Kinetic Metallization™

Interior Diameter (ID) Bores

AeroMat 2011 Session 1 - Emerging Materials & Processes - Spray Processes

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Overview

- Kinetic Metallization (KM) Process and Equipment
- WC-Co for Actuator Sleeve
- NiCrAlY for Thrust Chamber
- Dimensional Restoration of Aluminum Landing Gear Bores

Kinetic Metallization (KM) Process and Equipment

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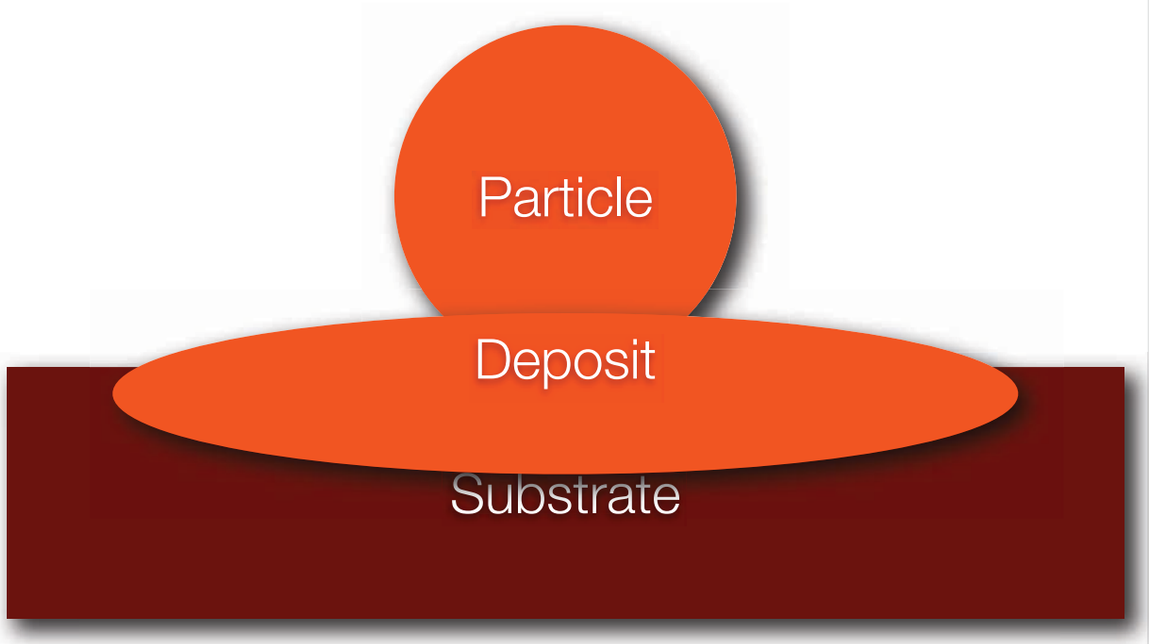
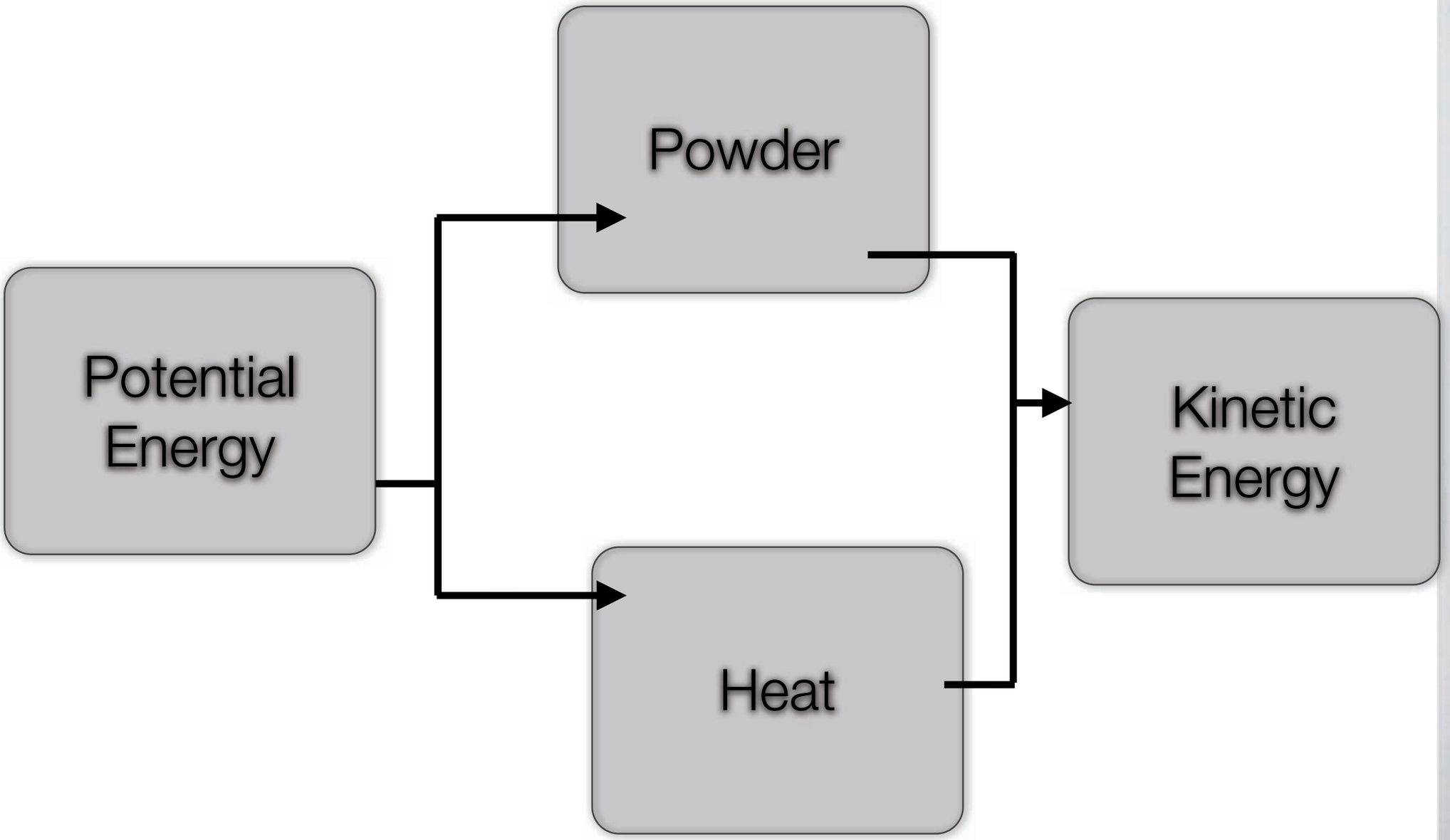
Introduction to Kinetic Metallization™ (KM)

- Metal deposition through particle impact
- Low-temperature << melting point
- **Sonic Mach 1 Nozzle**
  - High particle velocity > 750 m/s
  - Pressure < 1 MPa (150 psig)
  - Temperatures to 450C
  - Powder preheater & mixer
  - Powder injection at nozzle inlet
  - Low noise < 75 dBa @ 1 m
  - High quality coatings



Kinetic Metallization™ Difference



Mass Loading ~ 100% gas mass flow

Kinetic Metallization™ Difference

Gas Storage System

Ultra-fine Powder Fluidizing Unit

Sonic Deposition Nozzle with Powder Preheater & Mixer

2.5 kW Thermal Conditioning Unit < 150 psig

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Mass Loading ~ 100% gas mass flow

KM-Production Coating System (KM-PCS with Robot)

- Robotic KM Spray Gun
  - Repairs of large surfaces
  - Uniform coating thickness
  - Gas blending (He, GN2 or Air)
- Applicable Coatings
  - Air/GN2 (Al-Trans® , Cu, Zn, Ni)
  - He/GN2 (WC-Co, Ni alloys, Nb, Ta)
  - Composite polymers (PEEK, PTFE)
- Powder Loading
  - ~100% gas mass flow☜

☜Cold Spray limited to 5% gas mass flow

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KM-Guns

- **KM-Standard Gun**
  - Robotic rastering & translation
  - Uniform & large area coating repairs
- **KM-Handheld Gun**
  - Lightweight (< 5 lbs)
  - Round or oval nozzles (< 75 dBa)
  - Preheated powder chamber
  - Gas blending (He, GN2 or Air)
- **KM-ID Gun**
  - Bore internal diameters 3-inches (80-mm)
  - Bore Depths ~ 48-inches

So, what can KM do?

