HVOF Alternative: Kinetic Metallization™

WC-Co Coatings

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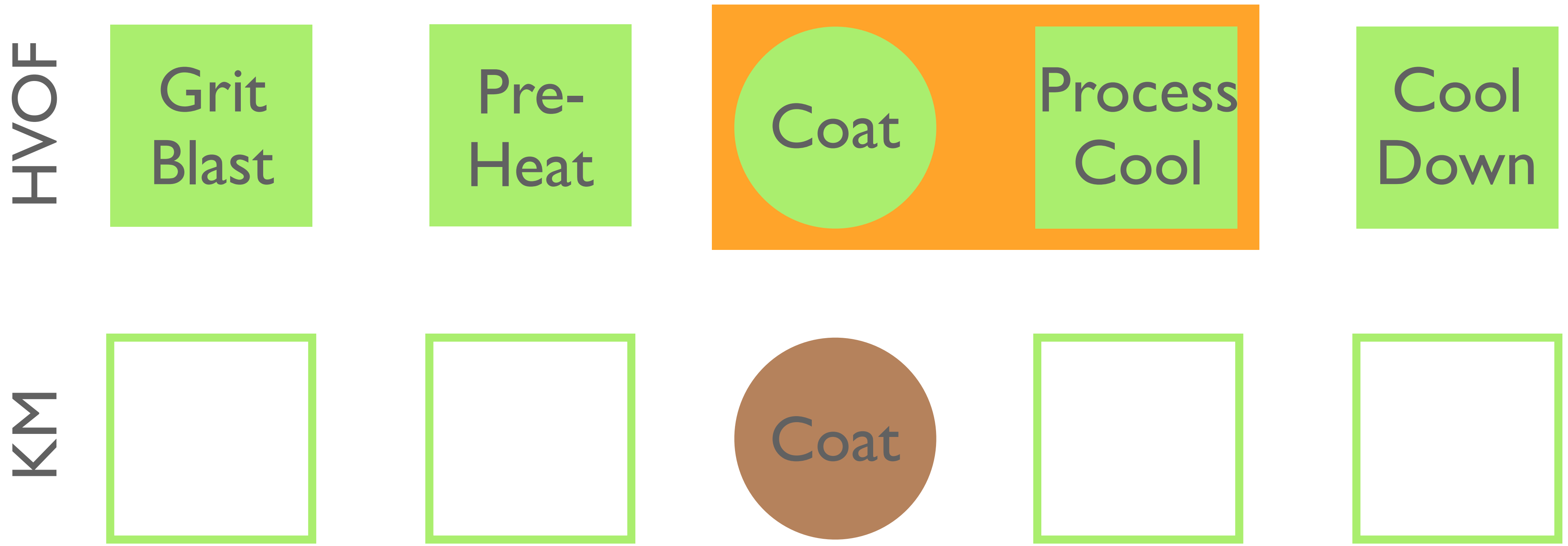
Overview

- KM vs. HVOF - Comparisons
  - Process & cost
  - Coating microstructure & performance
  - Superfinishing capabilities
- KM WC-Co tunable hardness coatings
  - nano-WC-Co coating
- Future of KM WC-Co and Conclusion

Hard Chrome Alternatives

- Executive Order EO13148
  - Applies to all federal agencies and includes hard chrome and chromate conversion coatings
- Identified Potential Alternatives
  - Coatings
    - WC-Co, WC-CoCr
  - Processes
    - HVOF
    - Kinetic Metallization Process

KM vs HVOF Process



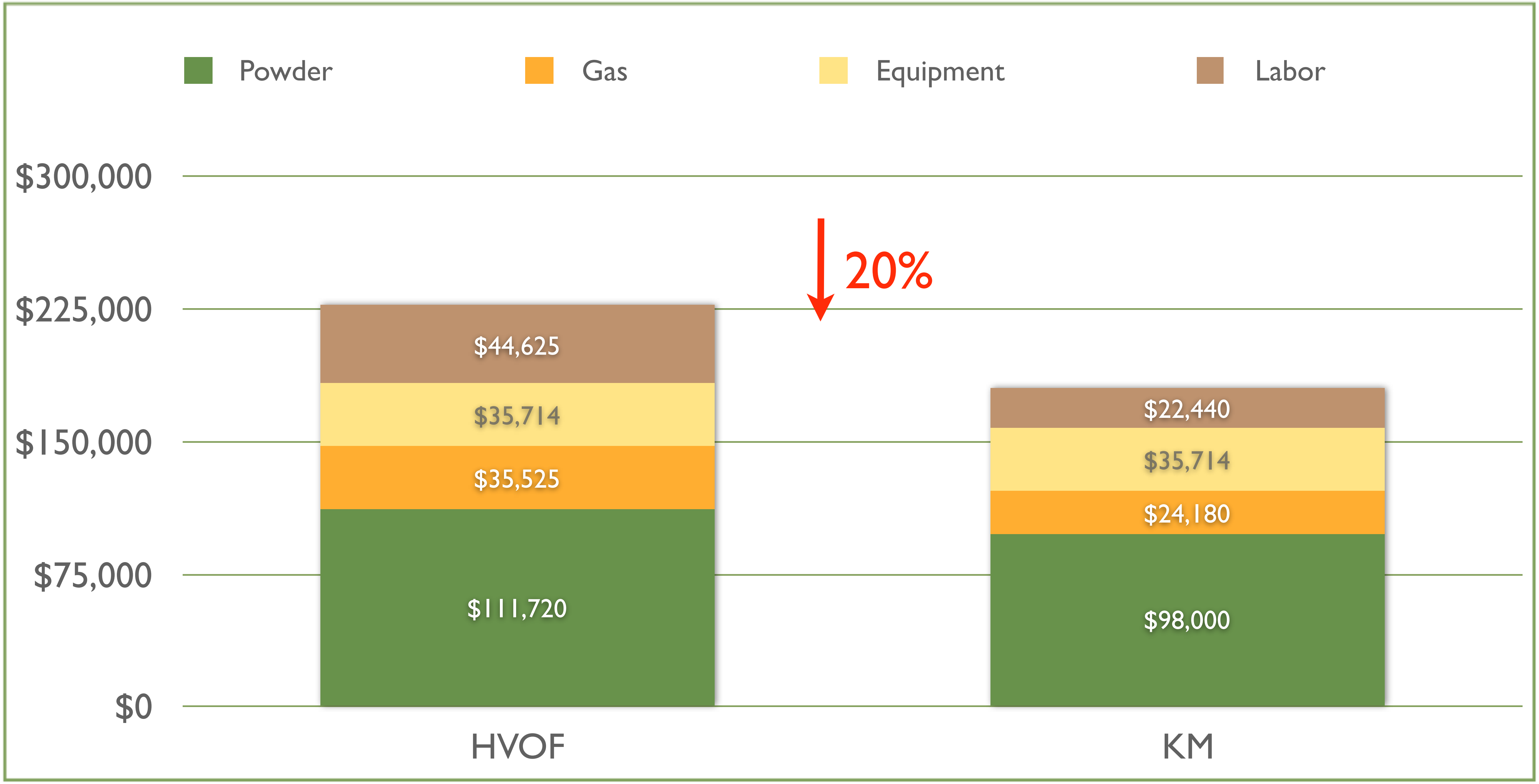
KM WC-Co Features and Benefits vs HVOF

Eliminates	**Enhances**
Grit Blast	Fatigue resistance
Preheat	Throughput
Process cooling	Simplicity
Cool-down	Throughput
Heat distortion	Usability
Masking	Throughput
Sharp transitions	Fatigue resistance
Porosity	Ductility
Oxide inclusions	Ductility, corrosion resistance
Explosive Gases	Safety

KM vs. HVOF Costs

- Hypothetical Actuator (1,500 parts per year)
  - Dimensions 36" x 4" OD
  - Labor Rate @ $17/hr
  - 60% Deposition Efficiency (t = 0.008")
  - Capital Equip - 7 Yr Life
- Adv. Materials & Processing (May 2004)

Annual Cost Summary



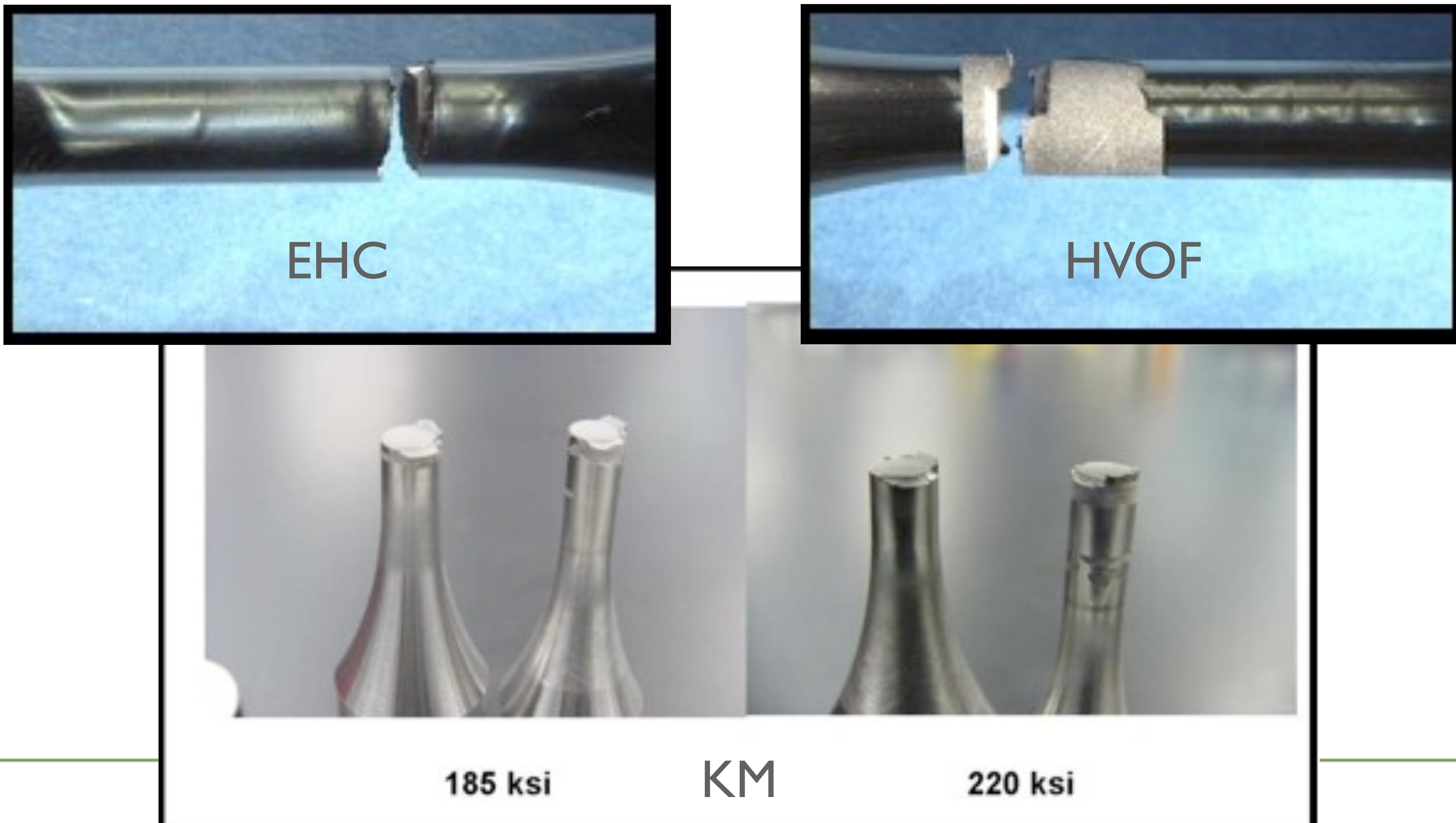
PEWG Review

- Endorsed by OC-ALC and
- Assess and verify KM for
  - Repair and manufacturing GTE components
- Assess microstructure
  - GEAE F50TF71
- Evaluate fracture characteristics

