



Super Hard Steel Supersonic Particle Deposition

Presented by:

Scott Grendahl (410) 306-0822
sgrenda@arl.army.mil

US Army Research Laboratory

Aberdeen Proving Ground, MD 21005

*Replacement of Hard Chrome Plating
Program Review Meeting*

19 November 2003

Kennedy Space Center Visitors Center

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 19 NOV 2003	2. REPORT TYPE	3. DATES COVERED 00-00-2003 to 00-00-2003			
4. TITLE AND SUBTITLE Super Hard Steel Supersonic Particle Deposition		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U. S. Army Research Laboratory, Aberdeen Proving Ground, MD, 21005		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES 23rd Replacement of Hard Chrome Plating Program Review Meeting, November 18-19, 2003, Cape Canaveral, FL. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 15	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



INEEL Super Hard Steel

Developed at the Department of Energy's Idaho National Engineering and Environmental Laboratory (INEEL)

- Material forms a Metallic Glass or Nano Composite Microstructure
- Low Cost - No Exotic Elements - Uses Conventional Spray Methods

- **Composition wt%:** C-1, Mn-2, Si-1.4, Cr-20, Mo-5, W-6
- **Microstructure:** Amorphous or Nano Crystalline
- **Uses:** Wear, Corrosion and Impact Resistance



Technical Data

Hardness

Vickers (300g)

Rockwell C (Conversion)