- Ag
- Al/Zn
- Al-4047 -Al/Si
- Al-6061
- Al-7075
- Al-CP
- Al-Trans -Al_2O_3
- Al-Trans- Co
- Al-Trans- Cr
- Al-Trans-Mo
- Al-Trans-Ni
- Al-Trans-SiC
- Al-Trans-SS
- Al-Trans-Ti
- Al-Trans-TiC
- Al-Trans-V
- 6061Al-Trans
- 7075Al-Trans
- Amorphous Al
- Amorphous Fe
- Amorphous Ni
- Au braze alloy
- C103 (Nb/Hf)
- Co
- CoCr
- CoNiCrAlY
- CoNiCrAlY/CBN
- Cr
- CrC/NiCr
- Cu
- Cu/SiC
- CuAlFe
- CuCr
- CuCrAl
- In
- In718
- Mo
- Nb
- Ni
- Ni/CBN
- Ni-braze
- NiCrAlY
- Nitinol
- Re
- Reactive Intermetallic Compounds
- Sn
- SnAg
- SnAgSb
- SS
- Ti/HA
- Ti/TiC
- Ti/TiN
- Ti6-4
- Ti-CP
- WC-Co
- Teflon PTFE
- Ultem Polyetherimide
- Nylon polyamides
- Polymer+
- Al_2O_3
- $BaTiO_3$
- Fused Silica
- Quartz

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WC-Co for Actuator Sleeve

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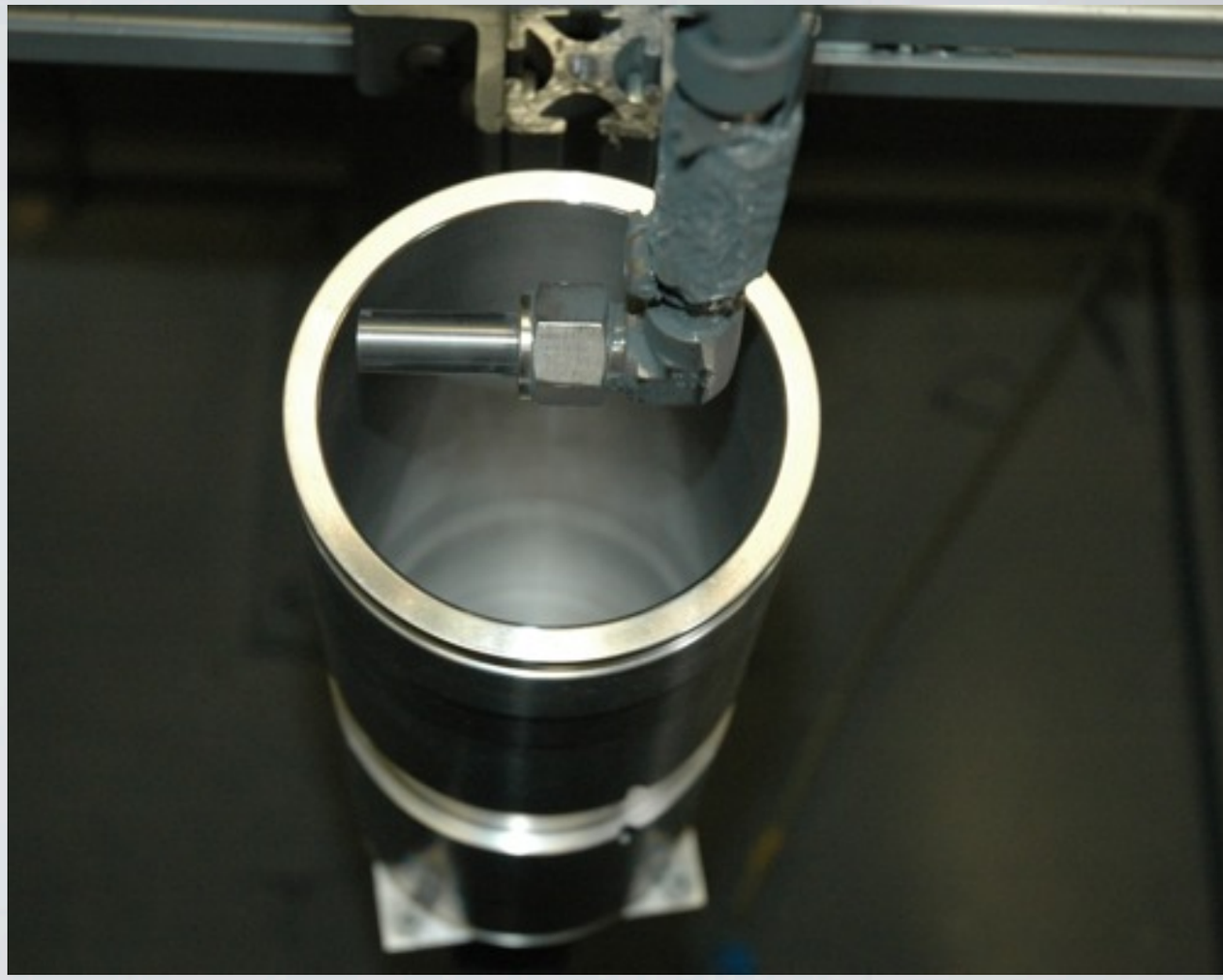