GEAE F50TF71 Specification

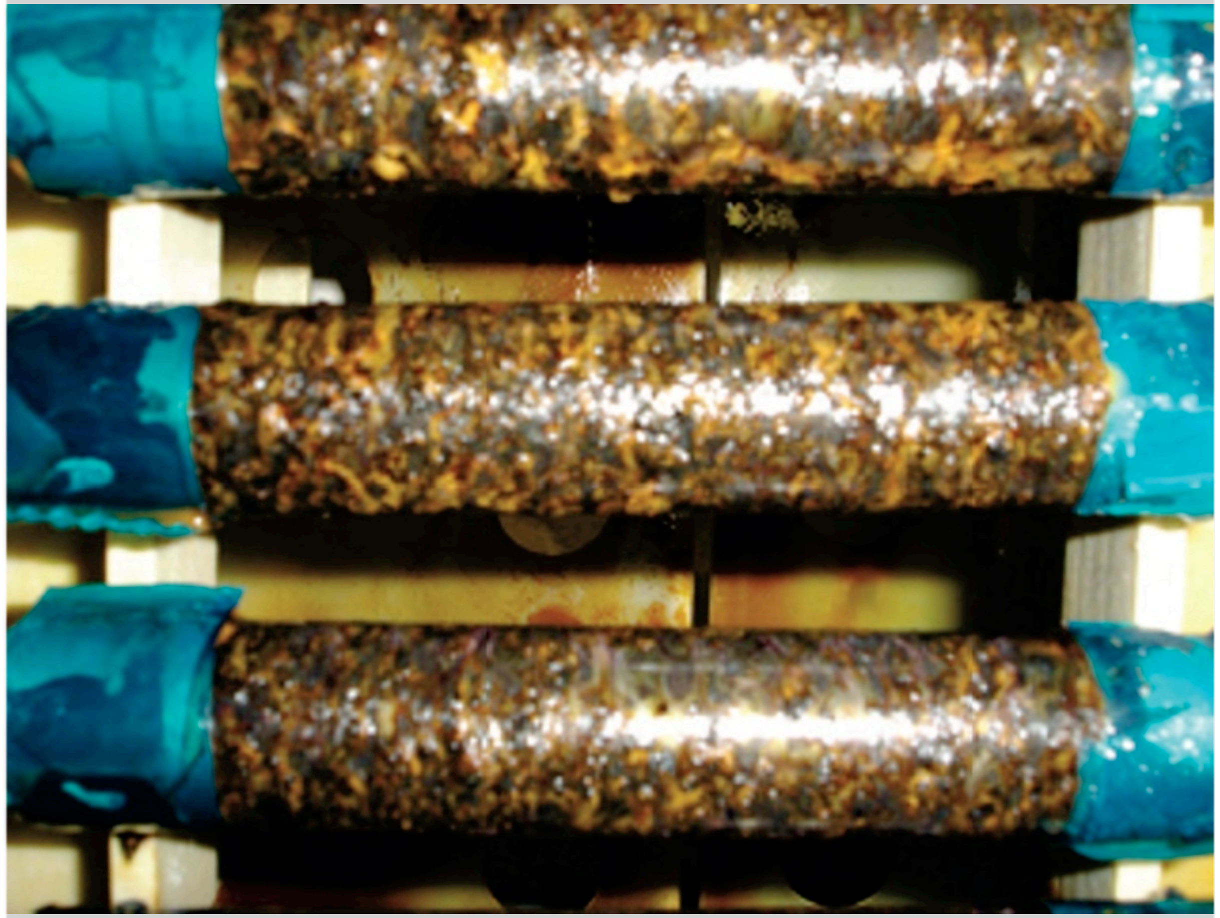
- Evaluated characteristics:
  - Transverse cracking
  - Delamination
  - Interface properties
  - Presence of coating voids
  - Presence of oxides
  - Presence of unmelts
  - Other abnormalities

Fracture Characteristics

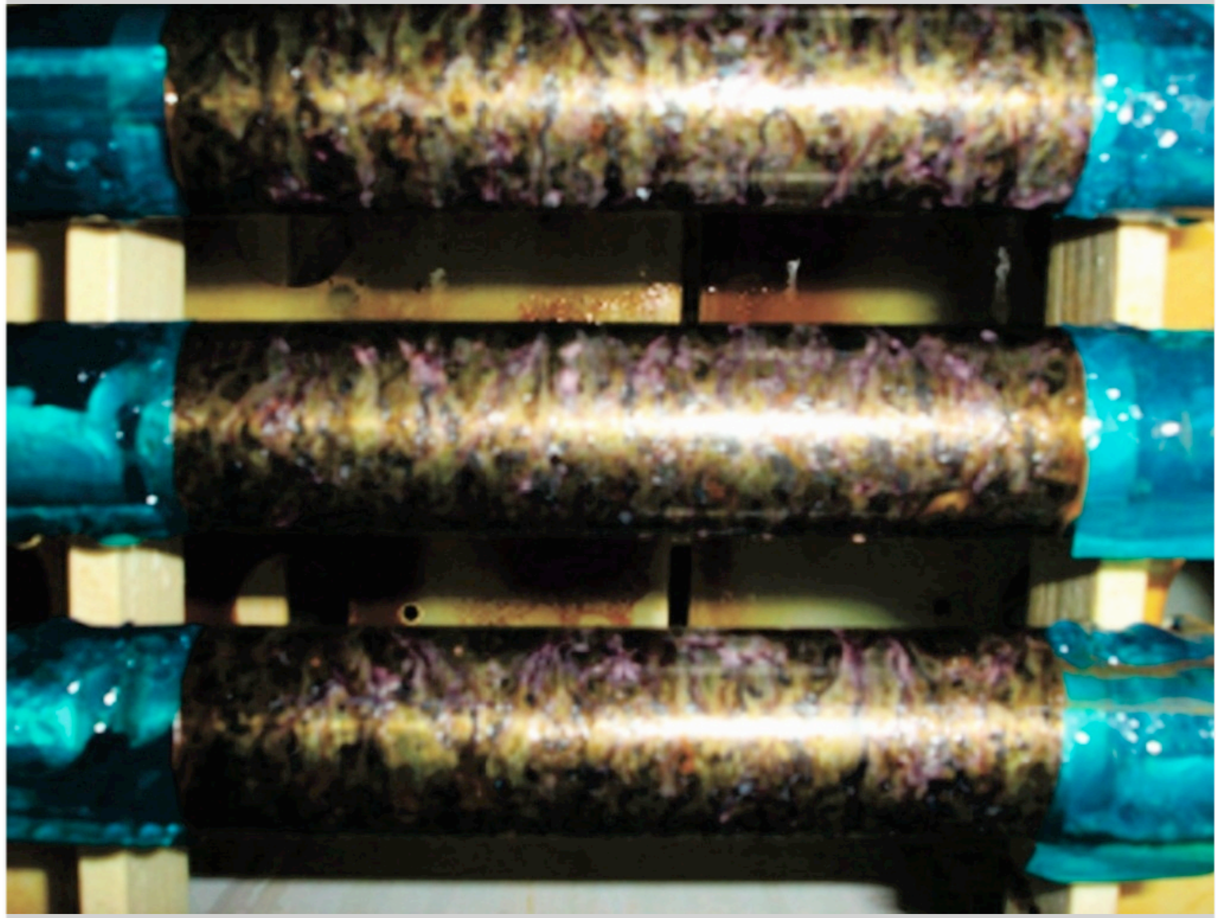


AFRL/MLSC Study

- 2” LCF Samples
- 4340 High-Strength Steel substrate
- Compare KM to HVOF & AC-HVAF
- Landing gear actuator loading
- coating 0.020” as sprayed
  - Grind to desired thickness
- Additional 1” rods for ASTM B-117



0.003”



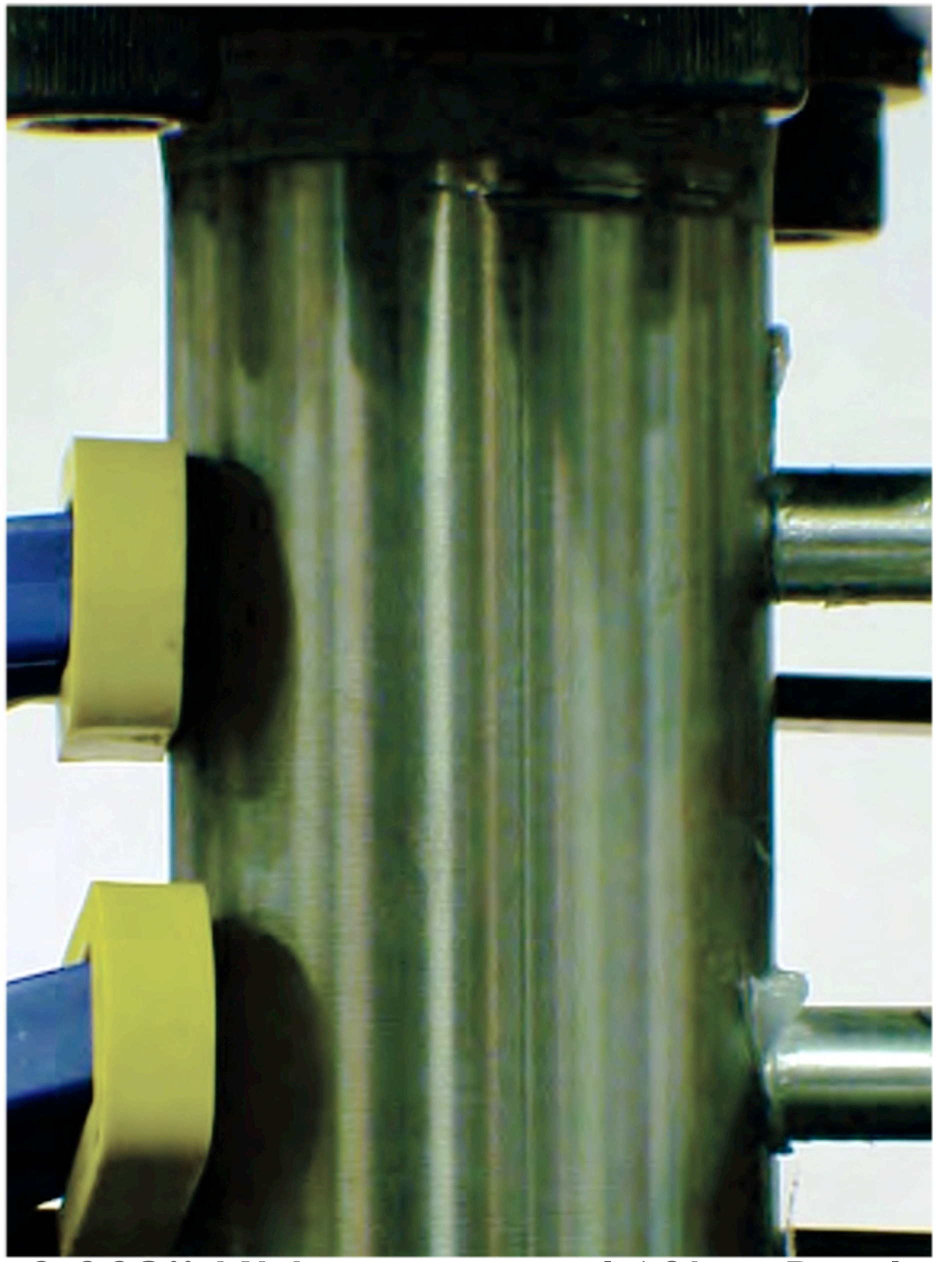
0.010”