as-HVOF sprayed

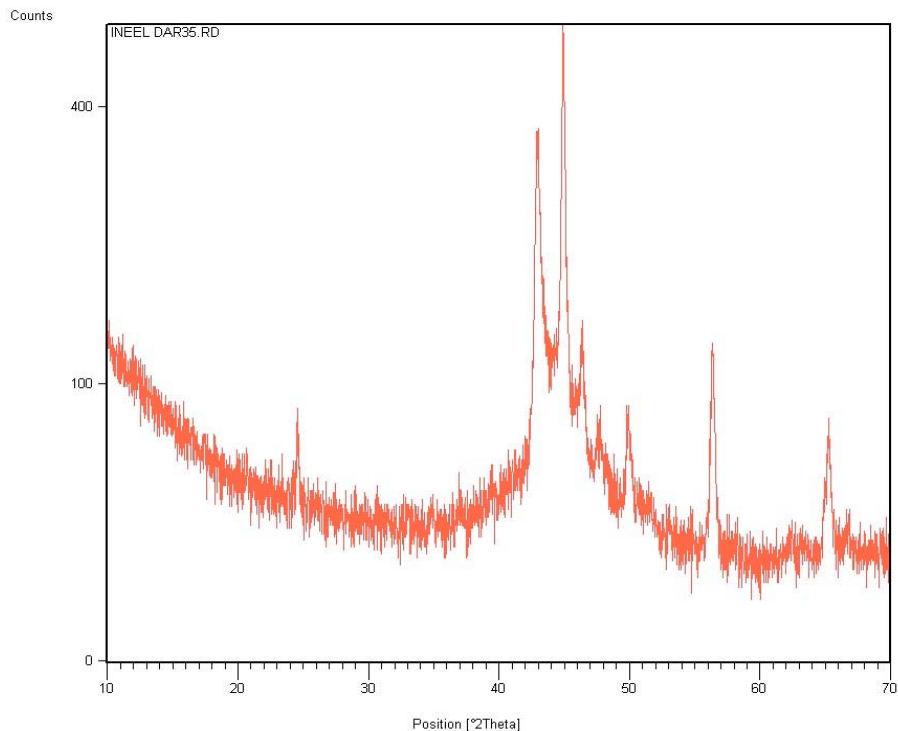
1034

69.4

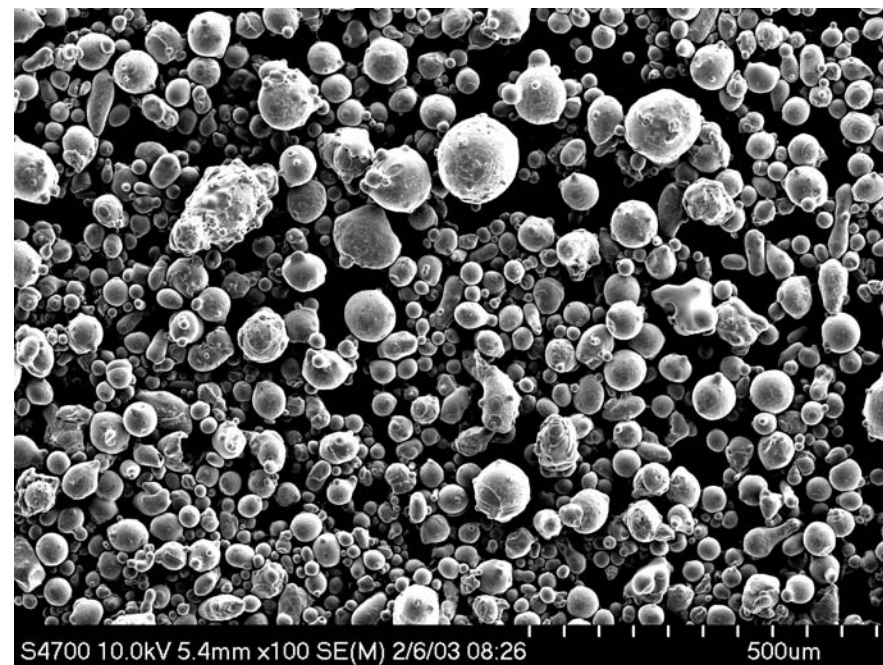
heat treated

1364

73.5