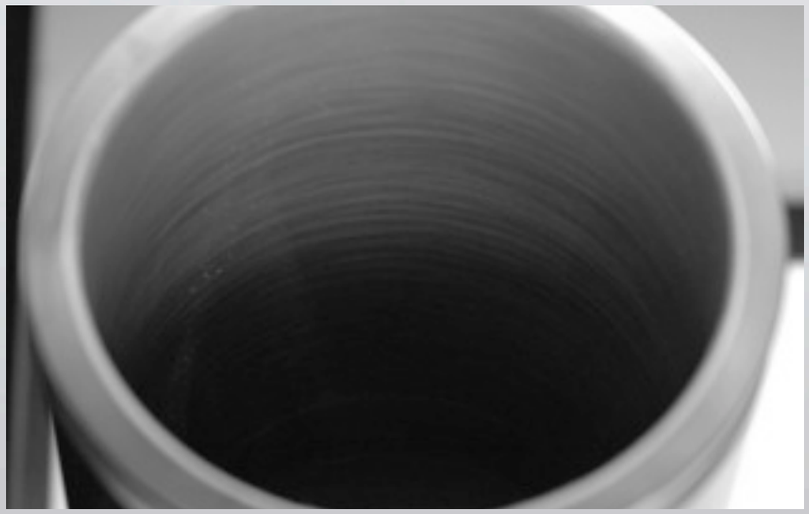

3.75” ID
x 16” deep bore

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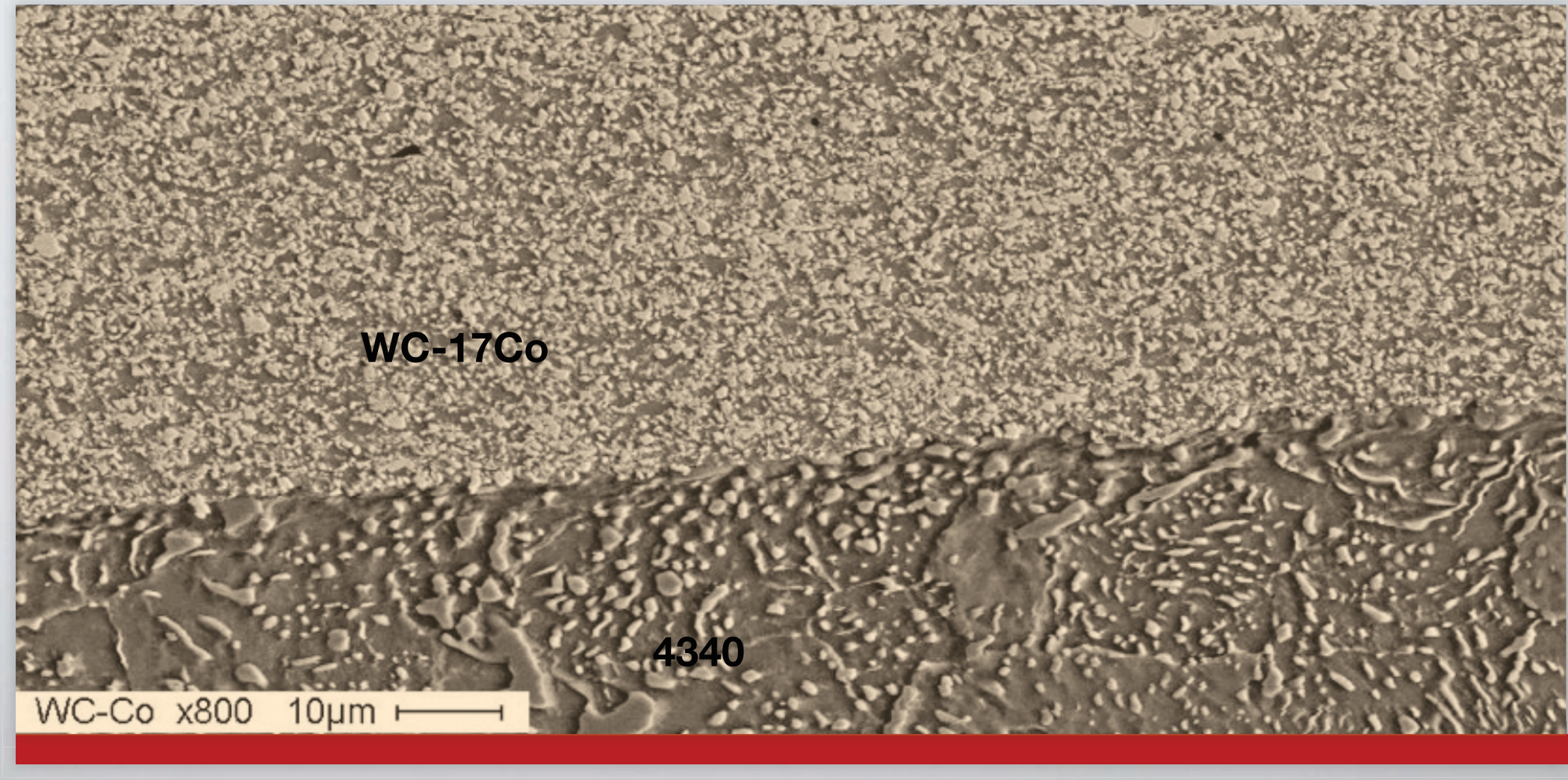
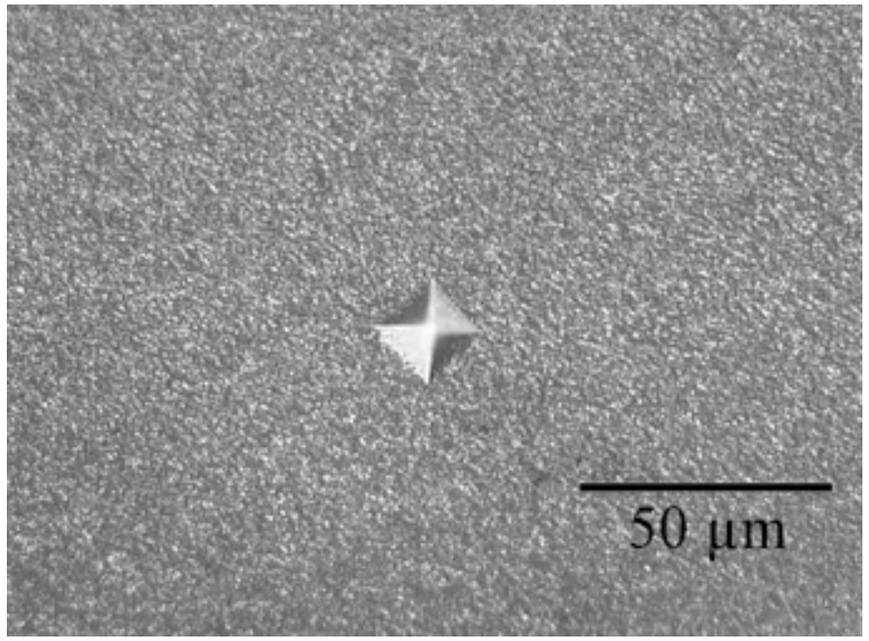
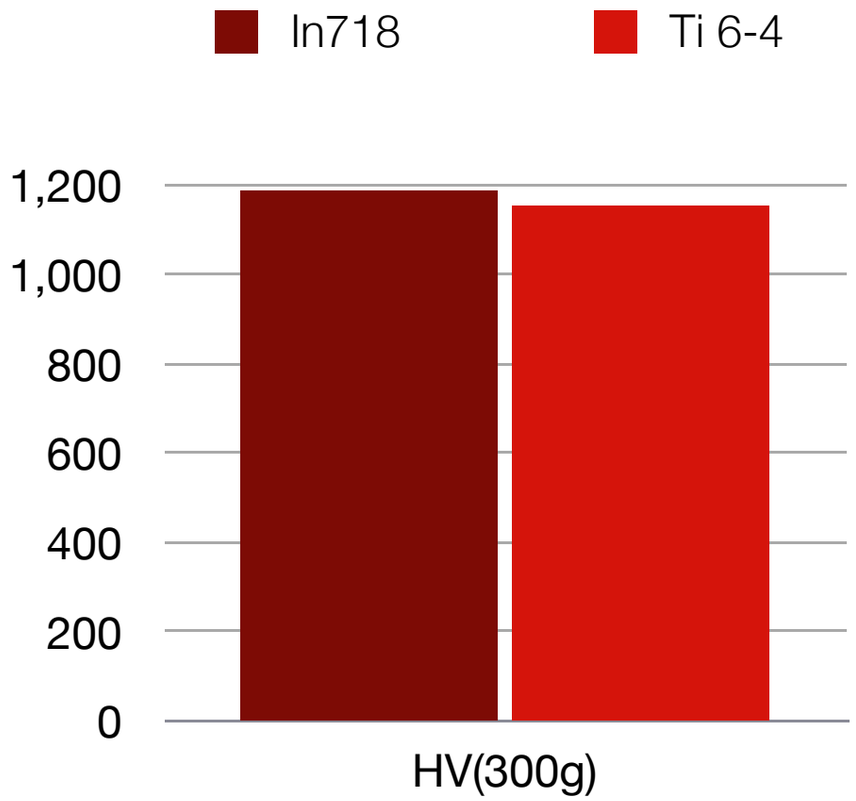
WC-Co Microstructure