Neutral Salt Fog 1,000hr

INOVATI

LCF Testing

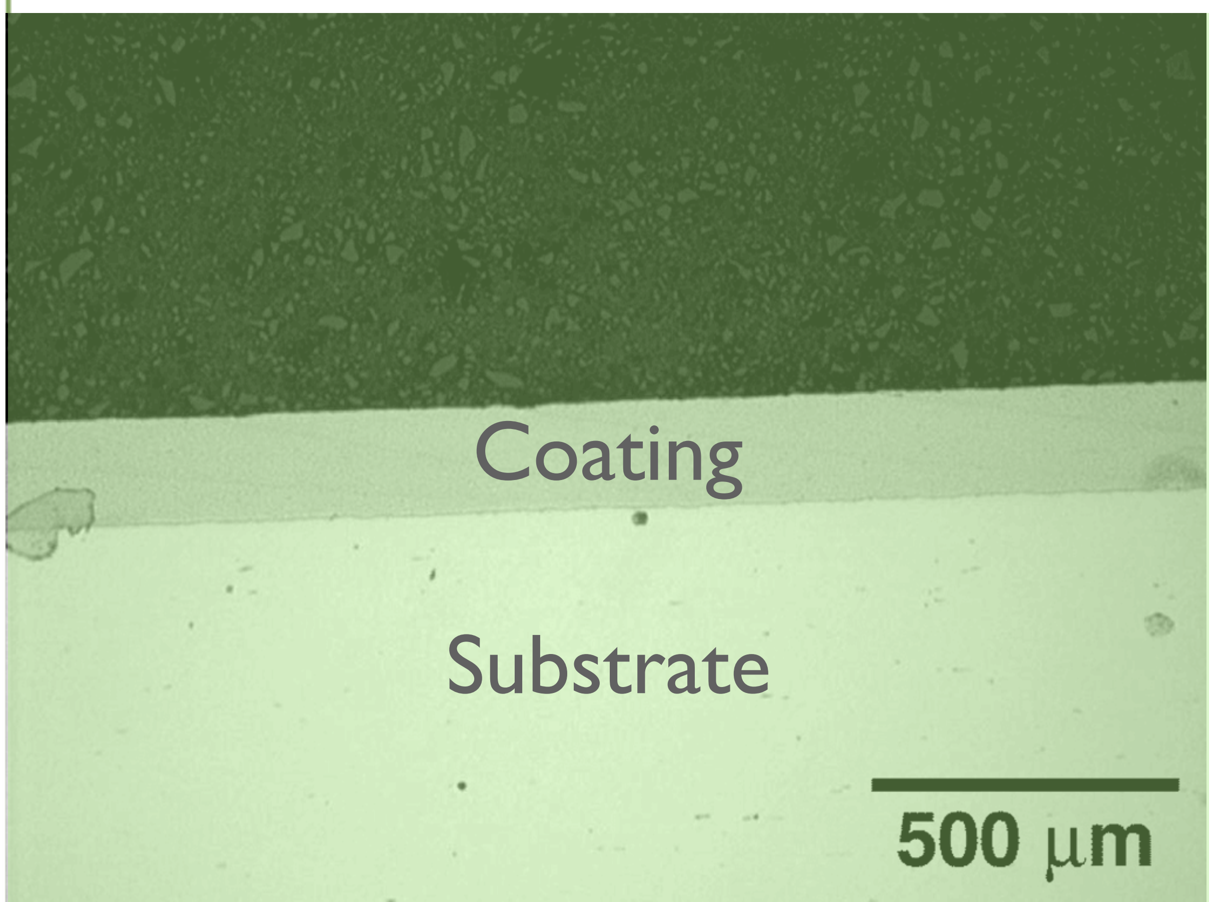
- Key finding for high-load (220ksi)
  - 0.005" coating integrity at 220ksi, R=-.33 equaled 0.003" HVOF
- More ductile coating & uniform thickness provided improved grind performance over HVOF
  - Minimized overspray and removal
- Axial/radial micrographs taken



