

Laser Stripping of Aerospace Materials with Closed-Loop, Color-Recognition Control

**ASETS Defense 2009 Workshop
Sustainable Surface Engineering for
Aerospace and Defense
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Laser Surface Preparation

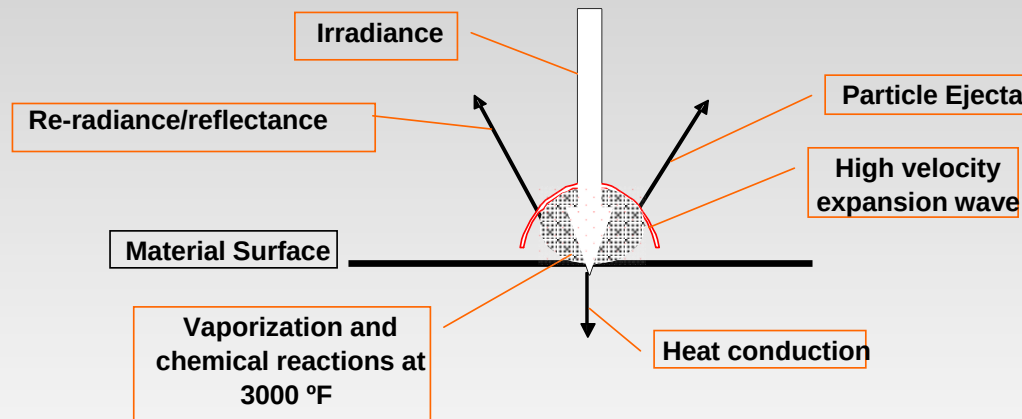
Laser Ablation is the 21st Century Solution for Surface Cleaning and Surface Preparation:

- Demonstrated Zero Reduction in Material Properties***
- Negligible Environmental Impact and Abatement Costs***
- Installable as Workcell in Existing Production Facilities***
- Versatile Configurations with COTS–NDI Components***
- Demonstrated Reliability and Maintainability***
- True Closed-Loop Control Enables Manual or Robotic Positioning of Laser Workhead with Color Recognition***
- Cost Competitive with Current Decoating Technologies***
- The Only Laser Process that is FAA Approved for Commercial Aircraft***
- Successful Applications with Aluminum, Titanium, Steel and Composite Materials***

Photoablation Physics

Laser Ablation Process

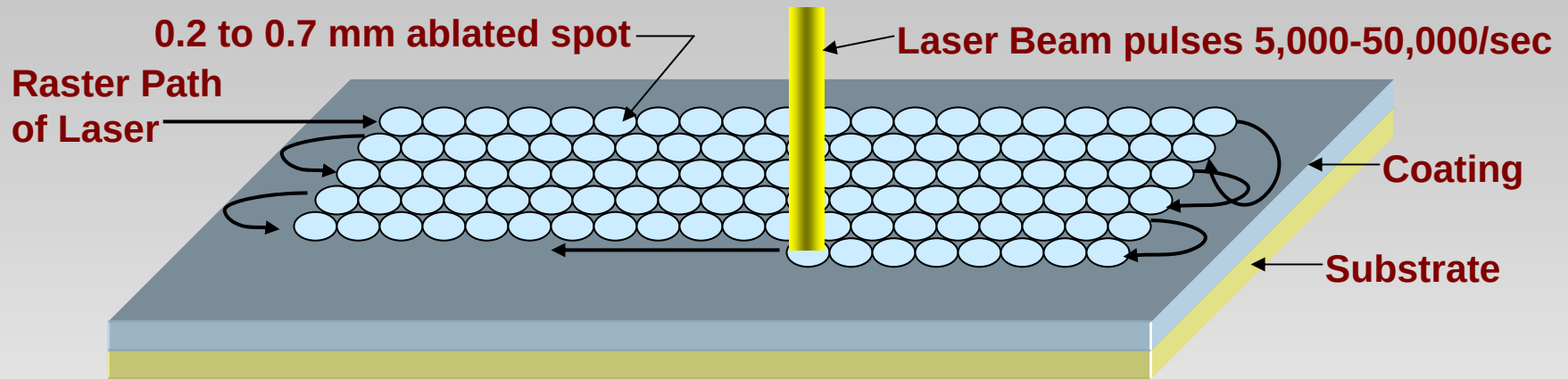
- High-Intensity Radiant Heating ($10\text{-}30\text{ MW/cm}^2$)
- Very Short Duration ($0.2\text{ }\mu\text{sec}$),



- High Reflectance, so Heat Conduction is Small
- $\text{Time}_{\text{Vaporization}} \ll \text{Pulse duration} \ll \text{Time}_{\text{Conduction}}$

Surface Physics

Laser Scanning



- Coating removal from aerospace materials
 - Metal oxides and dust → Particulate ejecta
 - Oils and solvents → $\text{H}_2\text{O} + \text{CO}_2$
- Process Parameters Optimized to Clean and Deoxidize / Depassivate Substrate Surface