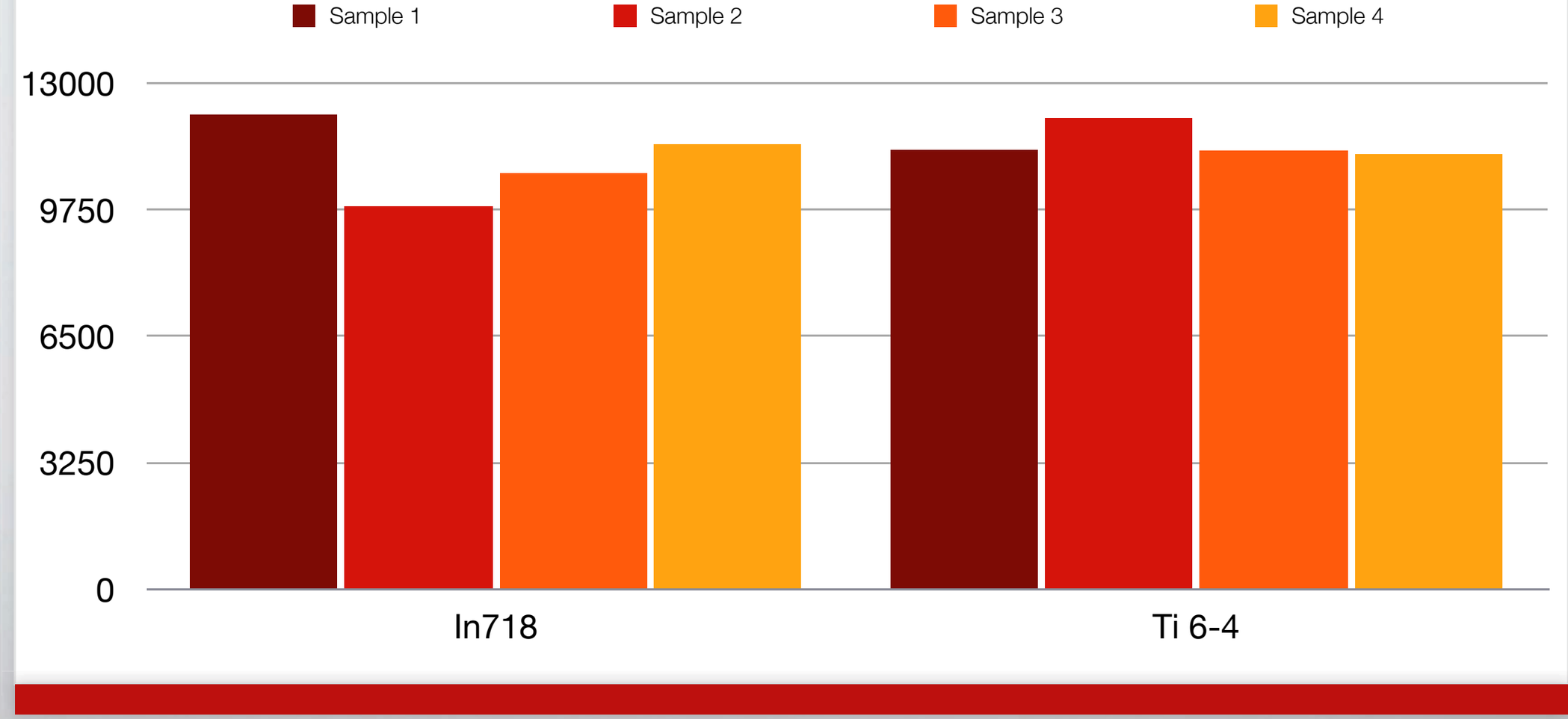
KM800 WC-Co Microhardness

- Vickers hardness - 300g load
- No indent cracks





ASTM C633 Adhesion Testing



KM800 WC-Co

NiCrAlY for Thrust Chamber

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National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field

3.5” Throat Thrust Chamber

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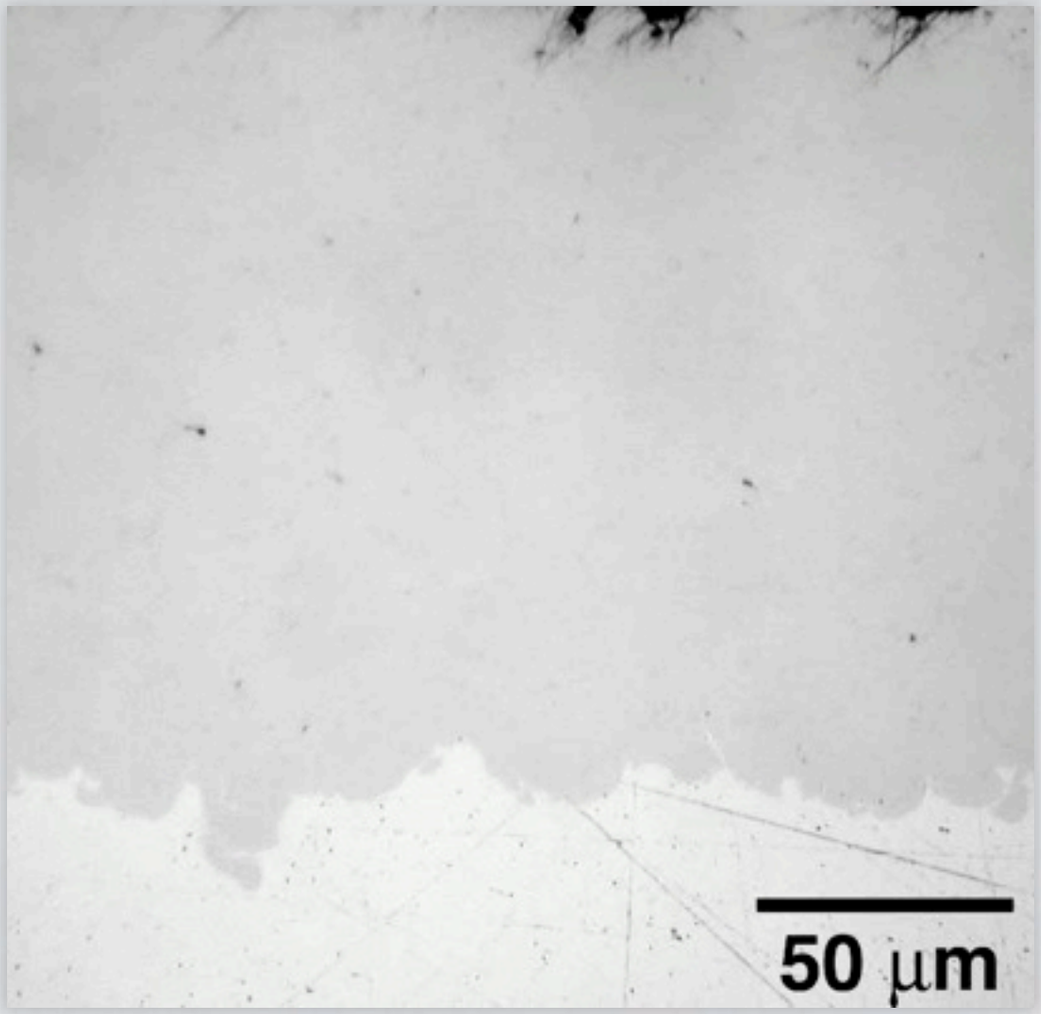

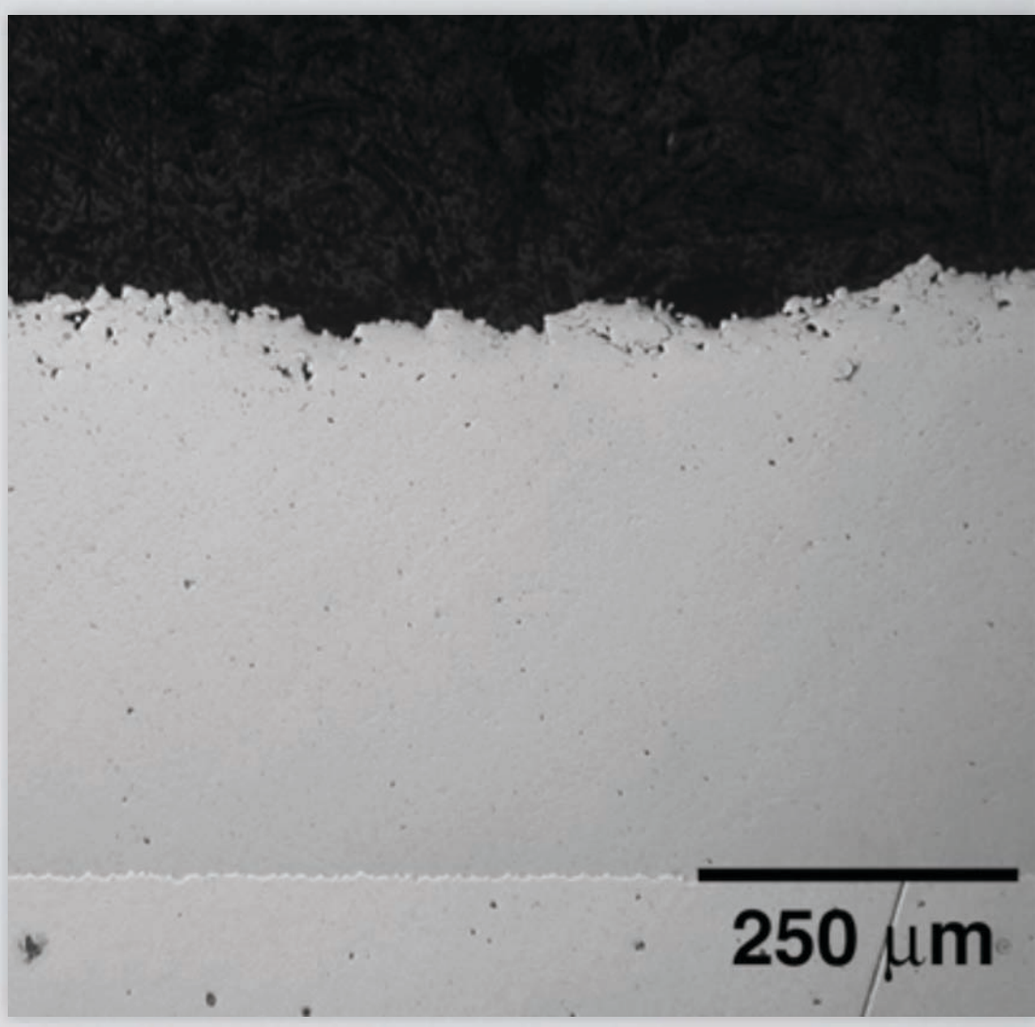

NiCrAlY on Cu Alloy

Dimensional Restoration of Aluminum Landing Gear Bores

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Process Requirements for LG Dimensional Restoration