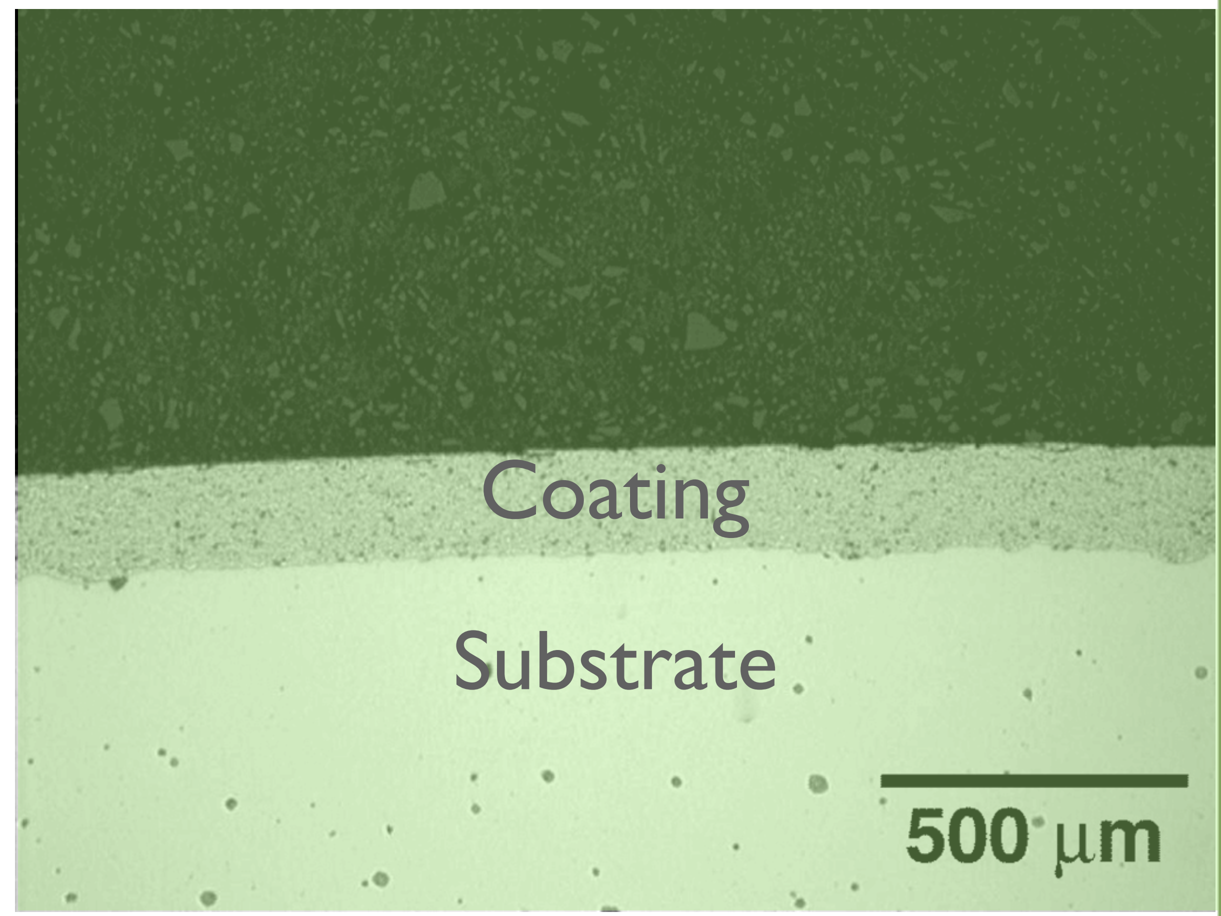
0.003" KM coating at 160ksi, R=-1

KM vs HVOF - Microstructure

KM



HVOF



200x Bright Field
50x Bright Field

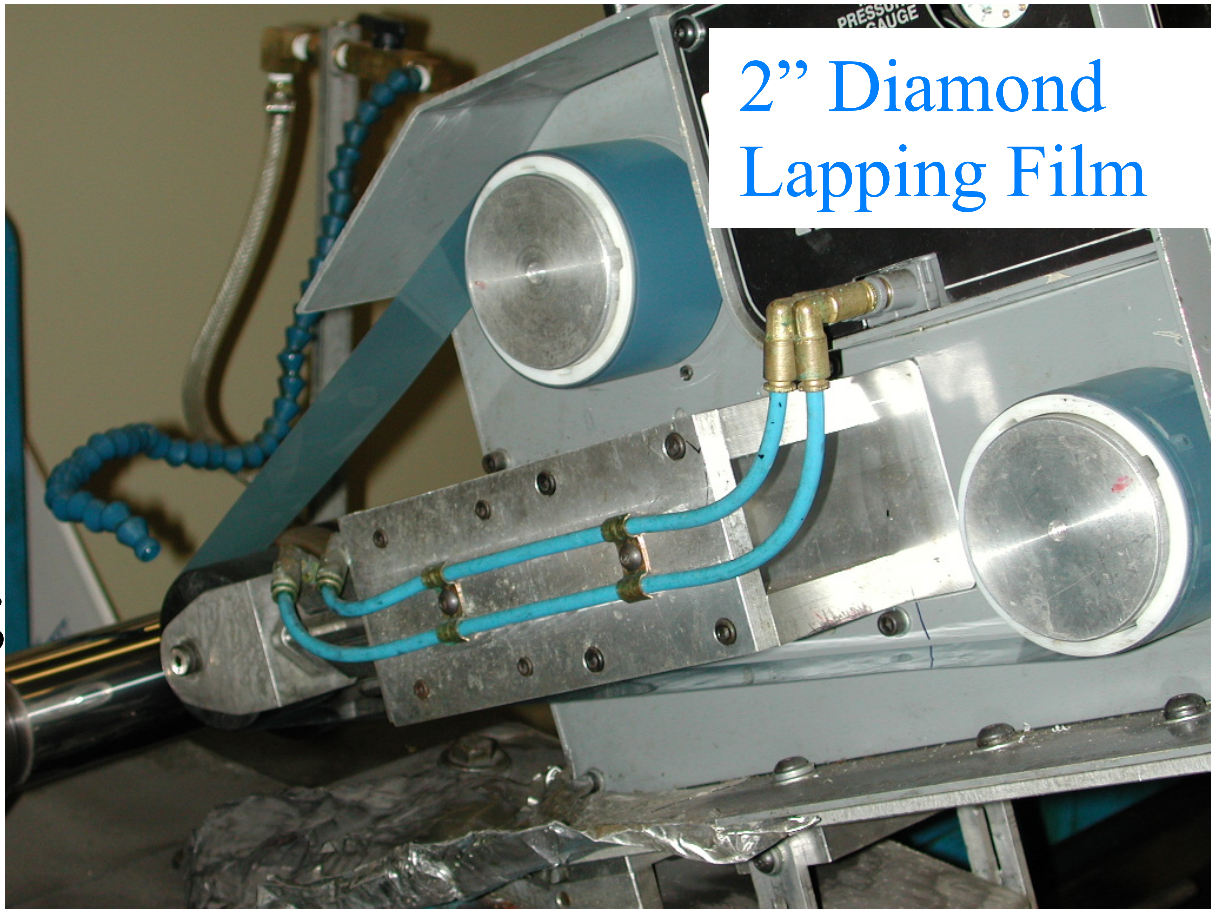
Superfinishing Study Objective

- Compare resultant surface finishes and visual appearances between Inovati WC-Co (83%, 17%) Kinetic Metallization (KM) and WC-Co-Cr (86%, 10%, 4%) High Velocity Oxygen Fuel (HVOF) coatings for a series of 3M Diamond Lapping Film (DLF) abrasive grades.

Superfinishing Parameters

- Platen Pressure: 38 psi gauge
- Platen: 65 Shore A Rubber Roller
- Oscillation: 50%
- Film Index: 1 1/8”/minute
- Part Speed:
  KM = 250 SFPM (401 RPM)
  HVOF = 228 SFPM (503 RPM)
- Traverse Rate: 18”/minute
- Abrasives: M74 Flexible Diamond; 663X DLF: 45µ, 30µ, and 15µ; 661X DLF: 9µ
- Passes: 4 per grade

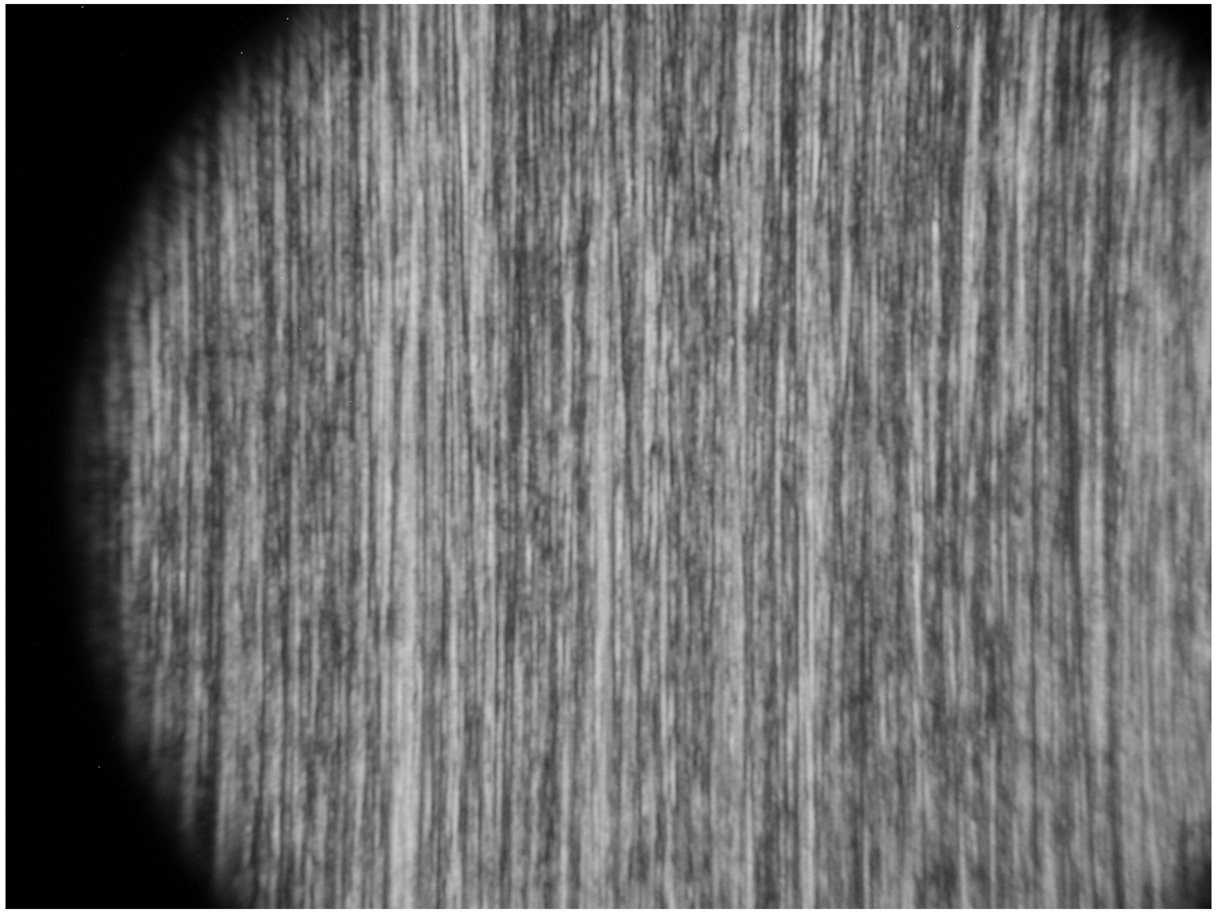
Finish Parameters: Ra, Rz, Rp, and Tp% @ 10 µinch below 5% Reference



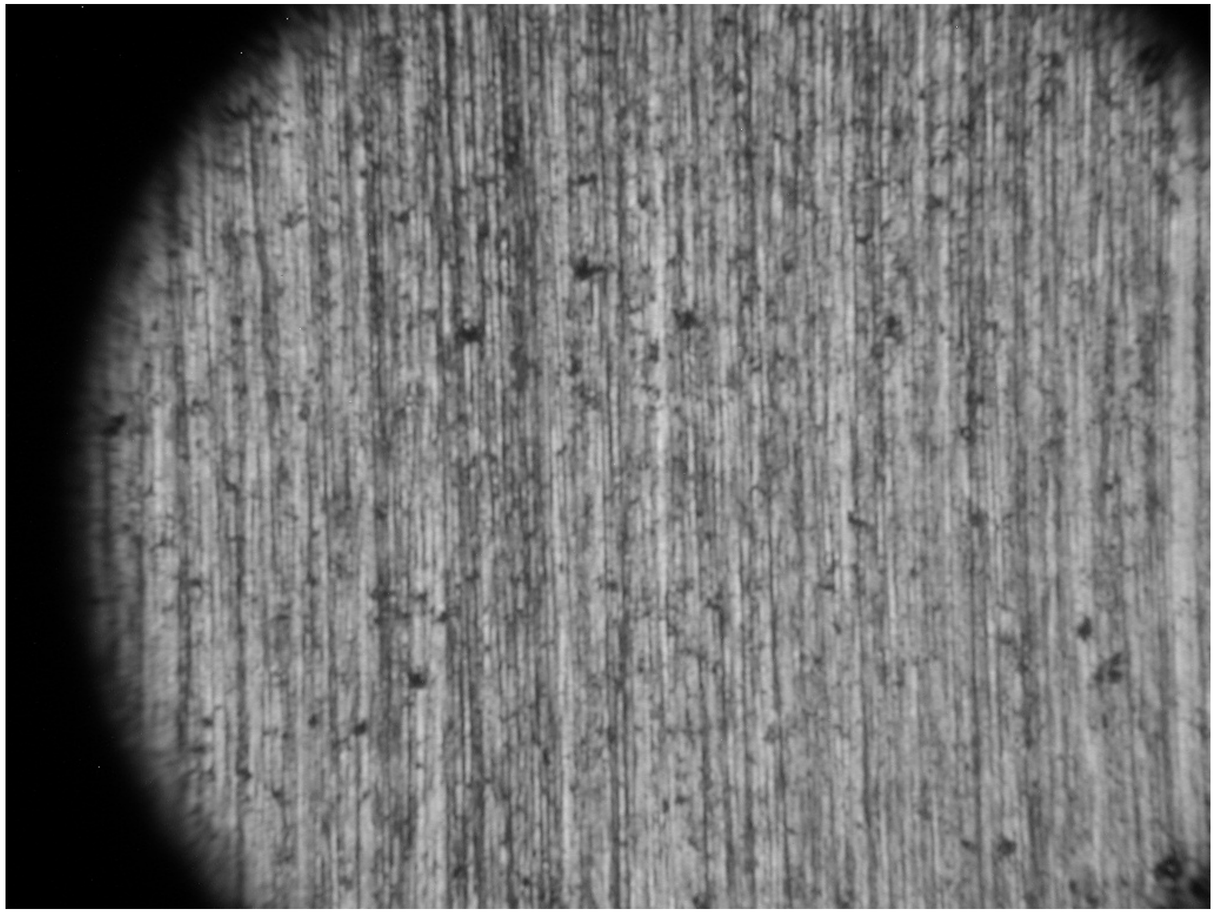
3M

30μ Finishes & Photos

	Ra	Rp	Rz	Tp%
KM	4.3	16.33	33.3	60.04
	4.15	15.25	32.76	65.72
HVOF	3.67	13.16	30.62	77.24
	3.37	20.85	31.56	82.33