Surface Physics

Photoablation-Induced Texture



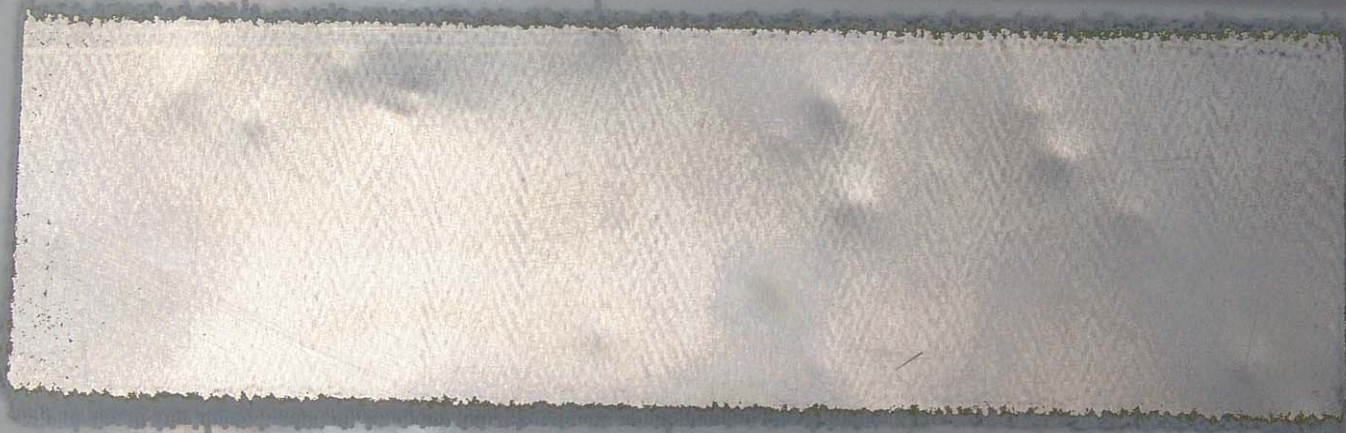
2024-T3 Alclad

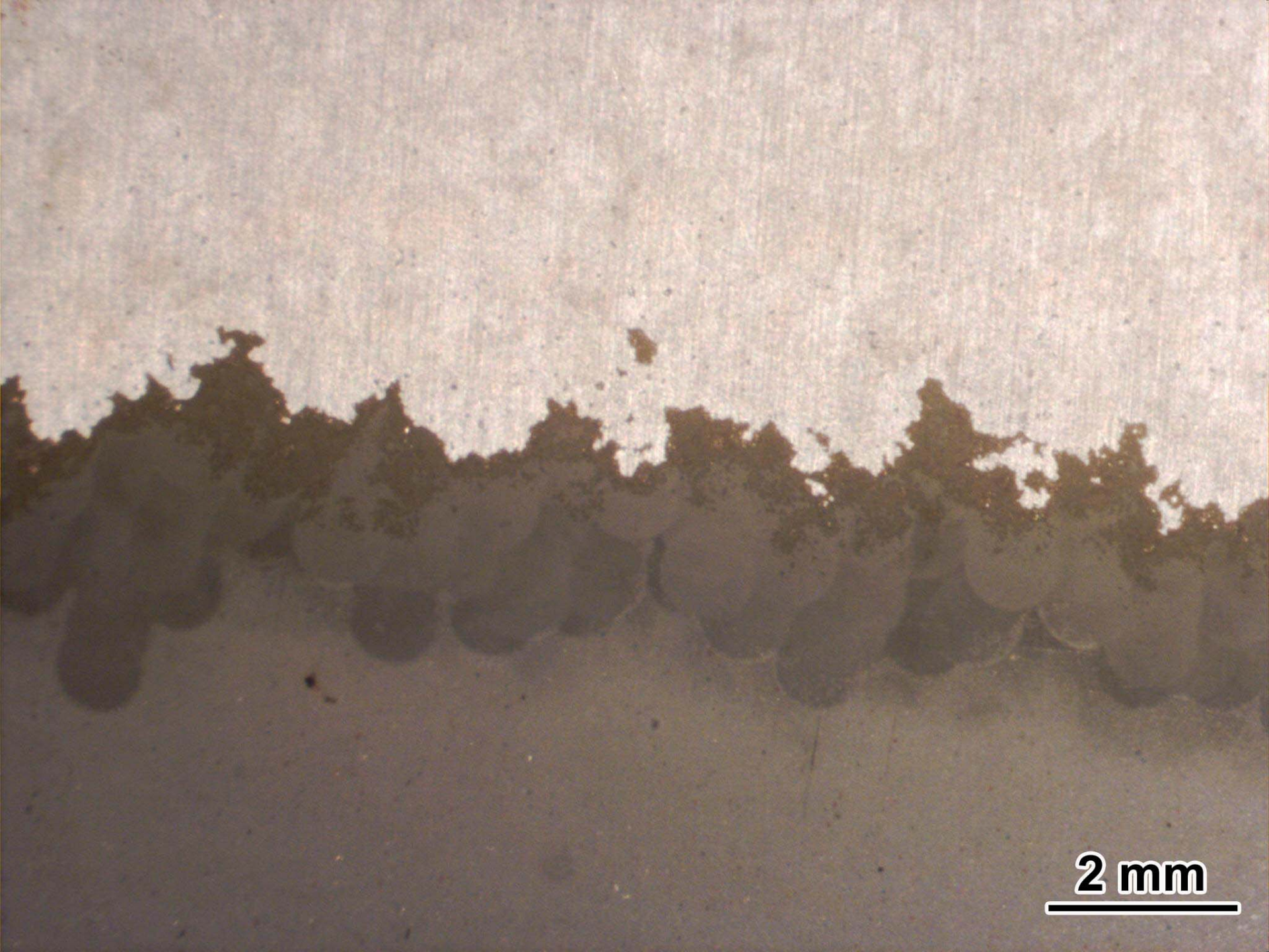
“Golf Ball” texture
0.7 mm dia. x
0.008 mm depth in
0.05 mm-thick clad
layer

- Laser Parameters can be controlled in order to achieve desired surface finish effects