- Deposition thickness of up to 0.025-inches
- Coating applied while maintaining a maximum part surface temperature of 225 F
- Overspray (dust) generated during the spray process must be adequately removed from the bores, which may include blind holes

Material Requirements for LG Dimensional Restoration

- Coating hardness must be equitable to 7075-T6
- Compatible with the Type III sulfuric-acid anodize process
- Fully dense and cohesive
- Adherence to base alloy to prevent delamination and spalling under loads

Screening Tests for Powder Formulations

Screening Test	Acceptance Criteria	Test Method References
Coating Thickness	0.025-inches minimum buildup	Metallographic Analysis
Coating Density	Fully dense	Metallographic Analysis
Adhesion – Machining of Coated Coupons	Machining coated coupons to ensure sufficient adhesion and ductility to permit final machining of LG components.	MIL-DTL-83488D, April, 1999
Hardness	> 150 HB (7075-T6)	ASTM E92 ASTM E384

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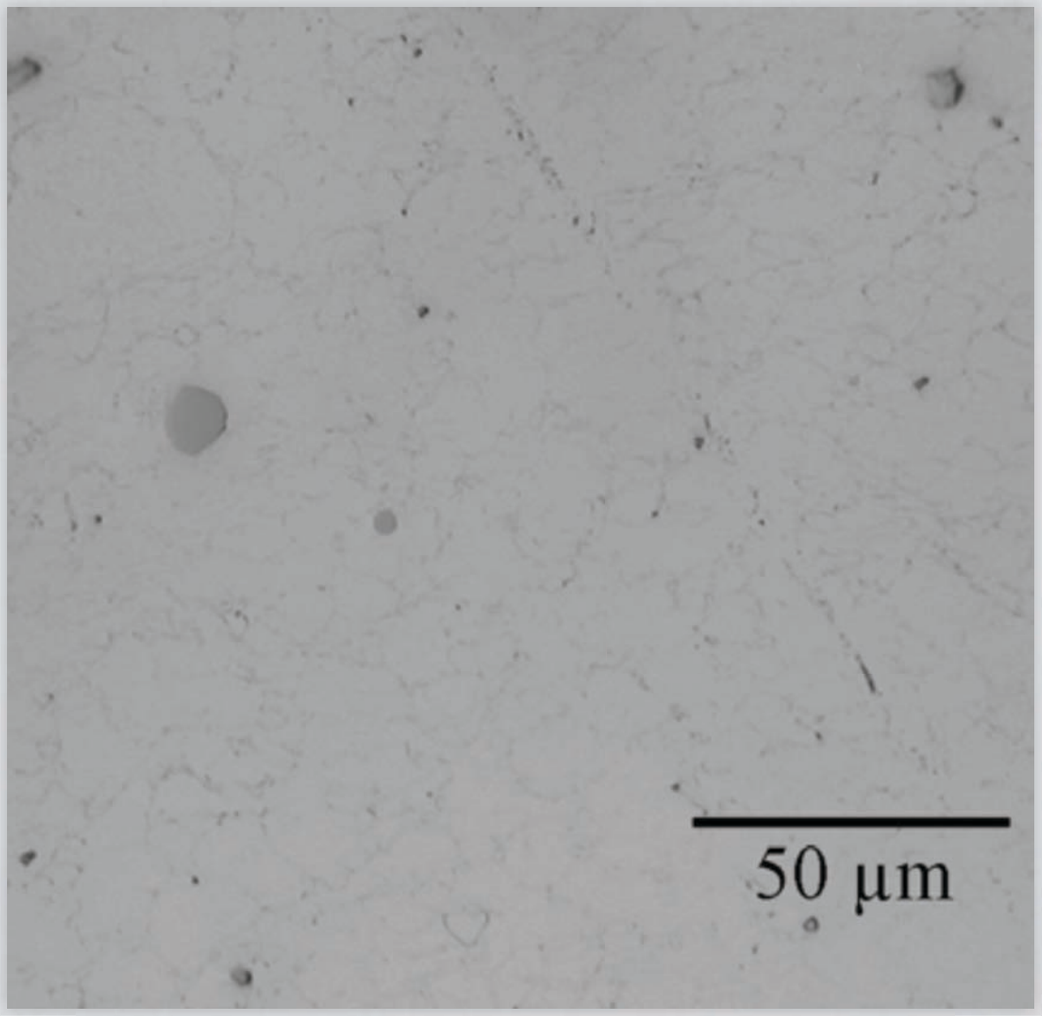

7075-Al

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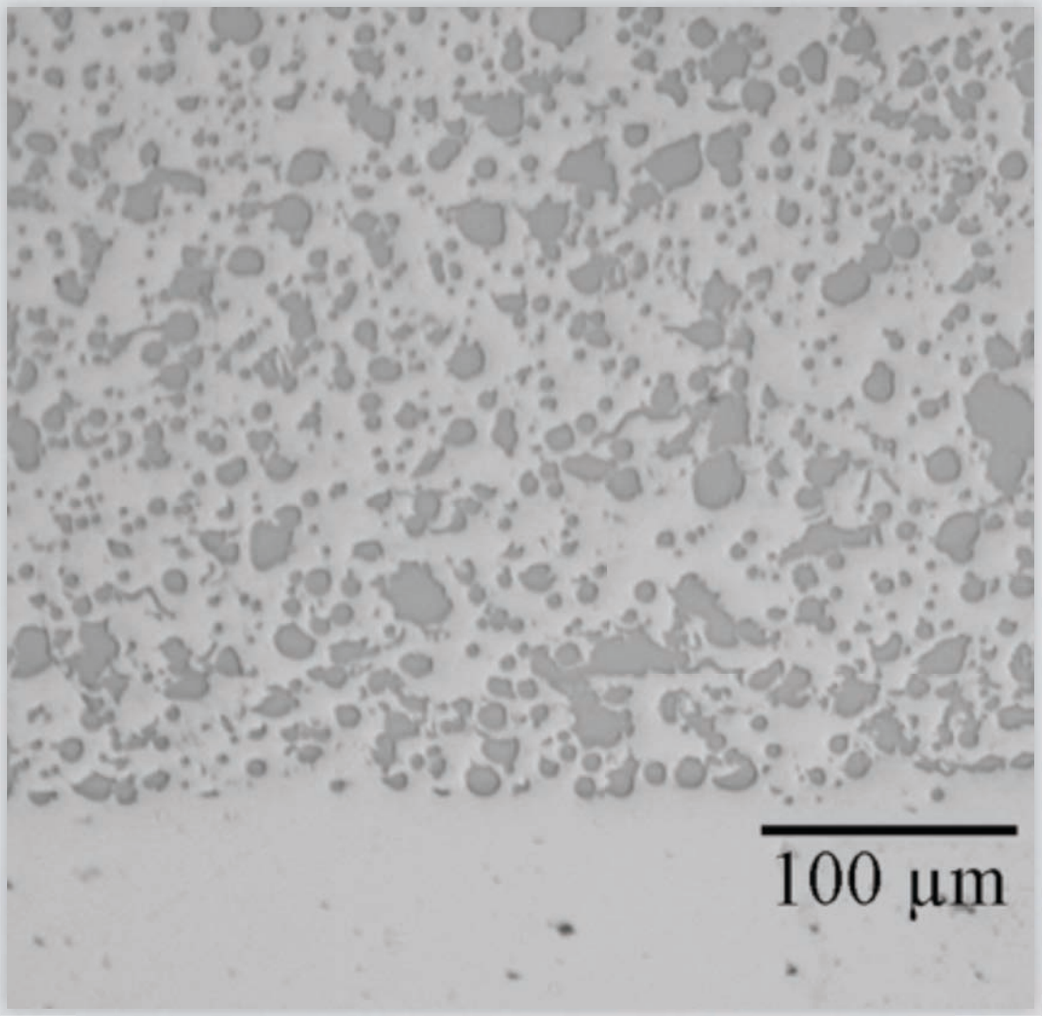