XRD Pattern DAR 35 Powder



DAR 35 Powder FSEM



Processing Approaches

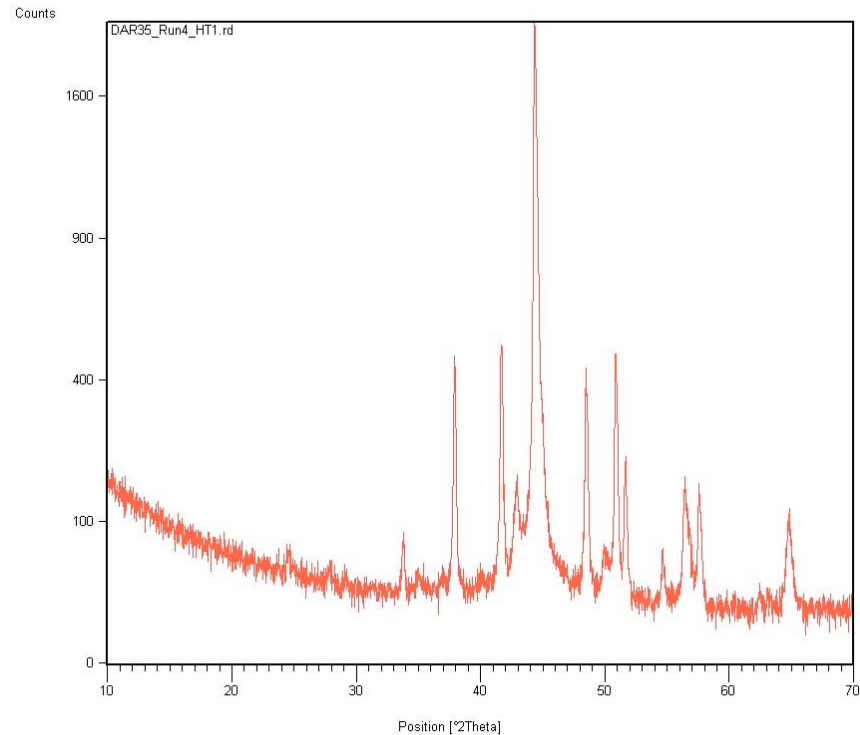
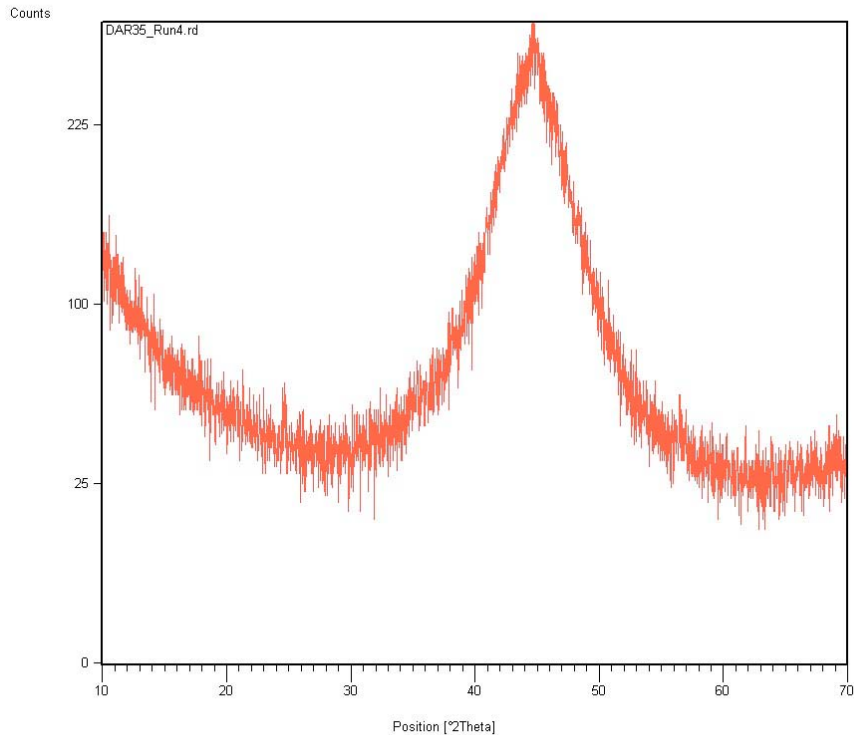