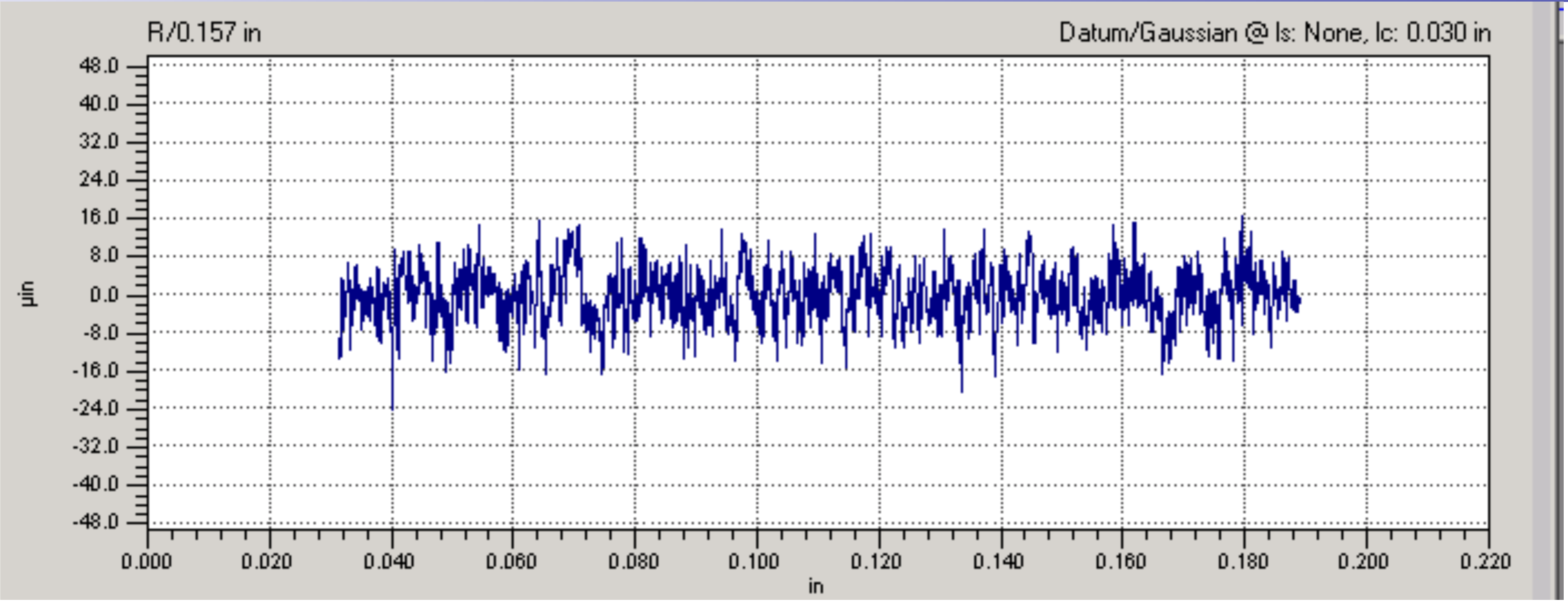


Kinetic Metallization, ~50X

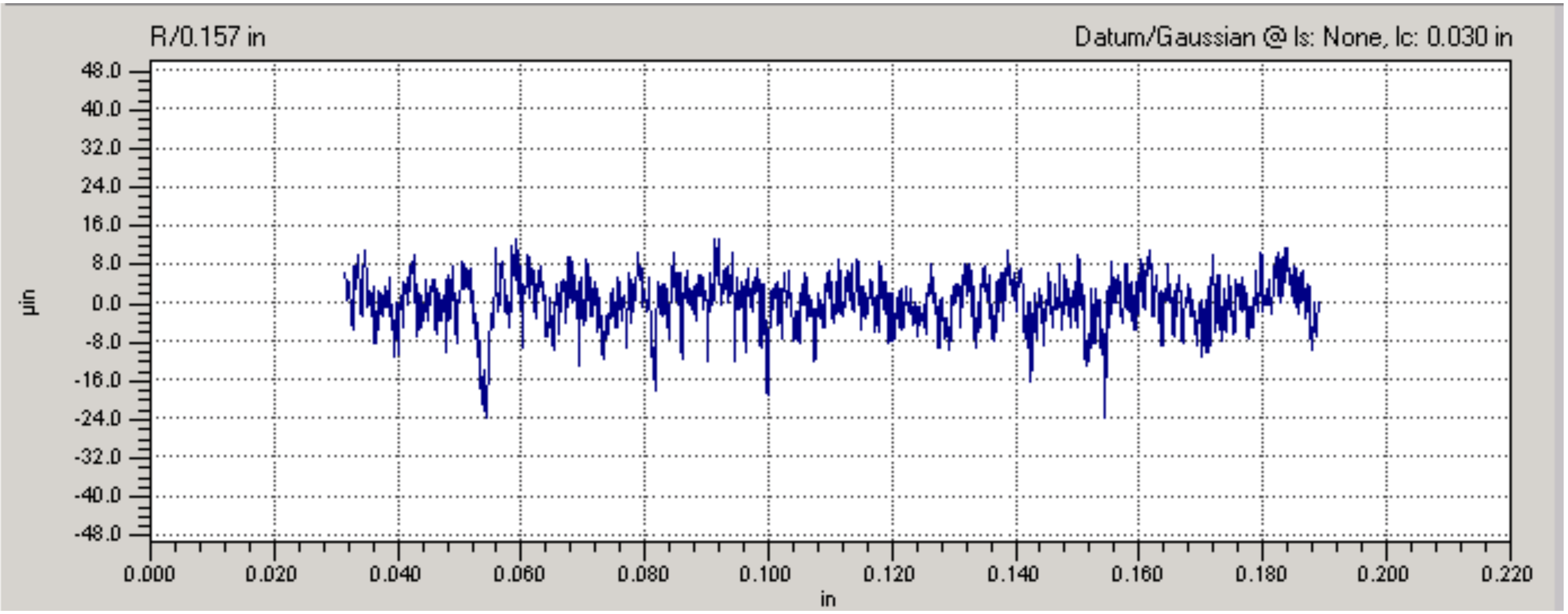


HVOF, ~50X

3M



KM 30µ DLF Trace

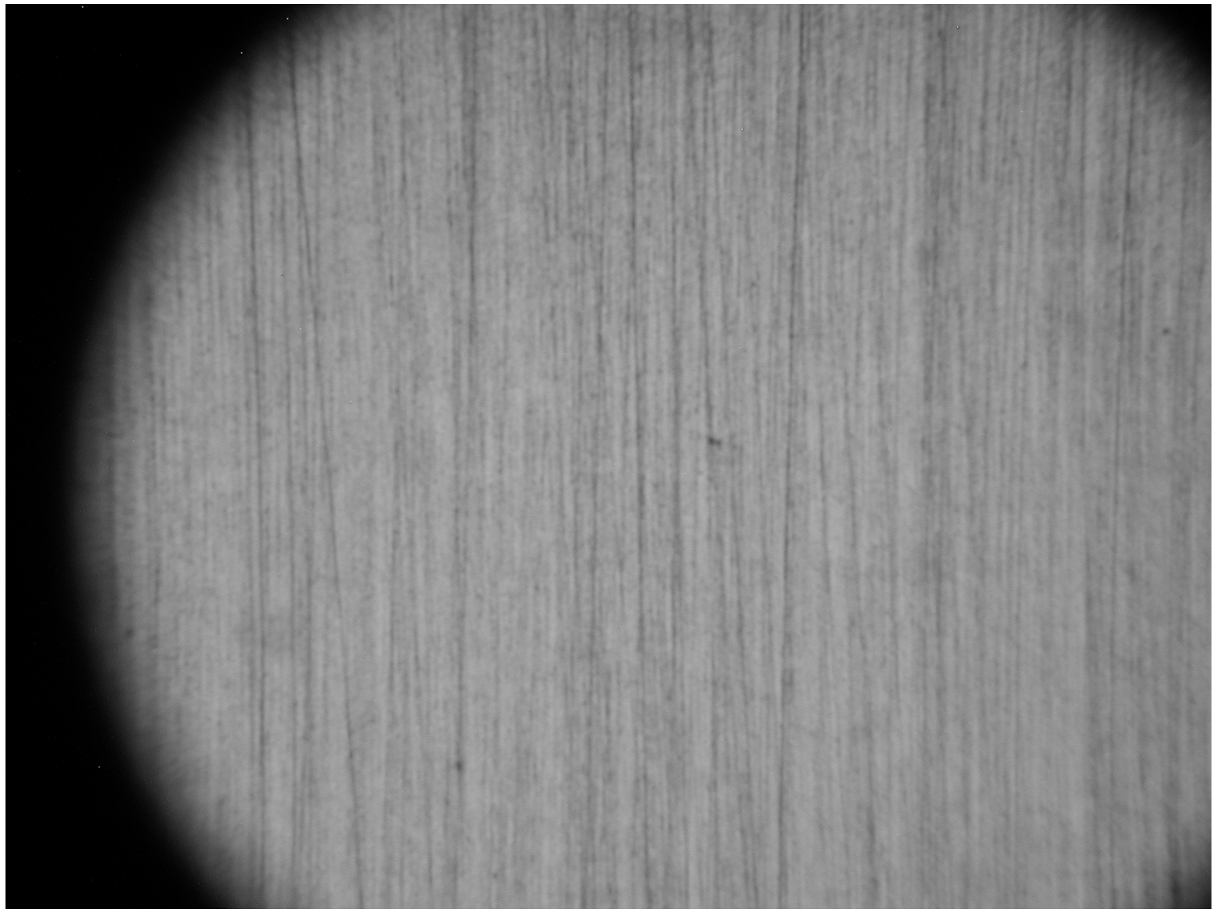


HVOF 30µ DLF Trace

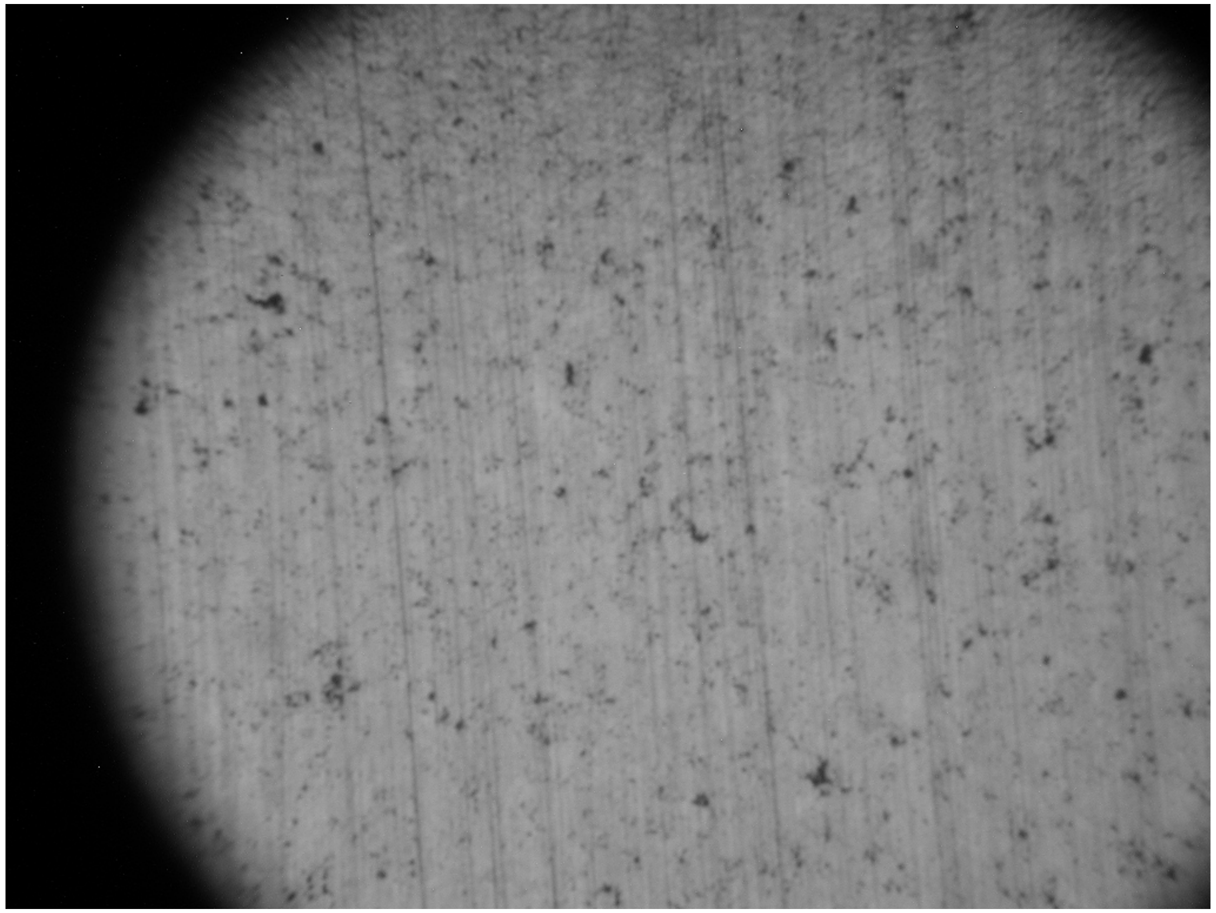
3M

9µ Finishes & Photos

	Ra	Rp	Rz	Tp%
KM	0.91	4.43	8.14	100
	0.88	4.41	7.41	100
HVOF	1.14	4.73	30.6	99.01
	1.35	5.57	24.07	99.01