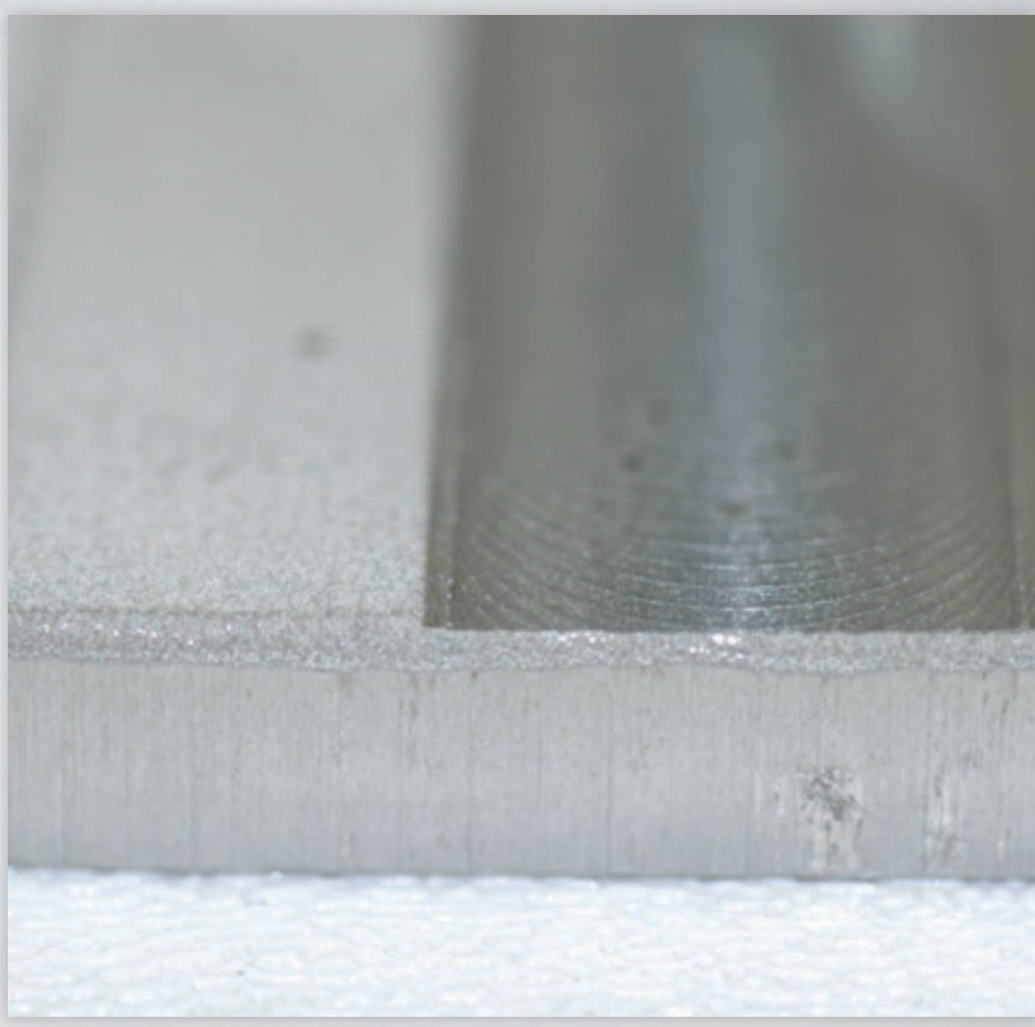

7075Al-Trans

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Coating Hardness

Coating Formulation	Measured Rockwell F (HRF)	Calculated Brinell Hardness (HB)	Calculated Rockwell B (HRB)
6061	77.9	86	36
6061/Al-Trans	93.5	126	64
7075	104.6	173	83
7075/Al-Trans	110.2	205	93

Screening Tests Results

Coating Formulation	Thickness	Coating Density*	Type III anodize compatibility	Hardness	Machinability
6061	Pass (>0.025”)	Pass	Pass	Fail (<150HB)	Pass
6061Al-trans	Pass (>0.025”)	Pass	Pass	Fail (<150HB)	Pass
7075	Pass (>0.025”)	Pass	Pass	Pass (>150HB)	Pass
7075Al-Trans	Pass (>0.025”)	Pass	Pass	Pass (>150HB)	Pass

* at 200x per MIL-STD-3021

ID Coating System - Qualification Tubes

- Coating applied to lower 10” of 36” deep tube
- Closed-end bonnet used to simulate closed-end bore of LG cylinder
- Coated tube section cross-section to assess coating quality
- Machinability assessment
- Type-III anodize post-process

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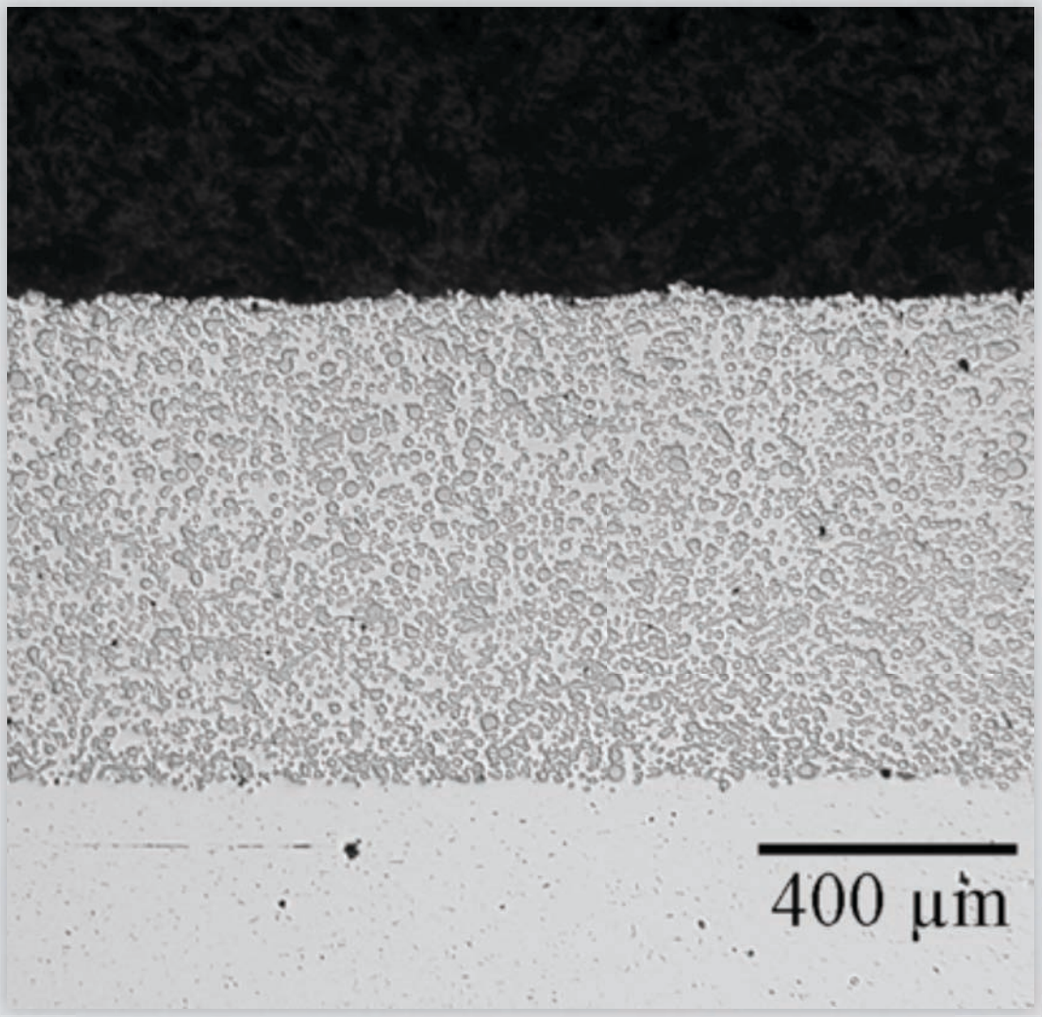