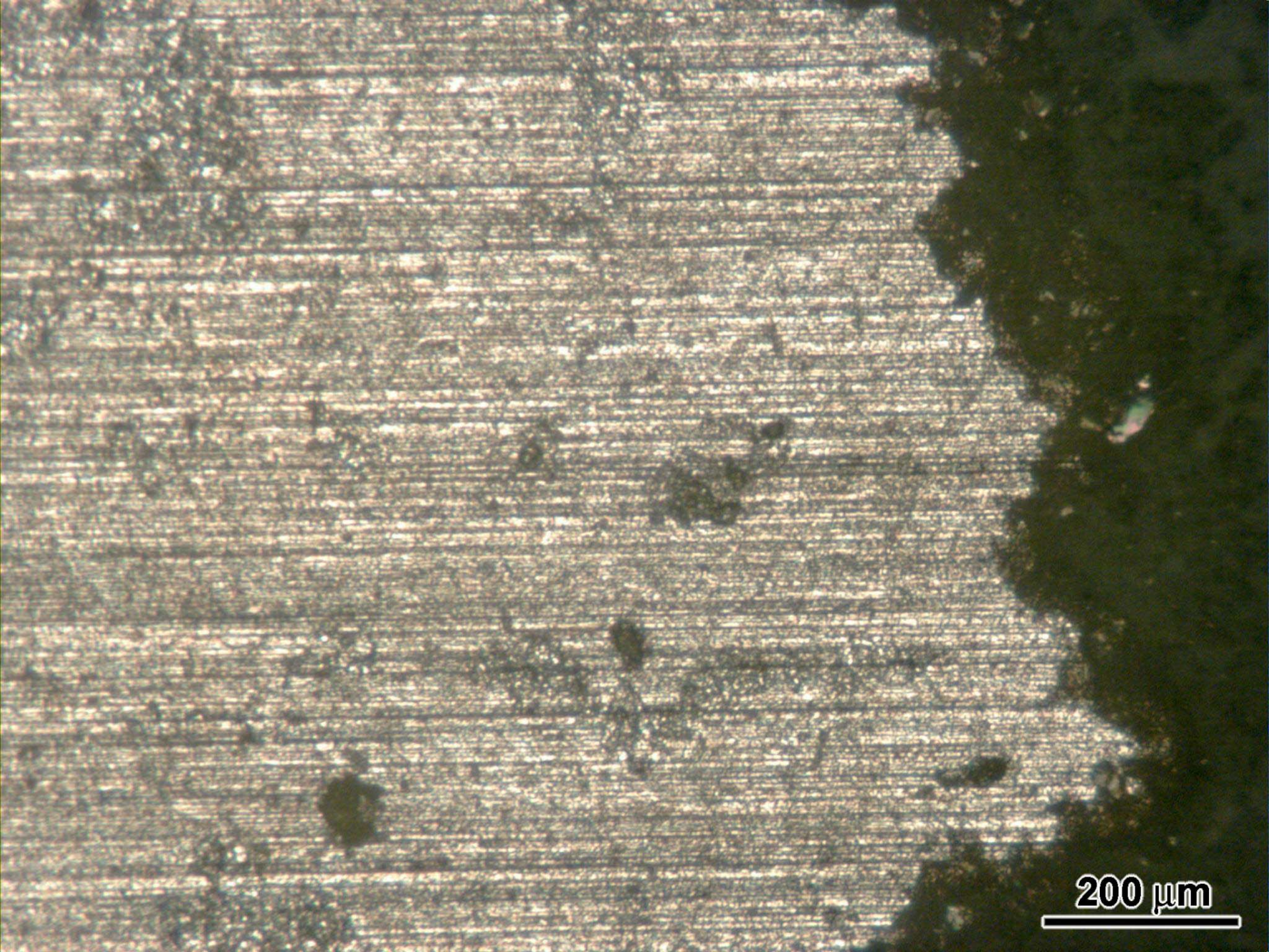


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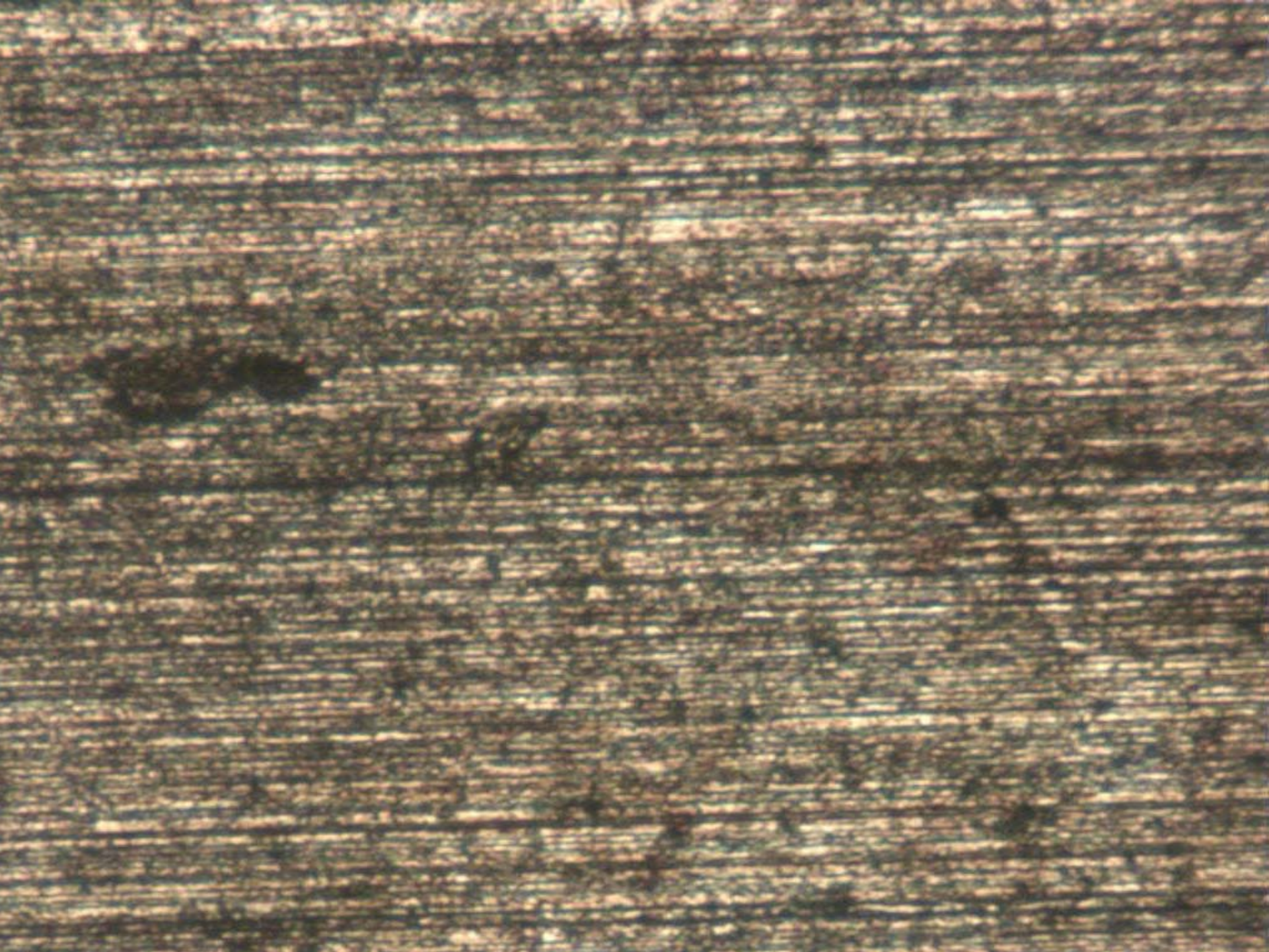