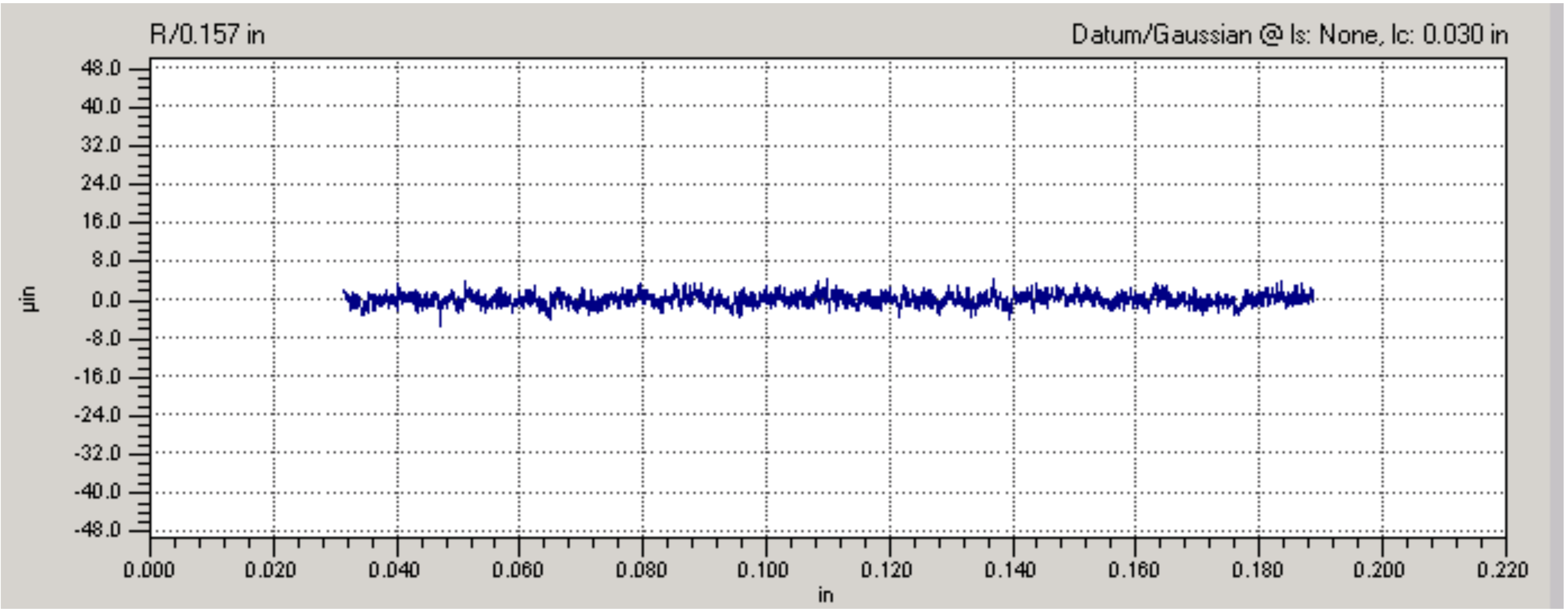


Kinetic Metallization, ~50X

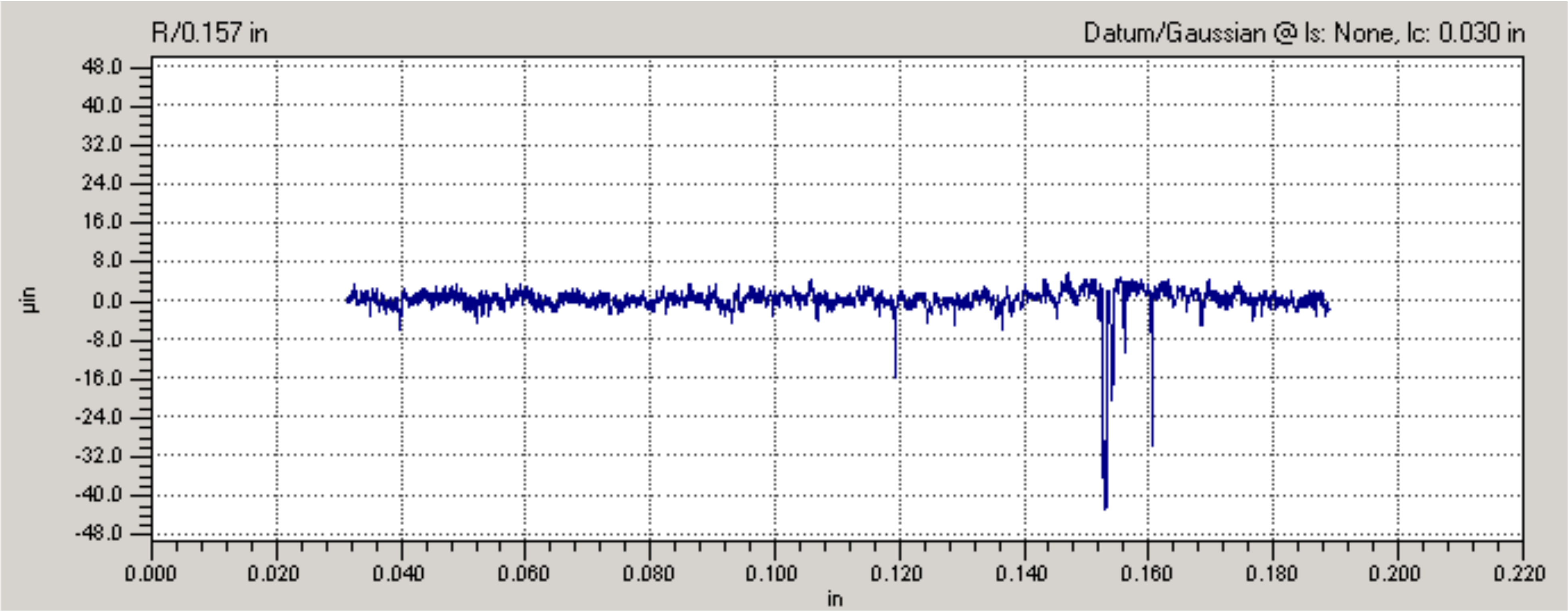


HVOF, ~50X

3M



KM 9µ DLF Trace



HVOF 9µ DLF Trace

3M

Surface Finish Summary

45μ

	Ra	Rp	Rz	Tp%
KM	6.51	24.6	55.9	36.1
	6.11	34.11	54.32	44.44
HVOF	5.17	19.54	41.34	56.06
	4.84	18.35	41.76	56.14

30μ

	Ra	Rp	Rz	Tp%
KM	4.3	16.33	33.3	60.04
	4.15	15.25	32.76	65.72
HVOF	3.67	13.16	30.62	77.24
	3.37	20.85	31.56	82.33

15μ

	Ra	Rp	Rz	Tp%
KM	2.08	8.31	16.07	98.35
	2.31	11.81	19.67	96.6
HVOF	1.89	6.4	20.61	97.83
	1.84	7.68	19.19	98.73

9μ

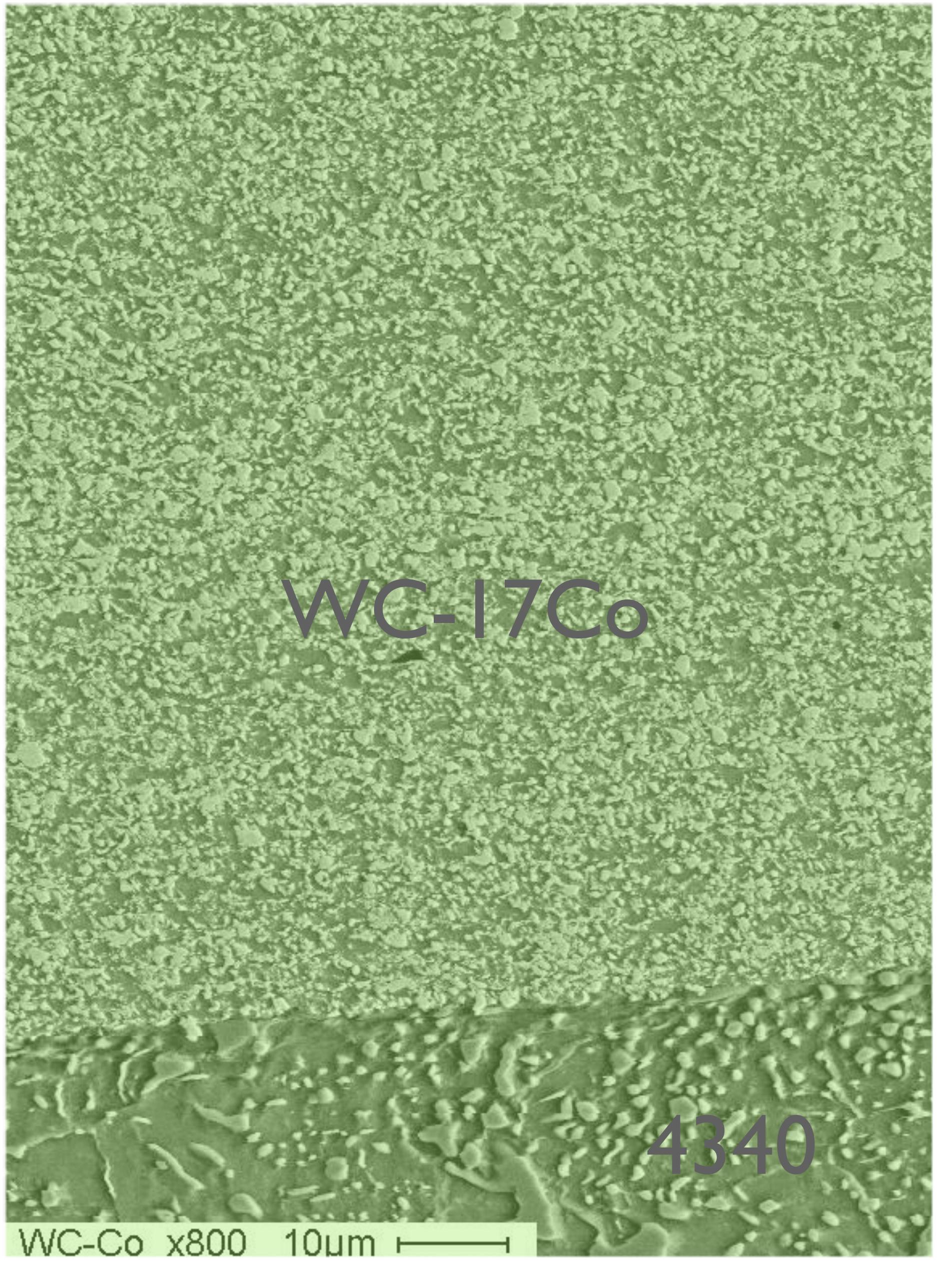
	Ra	Rp	Rz	Tp%
KM	1.03	4.01	7.97	100
	1.08	4.92	8.1	100
HVOF	1.17	5.16	12.16	99.42
	1.05	5.45	10.28	99.77

Conclusions

- KM coating appears to have very low porosity.
- Superfinishing produced similar results on KM and HVOF under similar conditions.
- No process optimization completed – time and finish results may be improved.
- KM finish and appearance results merit pursuit of a belt grinding study.
- WC-Co KM Grinding parameters predicted to be similar to WC-Co-Cr HVOF with an initial target removal rate of ~ 0.18 in^3/min.