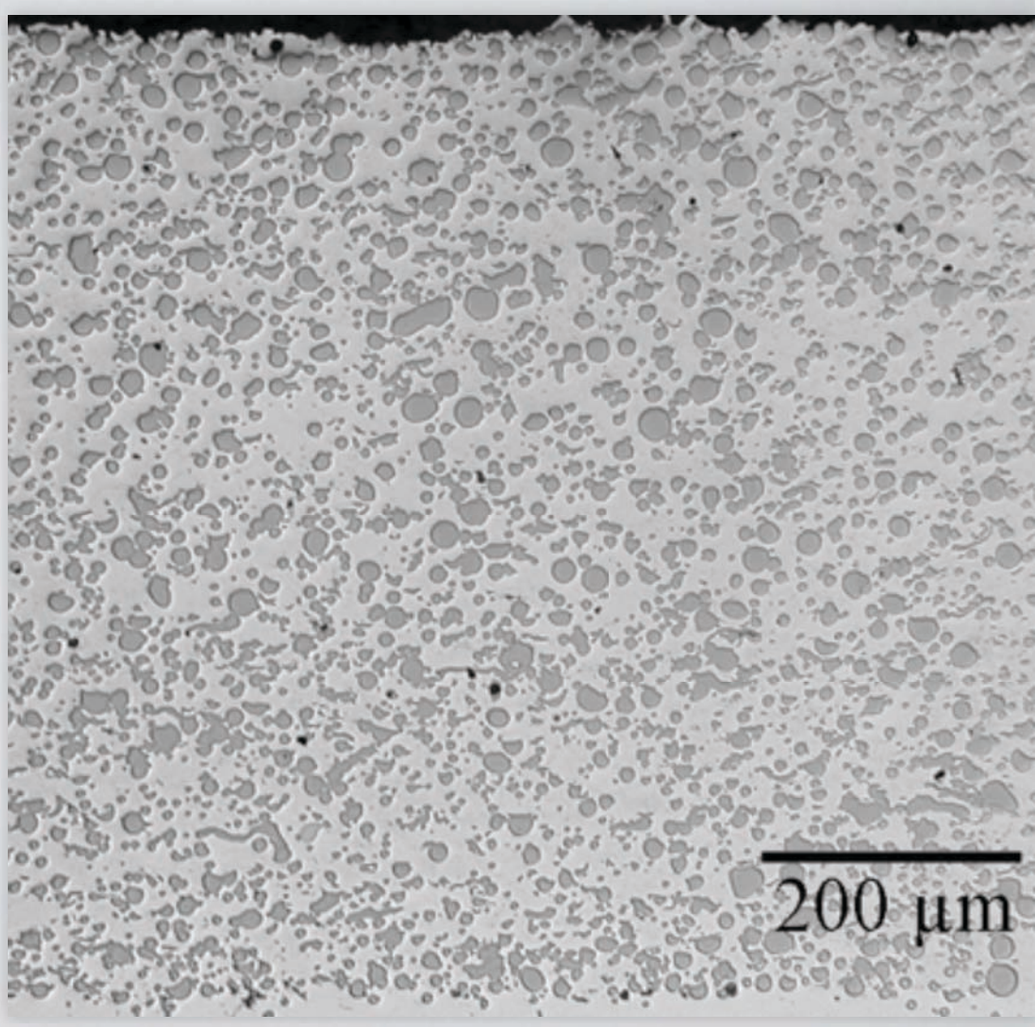

Optical Micrographs of 7075Al-Trans Coated Tube ID at 50x (left) and 100x (right) from lowest end of coated tube section

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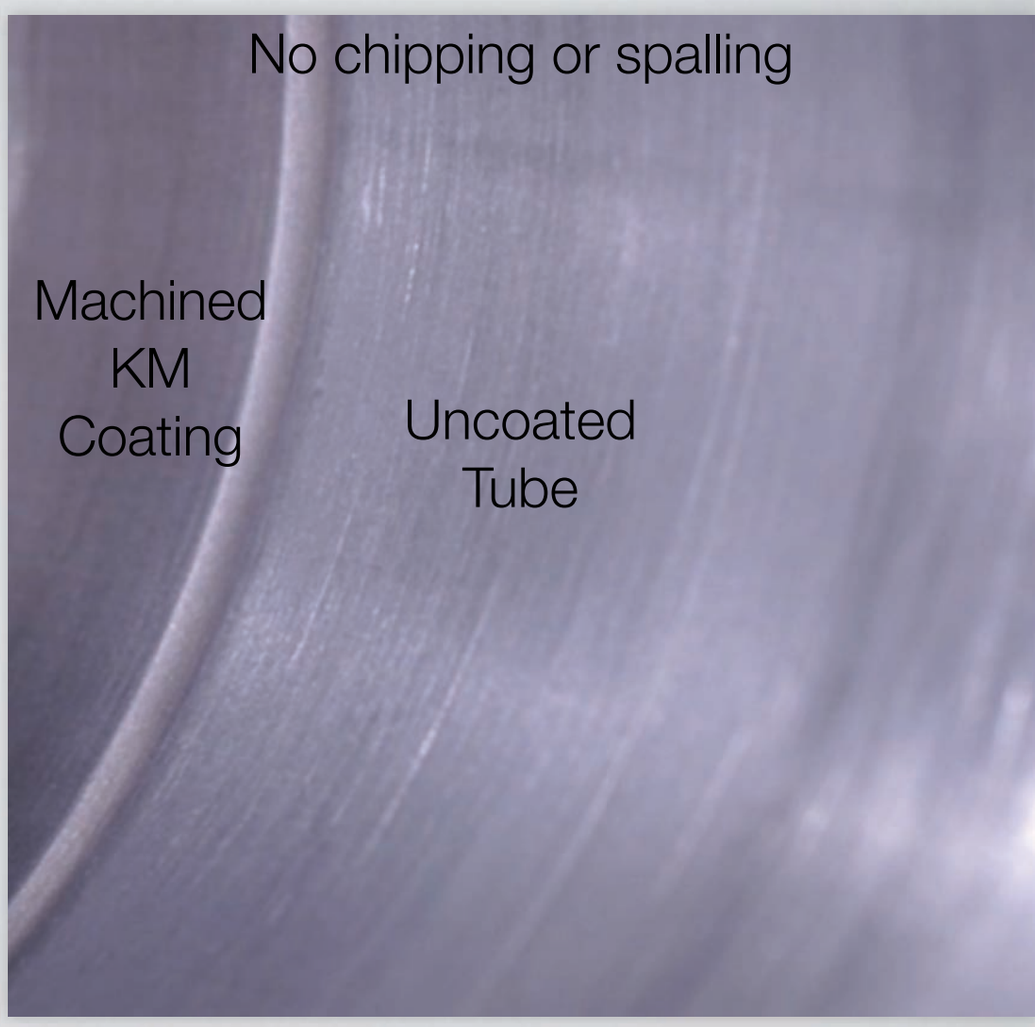

KM Coated ID Section being Machined (left) and After Machining
Demonstrated Integrity During Machining

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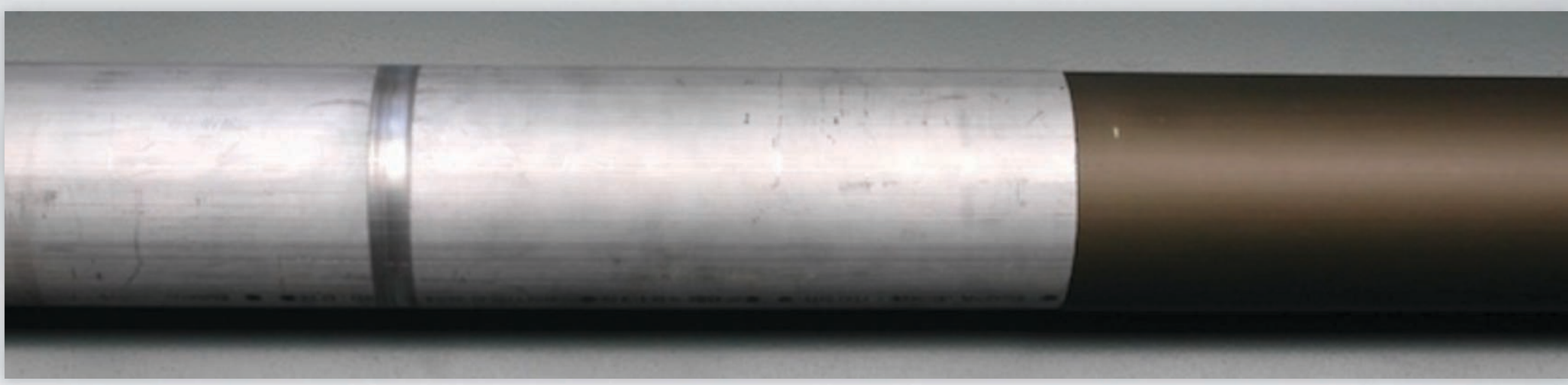