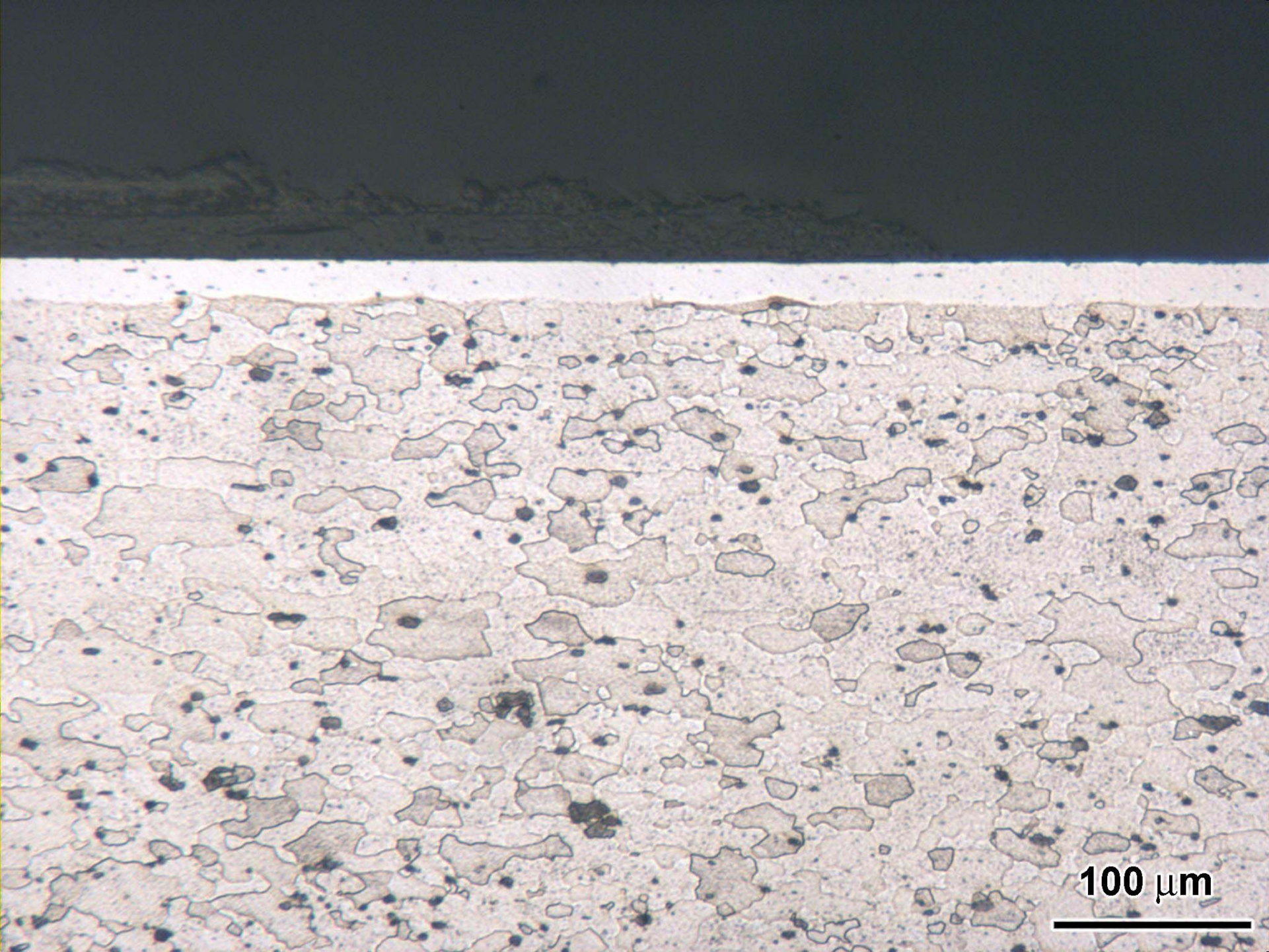


2 mm

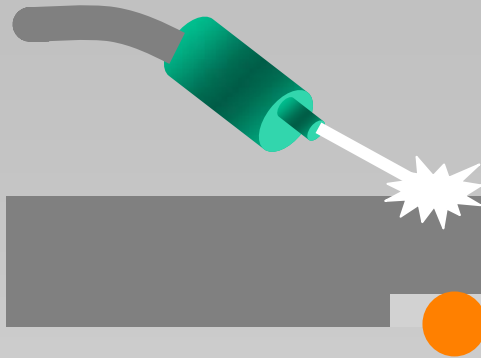


200 μm



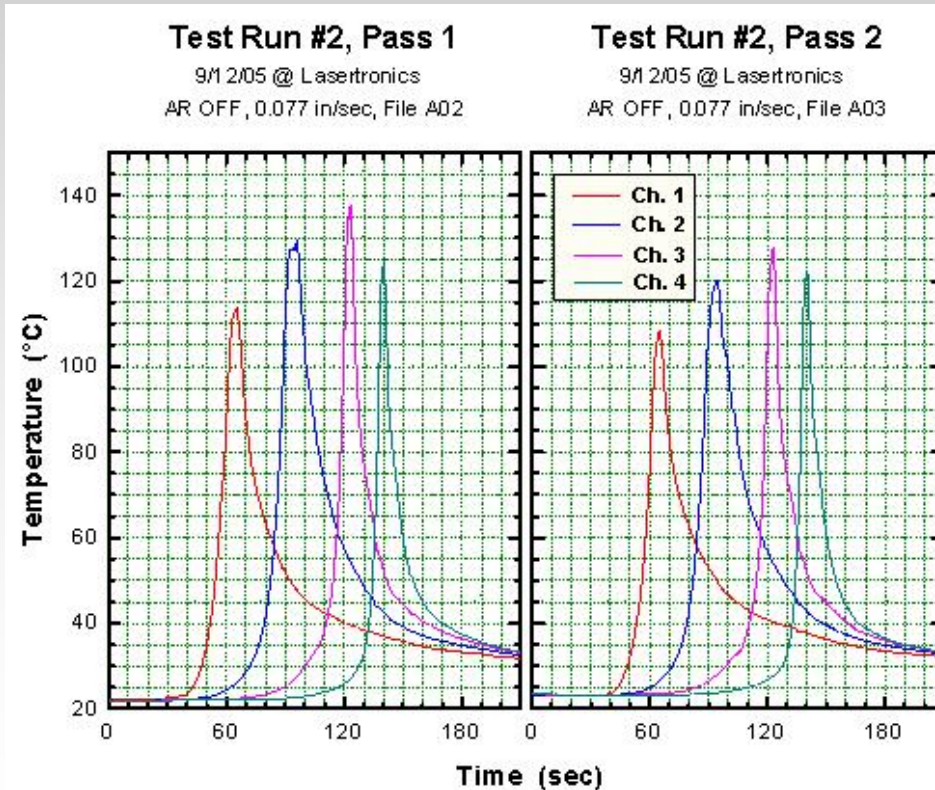


100 μm



Material Temperature

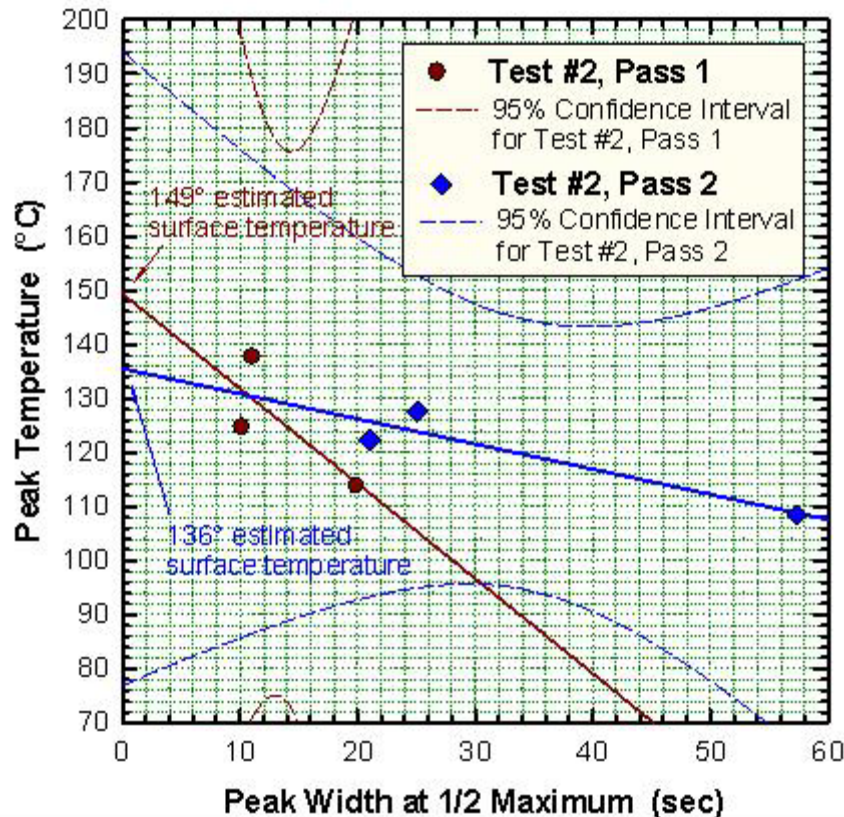
Channel 1 Channel 2 Channel 3 Channel 4



- Temperature data at 4 depths during paint removal from 2024-T3 Al Clad
- Peaks match laser traverse events
- Ch. 4 impacted by thermal mass of doubler plate

Surface Temperature Estimates

Well below reference values



2024-T3 References

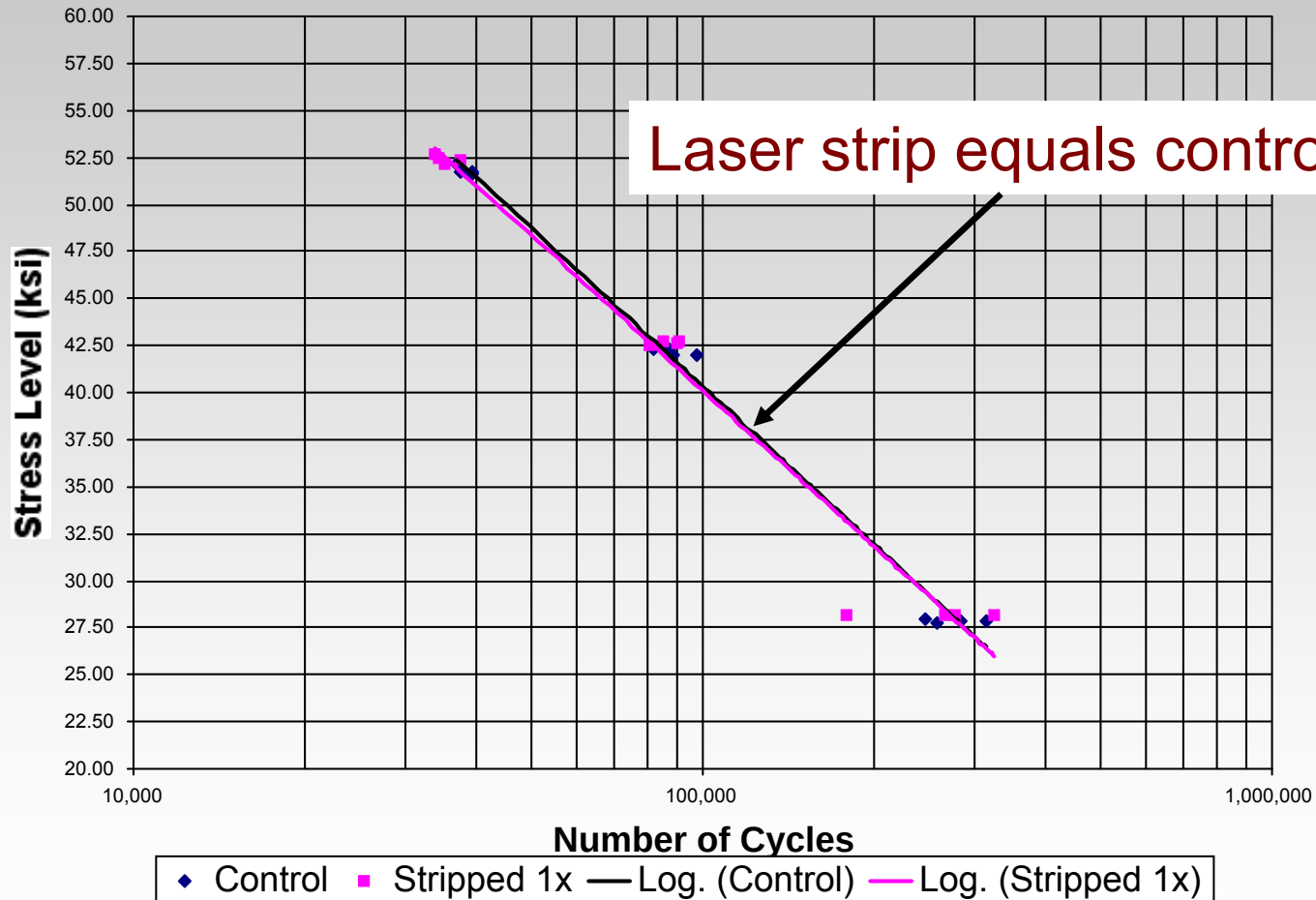
Annealing Temp
412.7 °C (775 ° F)

