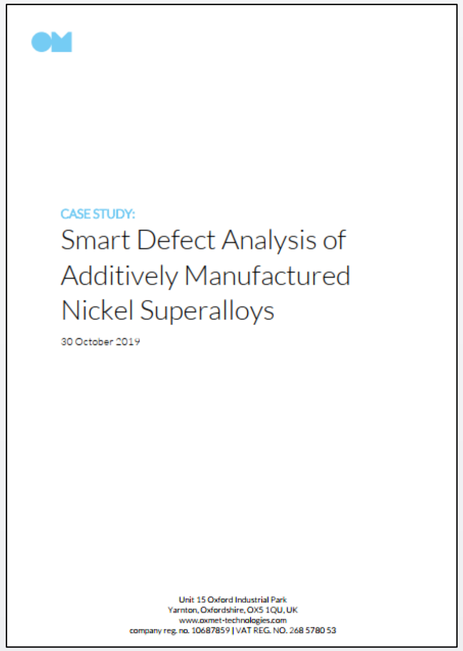
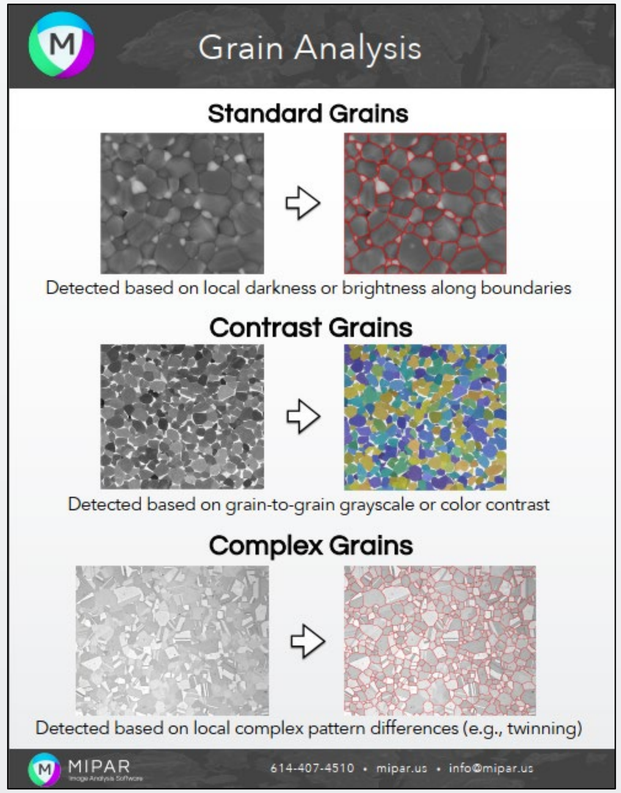
Metals Applications

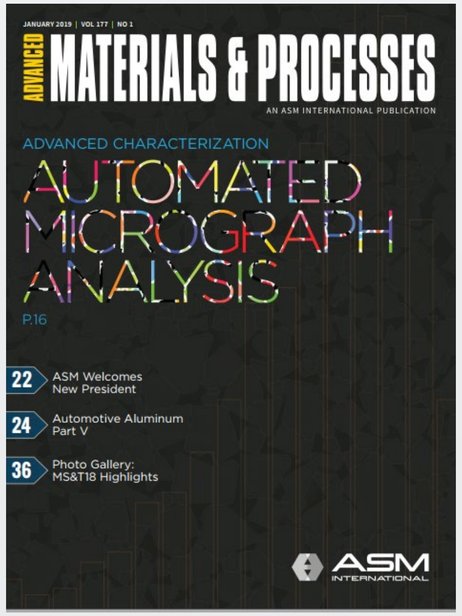
Additive Manufacturing







Titanium Research



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