- HVOF
- Plasma Arc Spray
- Cold Spray
- Spray Forming

Maintain Amorphous and/or Nanocrystalline Structure



Accomplishments Utilizing HVOF Technology



**XRD Pattern HVOF Diamond Jet
Amorphous Microstructure**

**XRD Pattern HVOF After Heat Treat
700° C for 10 min. Nanocrystalline**

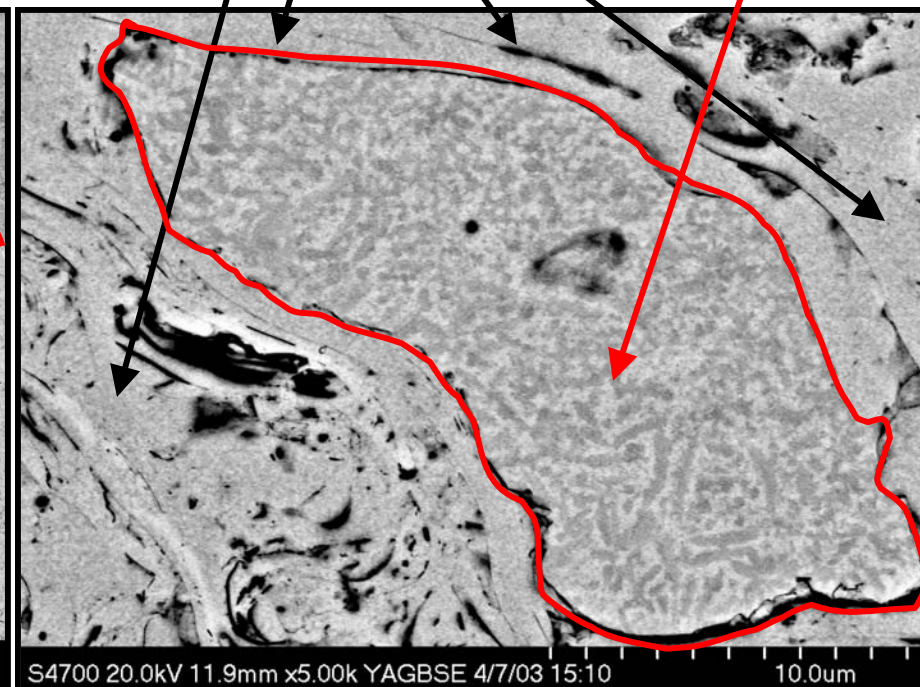
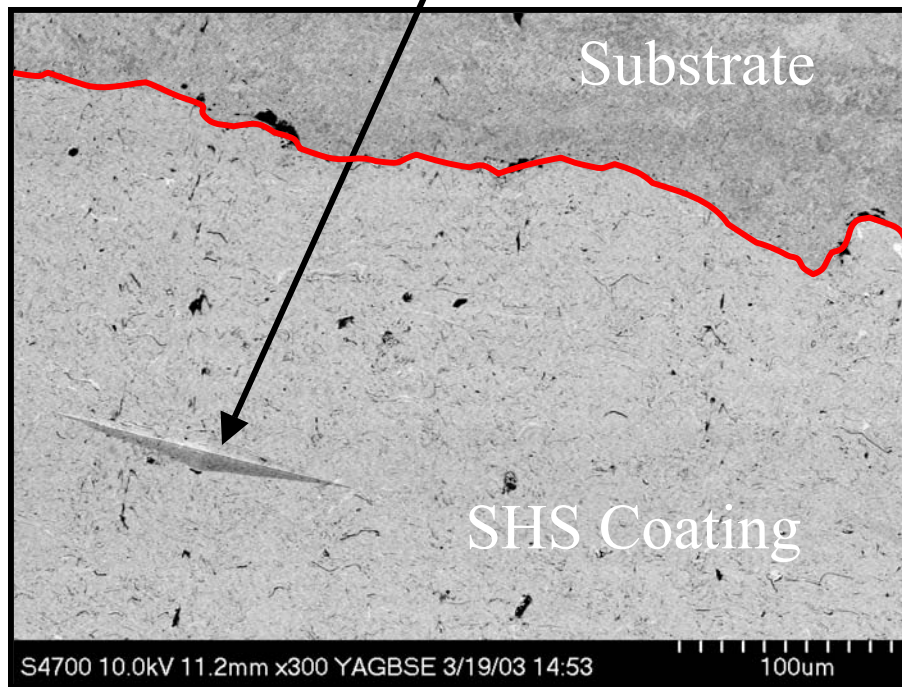