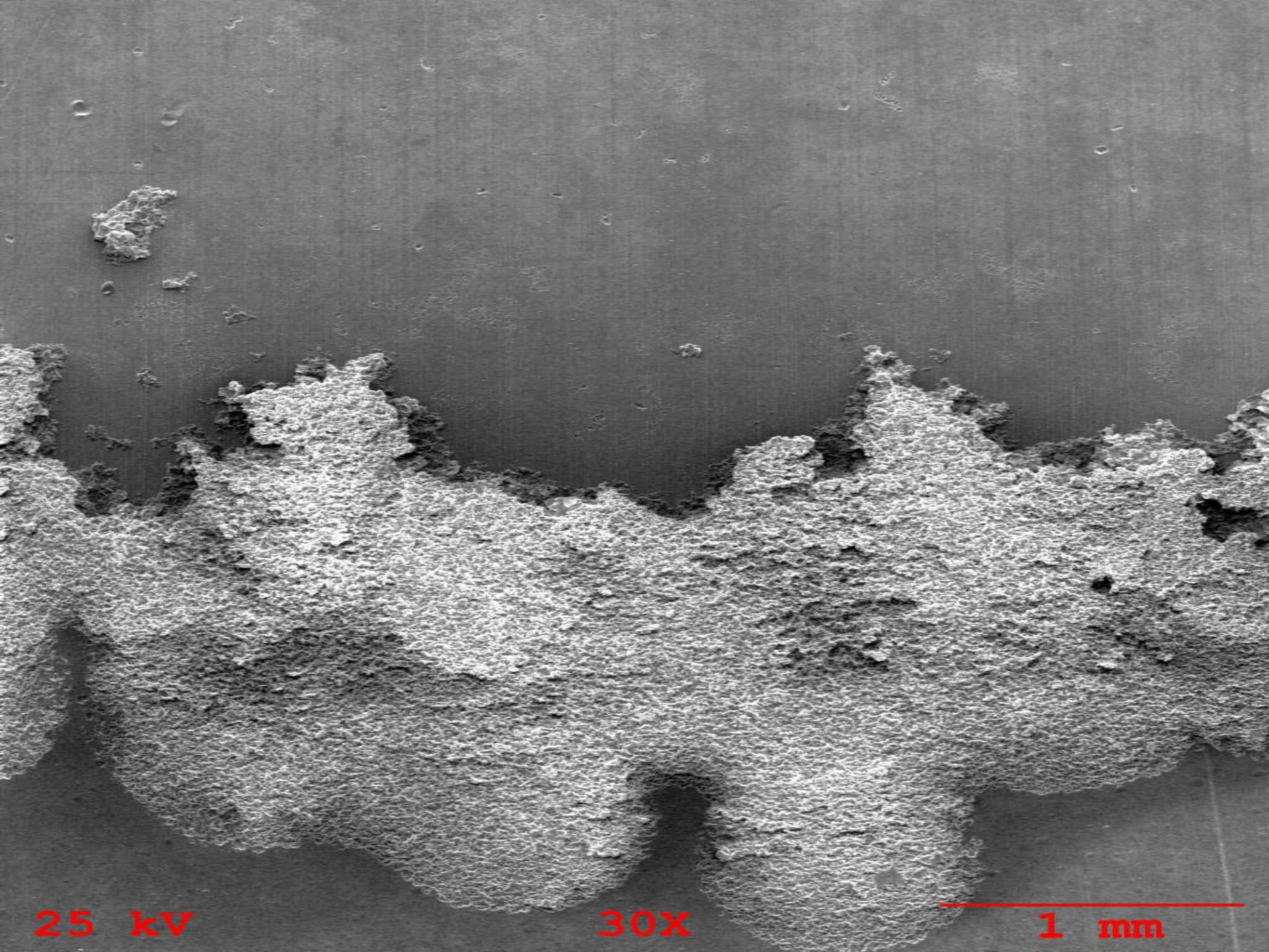
Solution Temp
493.3 °C (920 ° F)