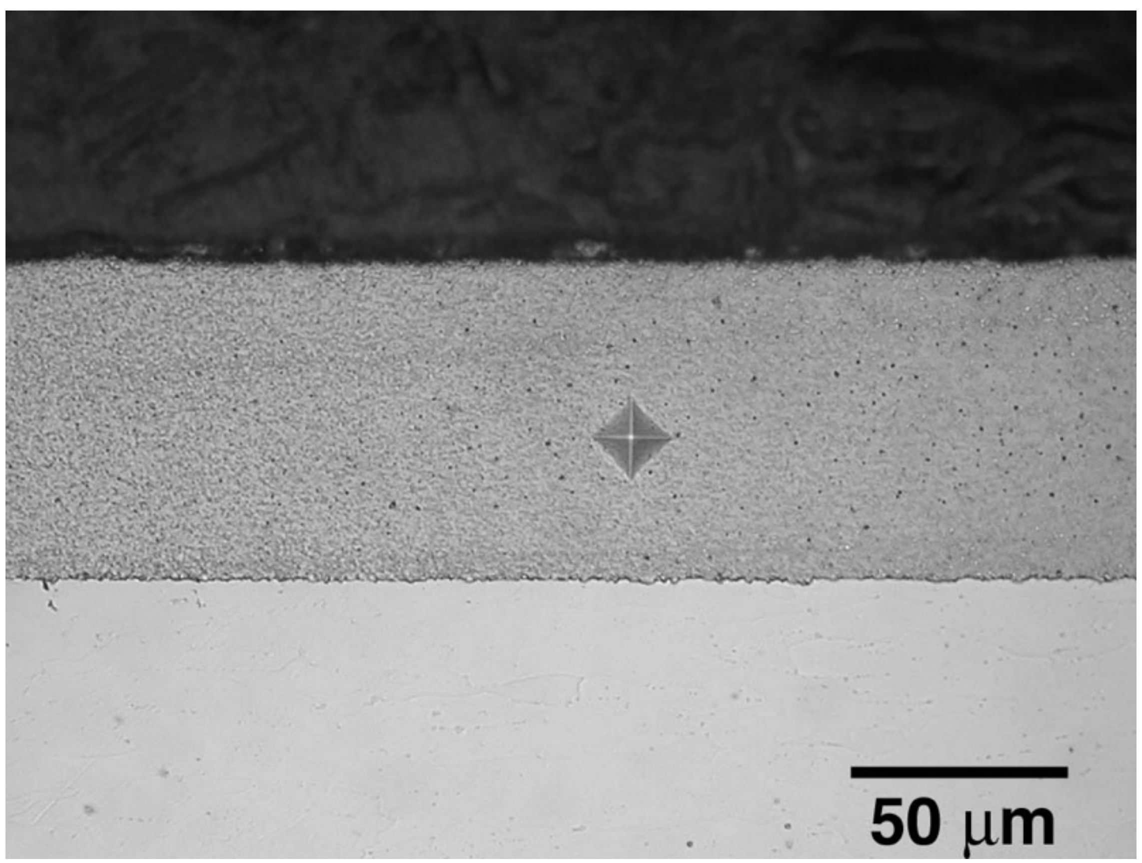
KM WC-Co on 4340

- Highly Uniform
- WC particles 2-4μm average
- Smooth interface

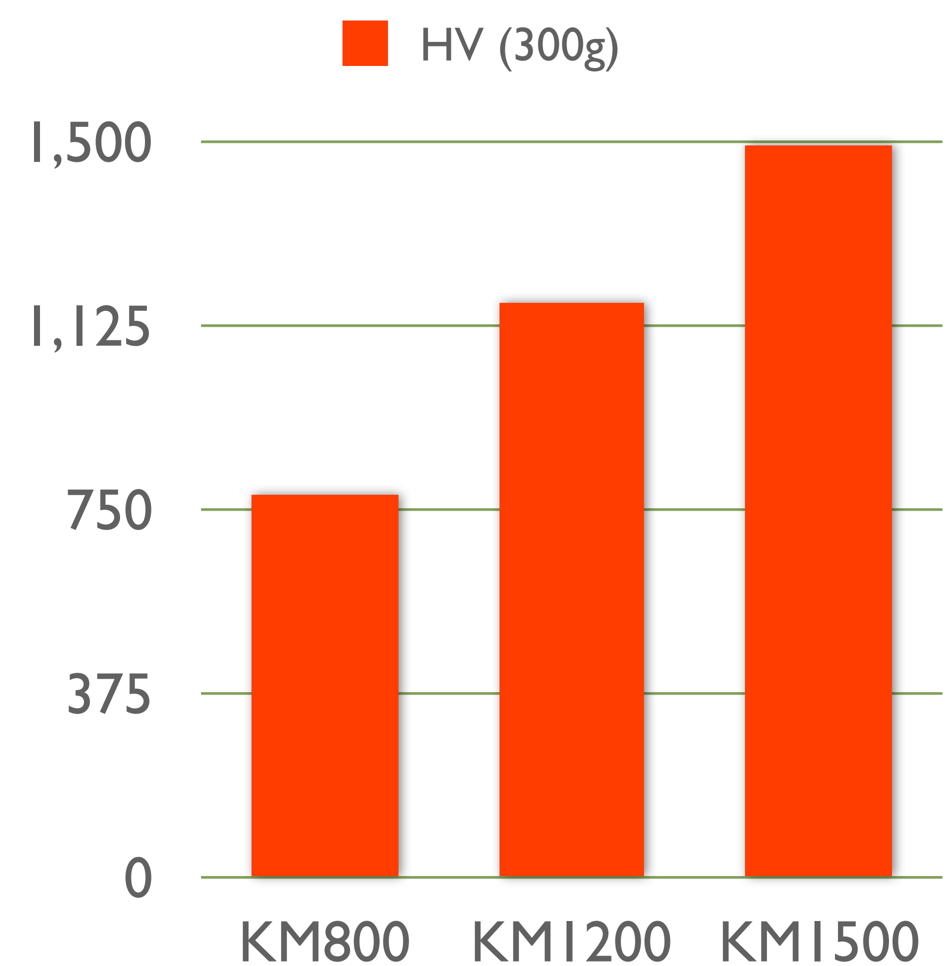


Tunable Hardness KM WC-Co

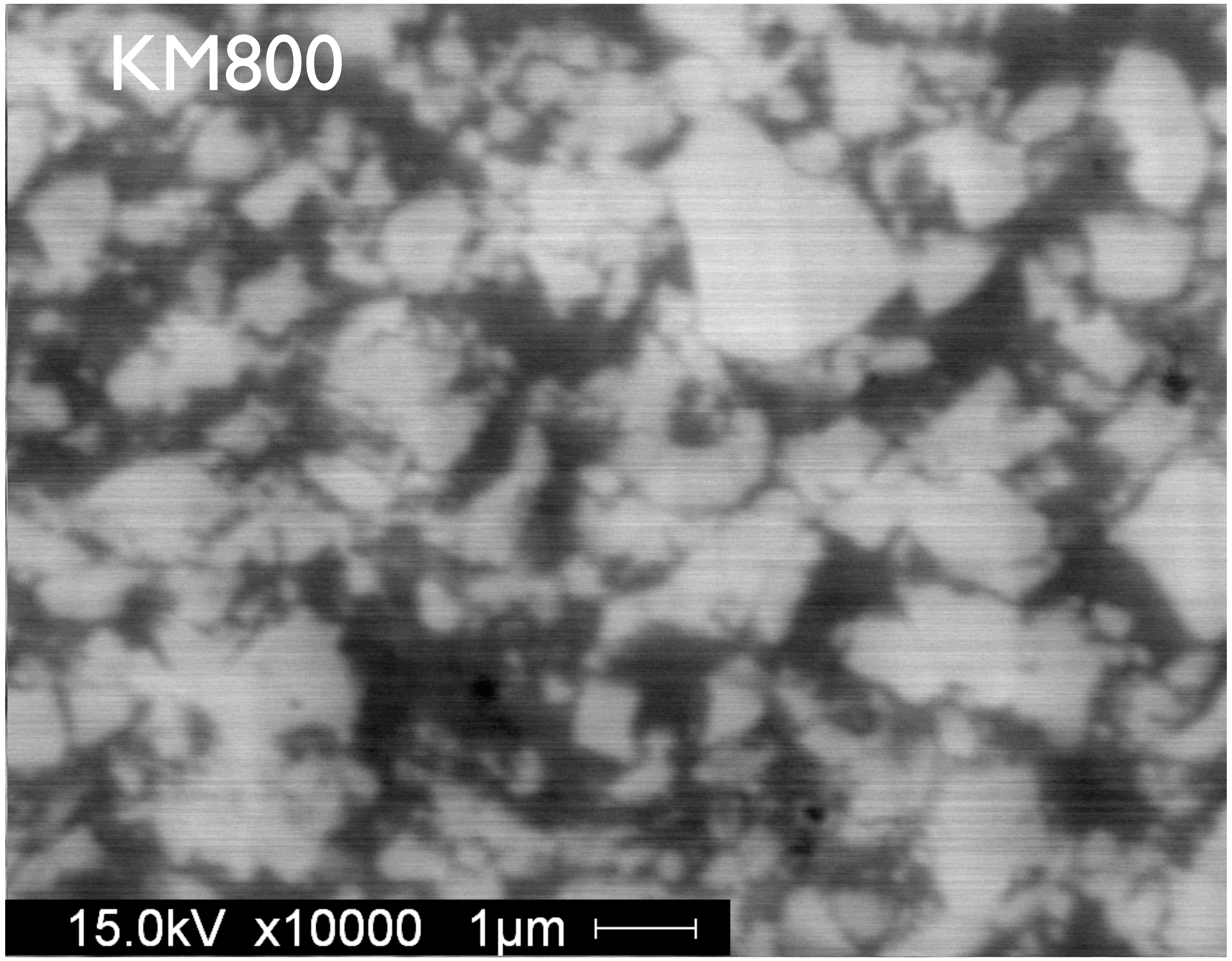
- Inovati powder blends combined with KM
  - yields tunable hardness
- Vary average WC particle size