36” Length of Tube Showing Lower 10” After Anodizing

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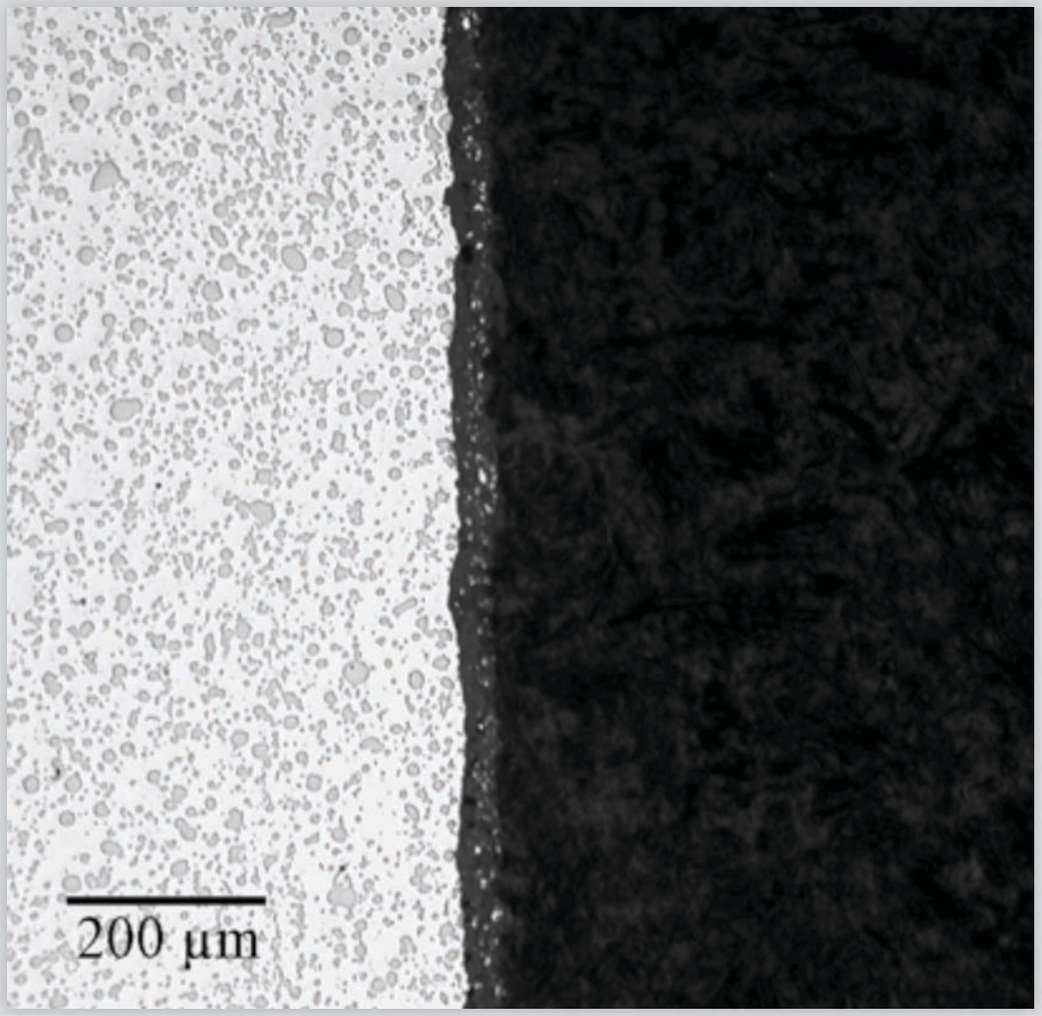
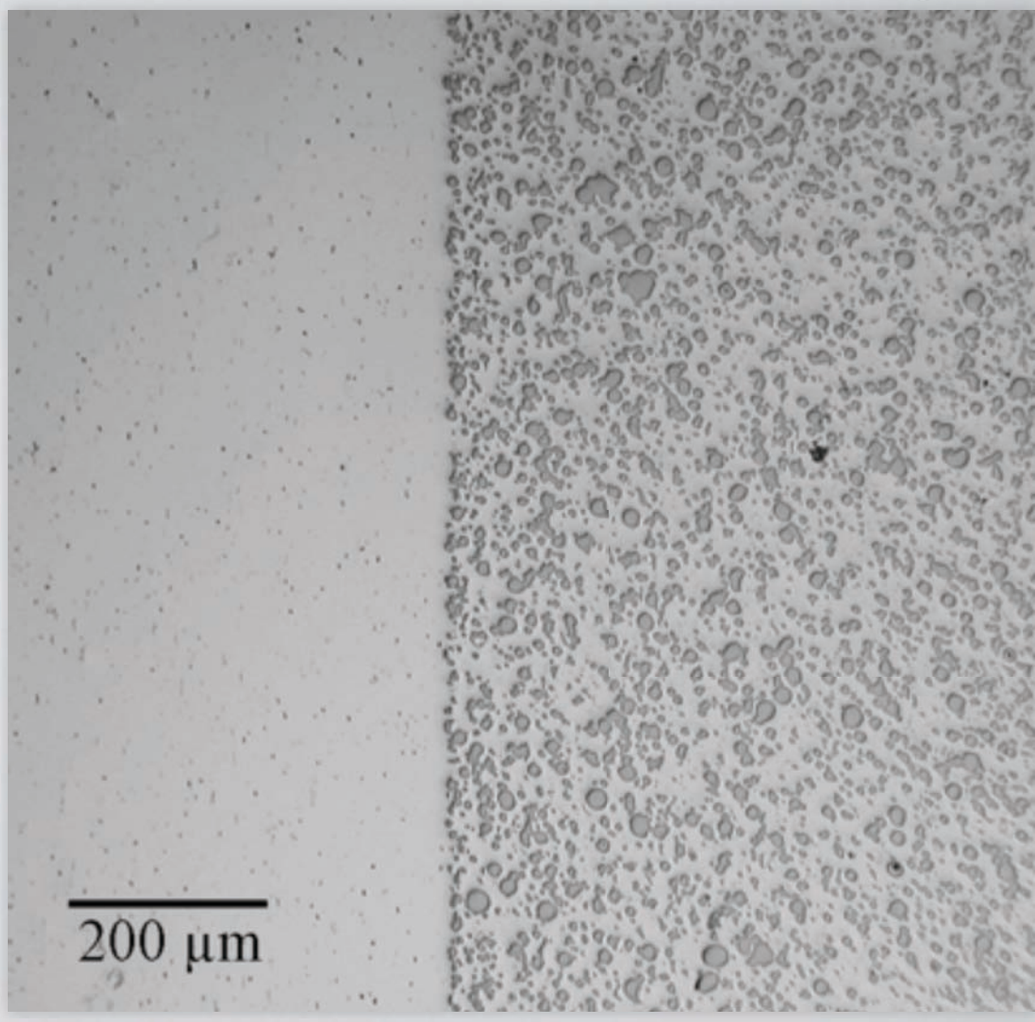
0.002” Nominal Anodized Thickness



Fully Dense (>99%) After Anodizing



KM Coating After Anodizing

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OEM Landing Gear

Process Requirements for LG Dimensional Restoration

- Deposition thickness of up to 0.025-inches
  - PASS – >0.030” capable
- Coating applied while maintaining a maximum part surface temperature of 225 F
  - PASS – Temperature did not exceed 200F
- Overspray (dust) generated during the spray process must be adequately removed from the bores, which may include blind holes
  - PASS – no loss of coating quality at bottom of closed-end bore

Material Requirements for LG Dimensional Restoration

- Coating hardness must be equitable to 7075-T6
  - PASS – Coating hardness >150HB
- Compatible with the Type III sulfuric-acid anodize process
  - PASS – 0.002” nominal anodized layer, KM coating remains fully dense
- Fully dense and cohesive
  - PASS – >99.5% dense at 200x per MIL-STD-3021, August 2009, section 5.2.3