Aging Temp
190.5 ° C (375 ° F)
for 8 -16 hours

S-N Fatigue Testing

GLC Fatigue Life Test for FAA - 2024-T3 Al-Clad

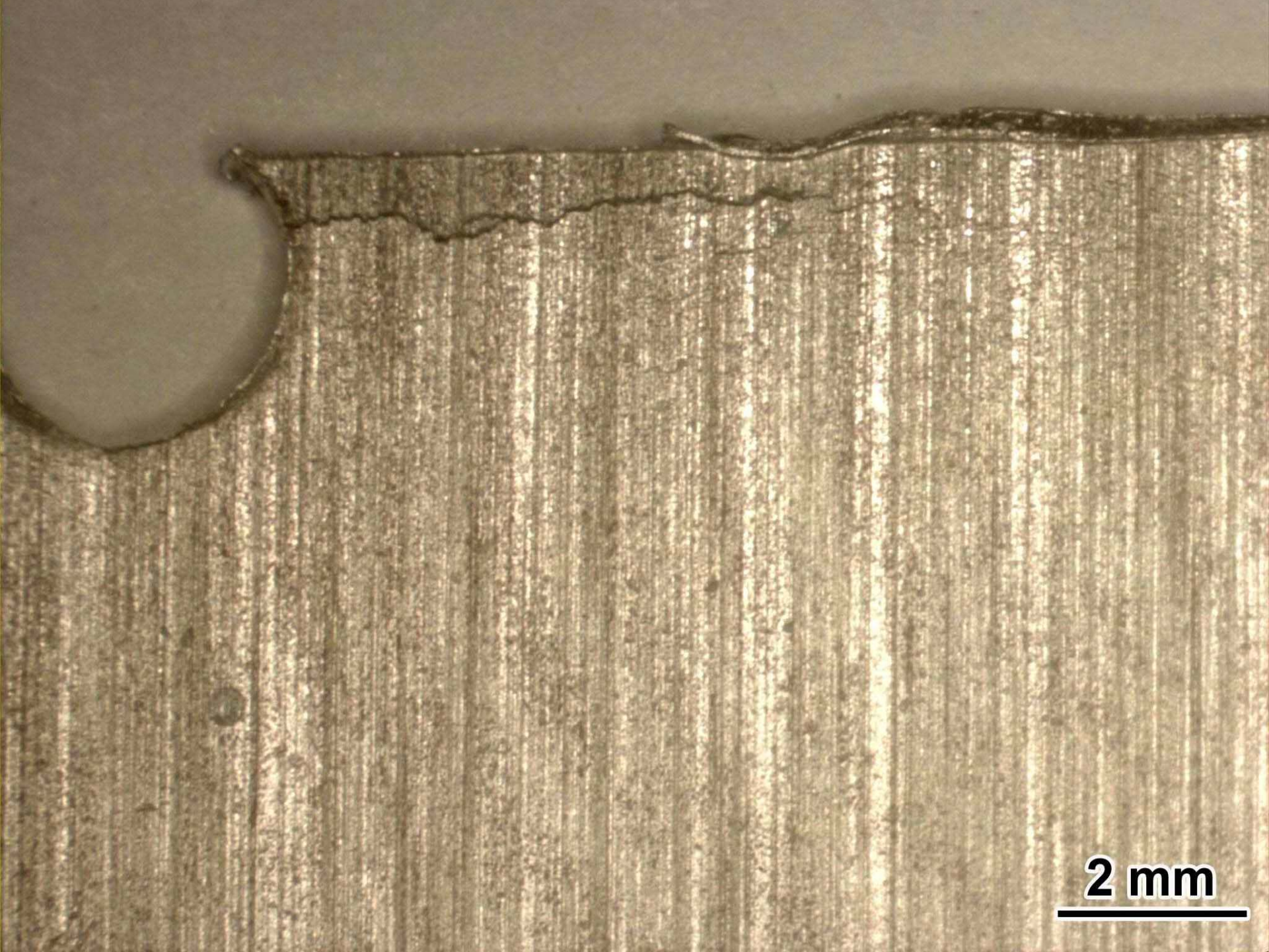




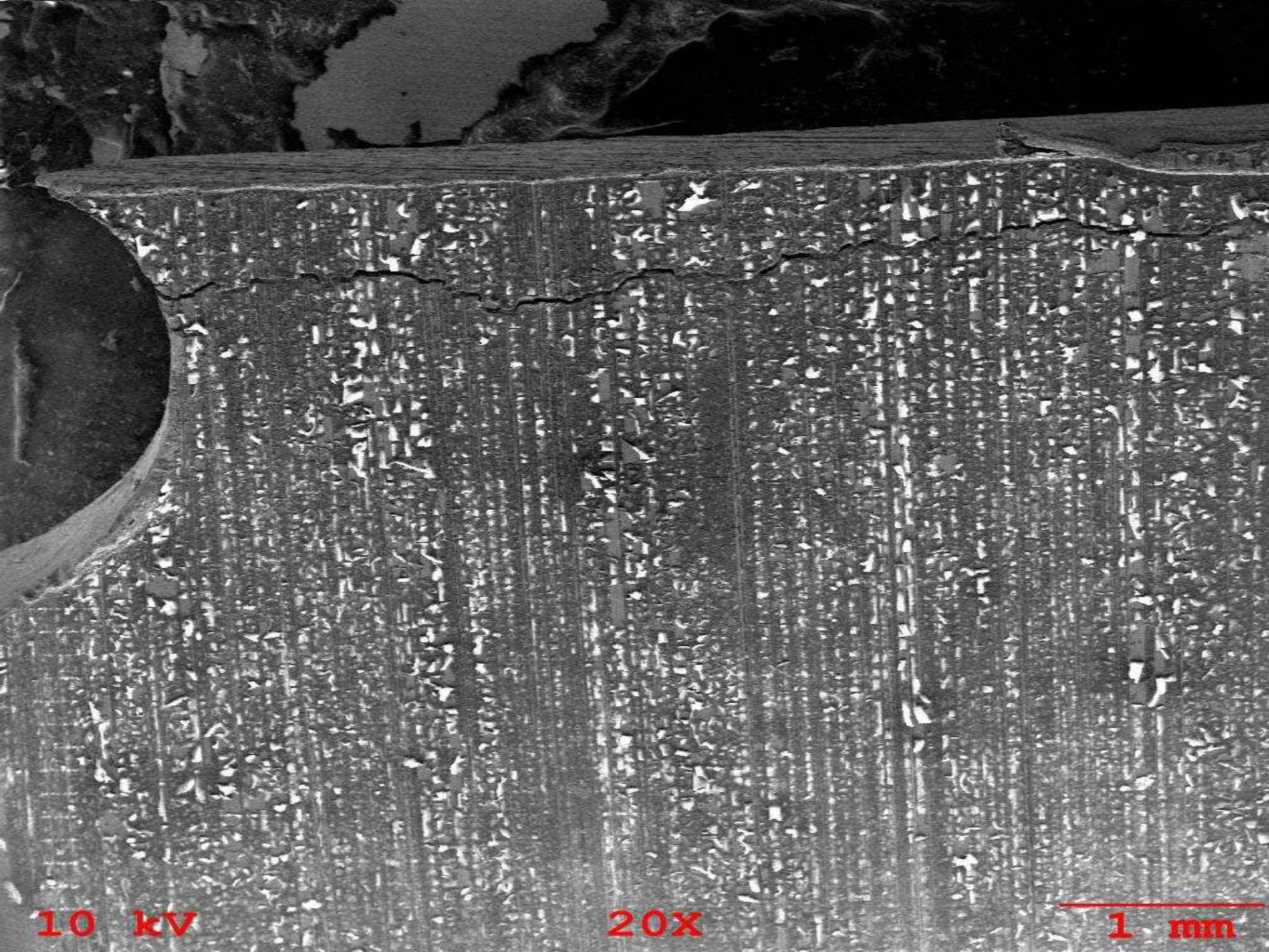
25 kV

30X

1 mm



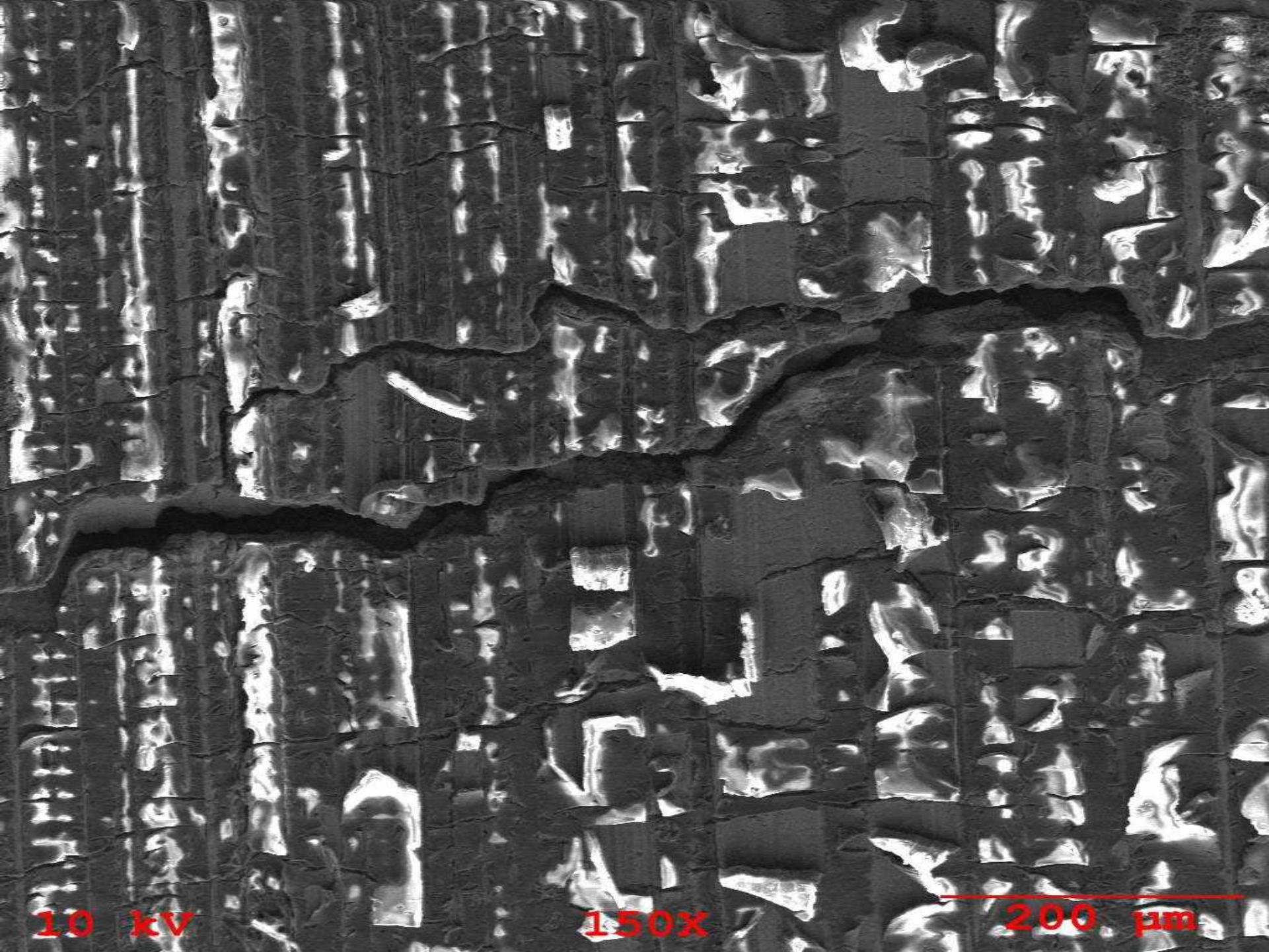
2 mm



10 kV

20X

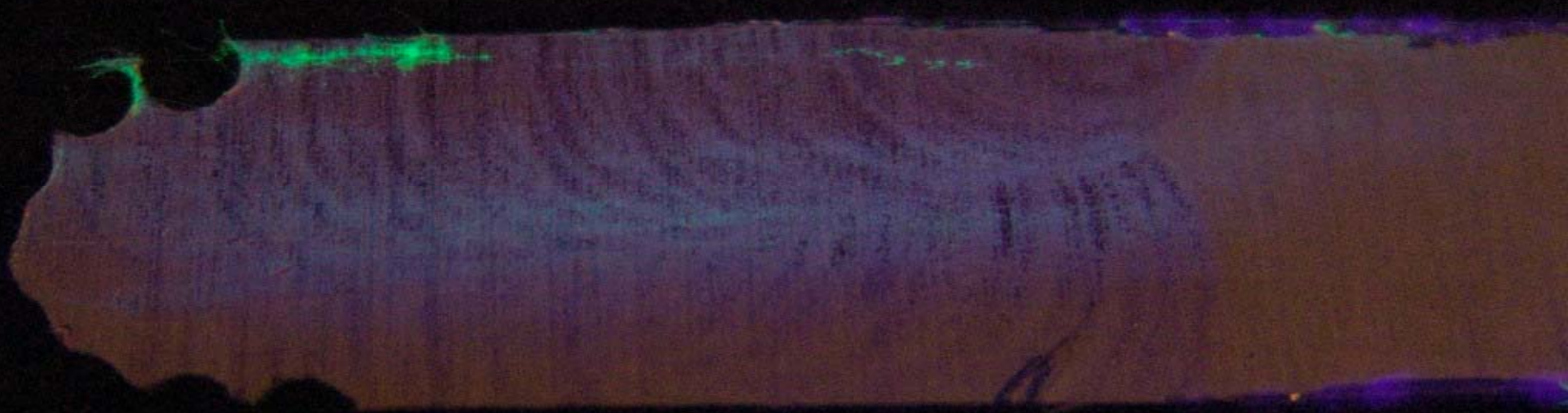
1 mm

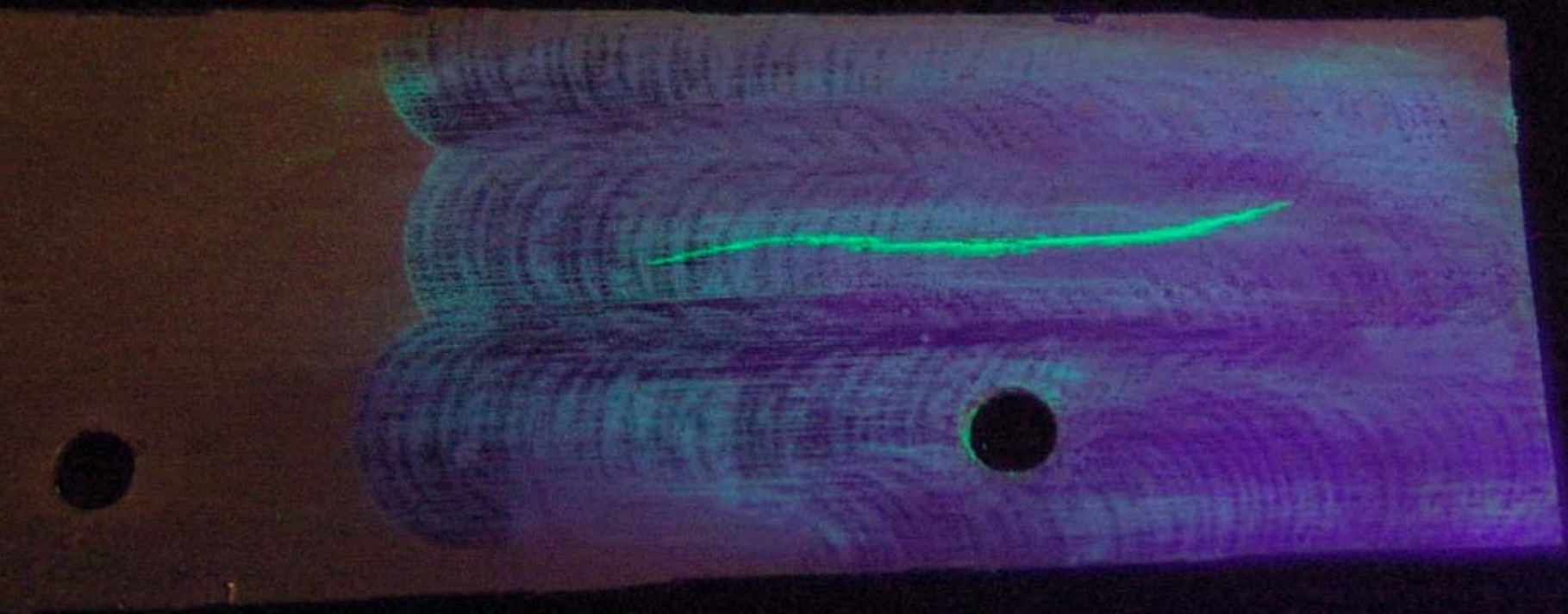


10 kV

150X

200 μm





Surface Preparation for Bonding

Archive tests in support of Northrop F-18, F-35, B-2

- *Application: Pre-bond surface prep of titanium, aluminum, and composite surfaces*
- *Technique: Inter-laminar shear testing*
- *Results and conclusions:*
 - Bond strength equivalent to any other process
 - Trial-to-trial deviations almost zero
 - “Eliminates the human error factor in aircraft manufacture” - Doris Reis, Senior F-35 M&P Engineer
 - *Significant environmental impact reductions*
 - *Worker health and safety benefits*

Substrate Damage Studies

- ***1989 - 1995 - US Navy, USAF***
- ***1995 - 1999 - EPA/NASA/USAF: Burlingame***
 - *“Very clean”*
 - *“Surface erosion - minimal”*
- ***More recent laser qualification programs***
 - *AFRL - JGPP laser system qualifications*
 - *NCMS / CTMA rotorblade depaint evaluation*
 - *FAA/GLC MA4872 evaluation for commercial aircraft*

GLC Material Tests for FAA

0.8 mm thick 2024 T3 Al Clad

<i>Parameter</i>	<i>Results</i>
<i>1. Peak surface temperature measured during stripping</i>	<i>130 to 150°C = no metallurgical impact</i>
<i>2. Microstructure analyzed before and after stripping</i>	<i>No change in properties</i>
<i>3. Microhardness measured before and after stripping</i>	<i>No change in properties</i>
<i>4. Microscopic surface texture measured after stripping</i>	<i>Texture effects in soft clad layer only</i>
<i>5. SAE MA-4872 fatigue life tested after 5 x laser stripping and repainting</i>	<i>Equivalent fatigue life <u>Process approved by FAA</u> <u>for use on commercial aircraft</u></i>