HV (300g) = 1495 kg/mm2



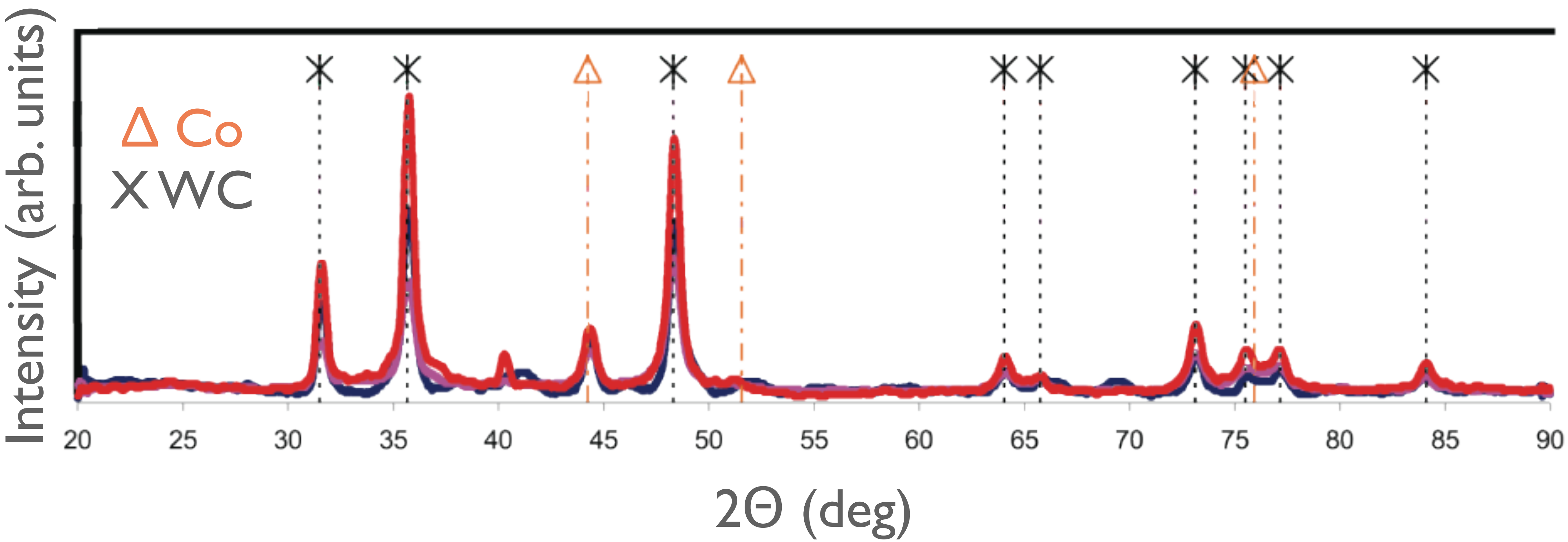
KM WC-Co Coatings: Microstructural Scale



Sohn's Group
AMPAC/MMAE
University of Central Florida

All Specimens Contain Co Solid Solution (Dark Gray) and WC Particles (Light Gray). Particle Size Ranges from 5µm to Submicron.

X-Ray Diffraction

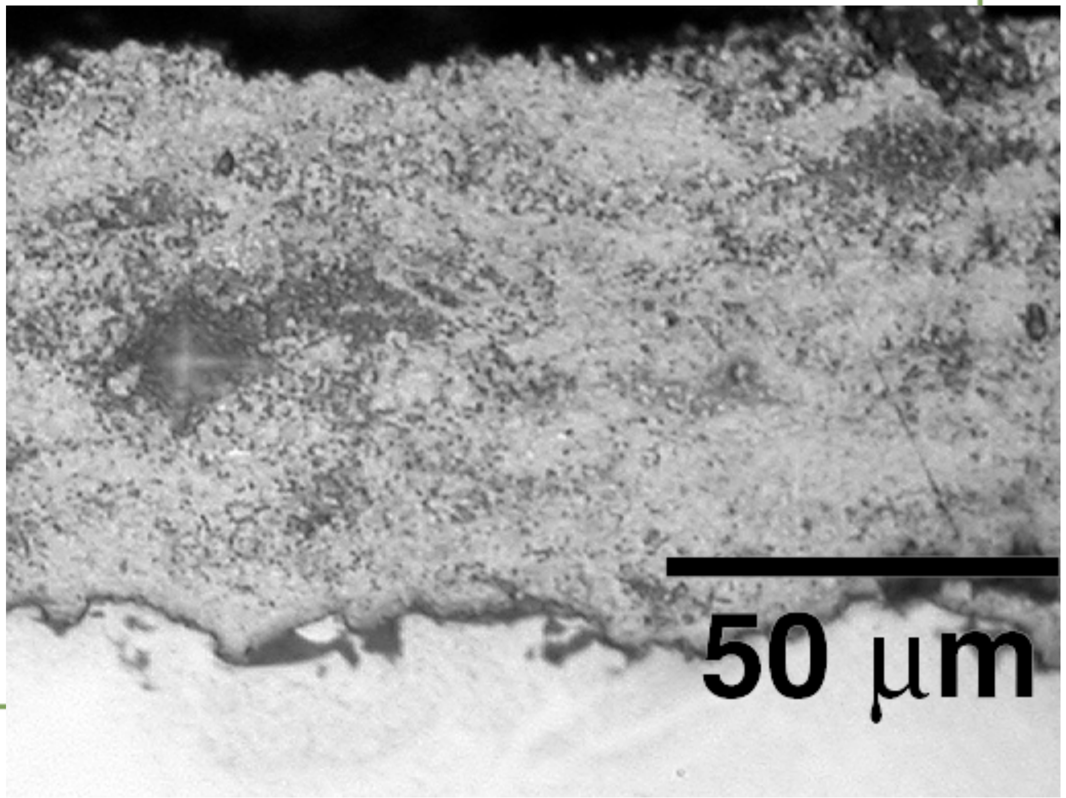


- No indications of metallic W
- No presence of Cobalt carbide

Sohn's Group
AMPAC/MMAE
University of
Central Florida

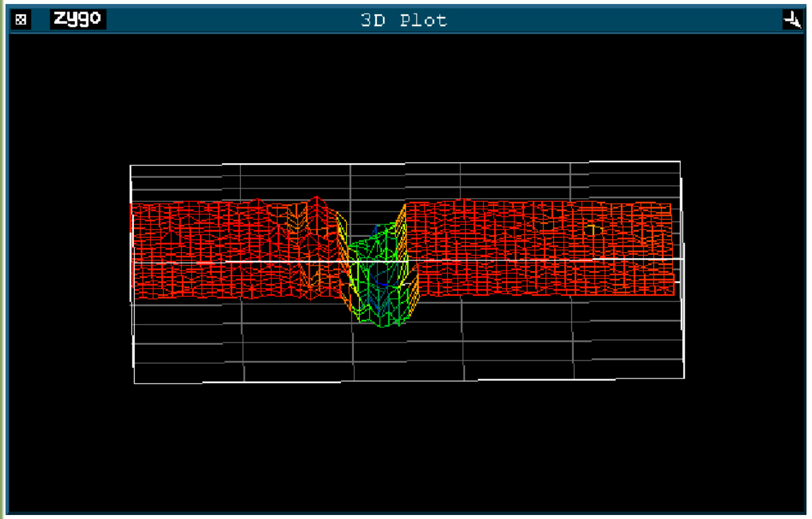
KM nano-WC-Co

- NSF Phase I SBIR
  - Goal: nano-grain WC-Co coatings
    - Anticipated Hardness of 2000HV
  - Received first round powder from China & University of Connecticut (Leon Shaw)
    - Obtained depositions
    - nanoWC-18%Co shows 1700HV_{300g}

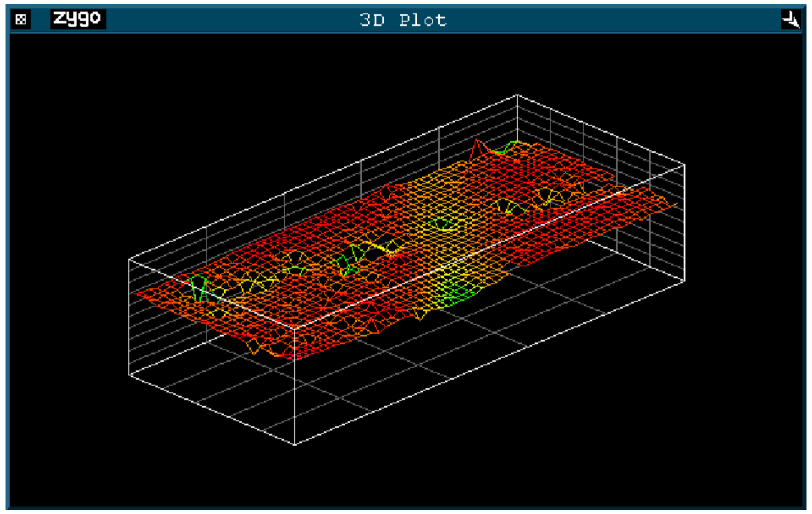


KM nano-WC-Co

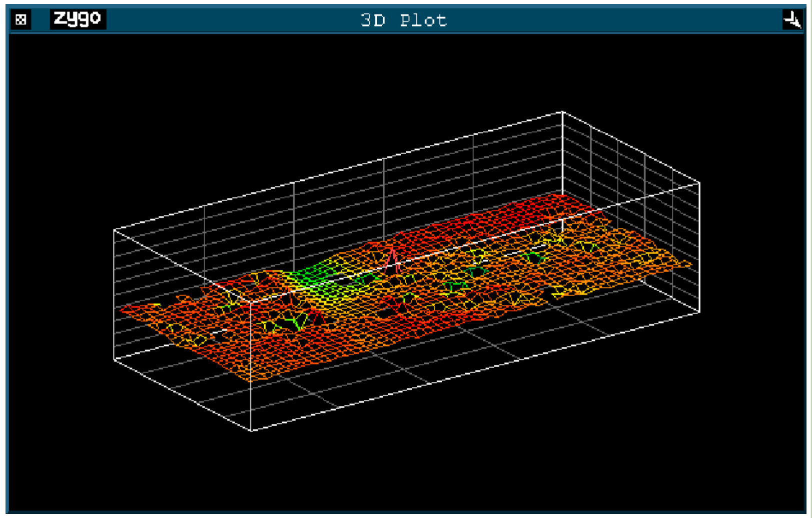
- Pin-on-disk wear testing shows nanoWC-Co wear rate approximately 4x less than KM800



KM800



nanoWC-Co



nanoWC-Co

- Moving forward to Phase II - Commercialization

Conclusions

- KM offers process and cost benefits over HVOF
- Inovati's proprietary powder blends combined with KM allow
  - tunable hardness
  - application specific WC-Co coating
- KM WC-Co is a commercially viable coating