Environmental Impacts

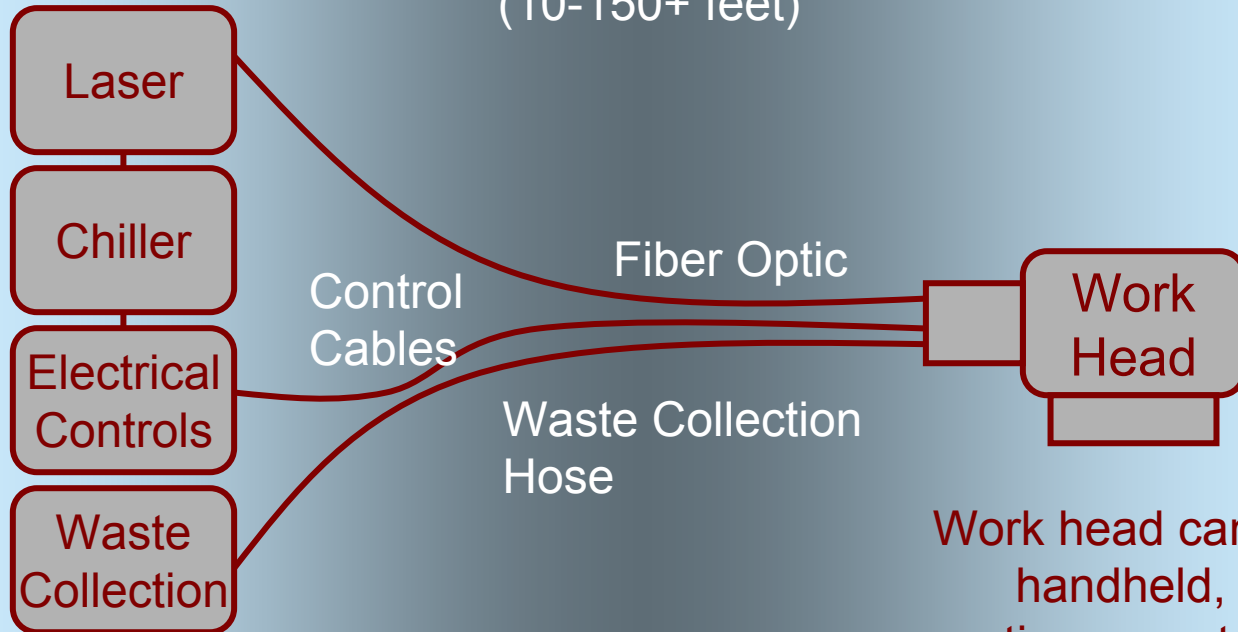
- *Surface ejecta:*
 - *Metal oxide and dust particulate*
 - *Oxidized hydrocarbons (CO₂, H₂O)*
 - *Minimal un-oxidized hydrocarbons*
- *Integral fume extraction entrains all waste – no surface residuals*
- *HEPA filter for particle collection*
- *Vapor discharge below action levels*

Laser Ablation System

Equipment can be
rack, vehicle
mounted or fixed

Umbilical
Cable
(10-150+ feet)

Remote
Portable
Work Head



Units are modular and can be
separately sourced

Work head can be
handheld,
suction-mounted or
robot-mounted

Color Recognition of Layers

- *USAF & Lockheed Martin coordinated support of F-22 SBIR*
- *Goal: Replace hand sanding for LO coating maintenance*
- *Phase I - 2001, Phase II- 2002 - 2004, US Patent Application - 2004*

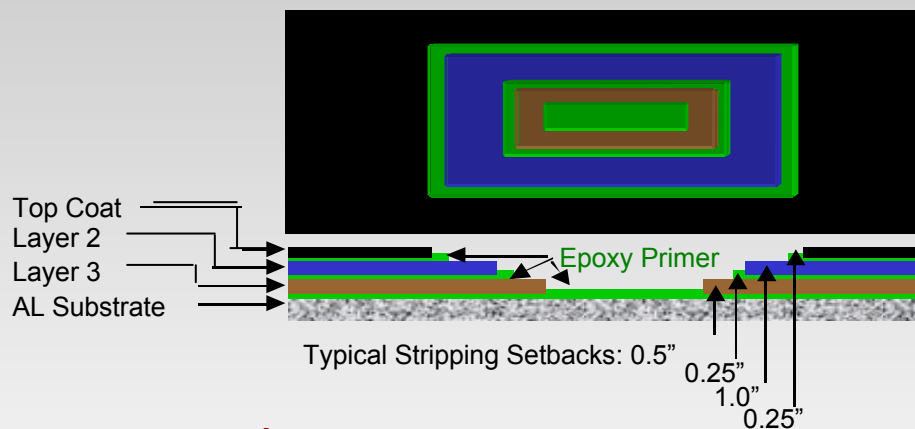


Figure 1 - Typical Stripping Requirements



Figure 3 - SBIR- Developed Workhead



Figure 2 - Actual Stripped Sample



Figure 1 - Current Rotor Blade Stripping at Cherry Point



Figure 2 - Example of Blade Sanding Damage



Figure 3 - Lasertronics Stripping Blade Sample

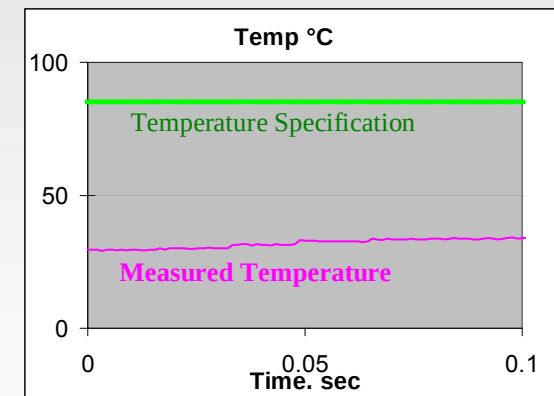
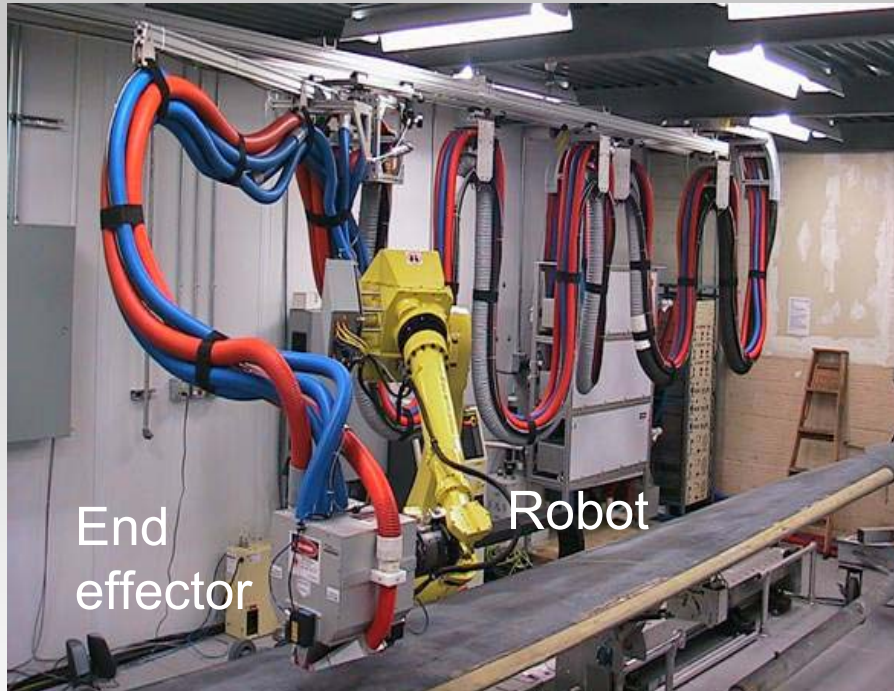


Figure 4 - Temperature during Laser Stripping

Defense Aerospace Installations



Automated rotorblade depaint,
Navy Fleet Readiness Center,
Cherry Point, NC



Hand-held system for
helicopter maintenance,
Patuxent River, MD

Reliability / Maintainability

- **Extended Service:**
 - April through September
 - 90 hrs/wk operation
 - >2000 hours
- **Reliability:**
 - Described as “Workhorse”
 - No optics cleaning required
 - No OEM service required
- **Maintainability:**
 - Field personnel completed all maintenance



Laser cleaning of thick corrosion layers from statuary on the City Hall of Philadelphia, PA



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