Microstructural Analysis of HVOF Coating

Hardness Indent

Amorphous

Nanocrystalline



HVOF As-Sprayed Microstructure

Microstructure After Heat Treatment



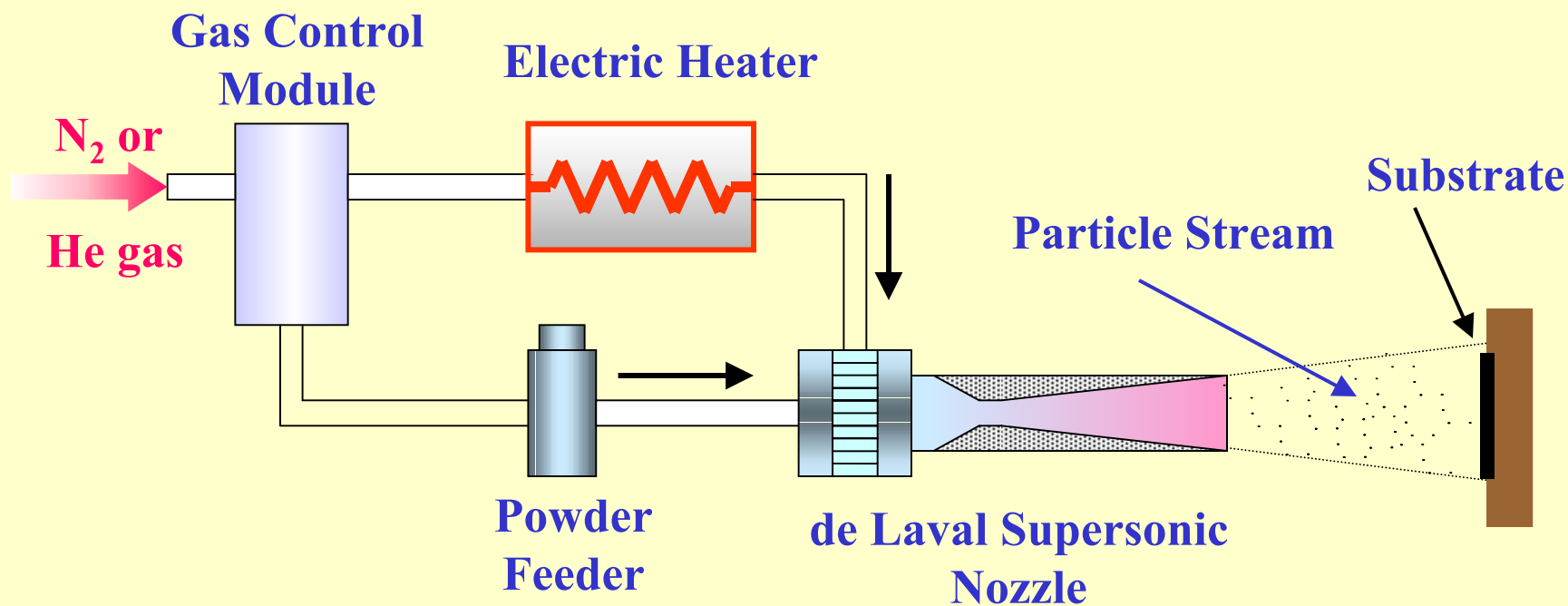
Supersonic Particle Deposition

•ARL -WMRD is the only facility within DOD and one of only a few entities in the USA to have a fully operational SPD System.

Main Gas Stagnation Pressure 100-500 psi Gas Temperature 0-1300°F Main Gas Flow Rate 30-100 CFM

Powder Feed Rate 10 to 30 pounds/hour

Particle Velocity 300-1500 m/sec.



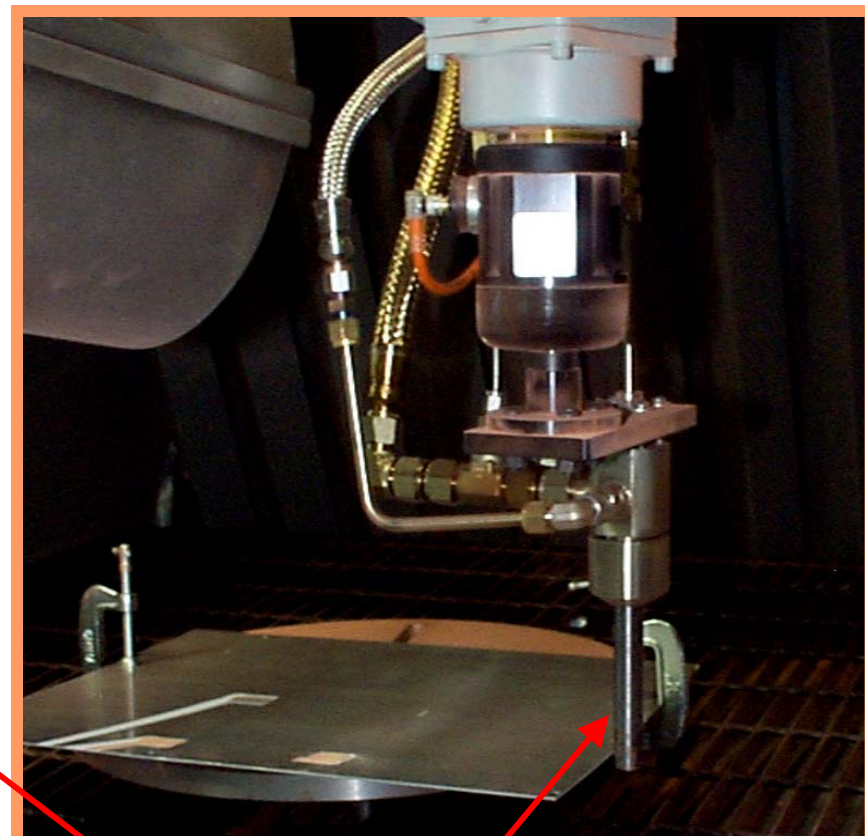
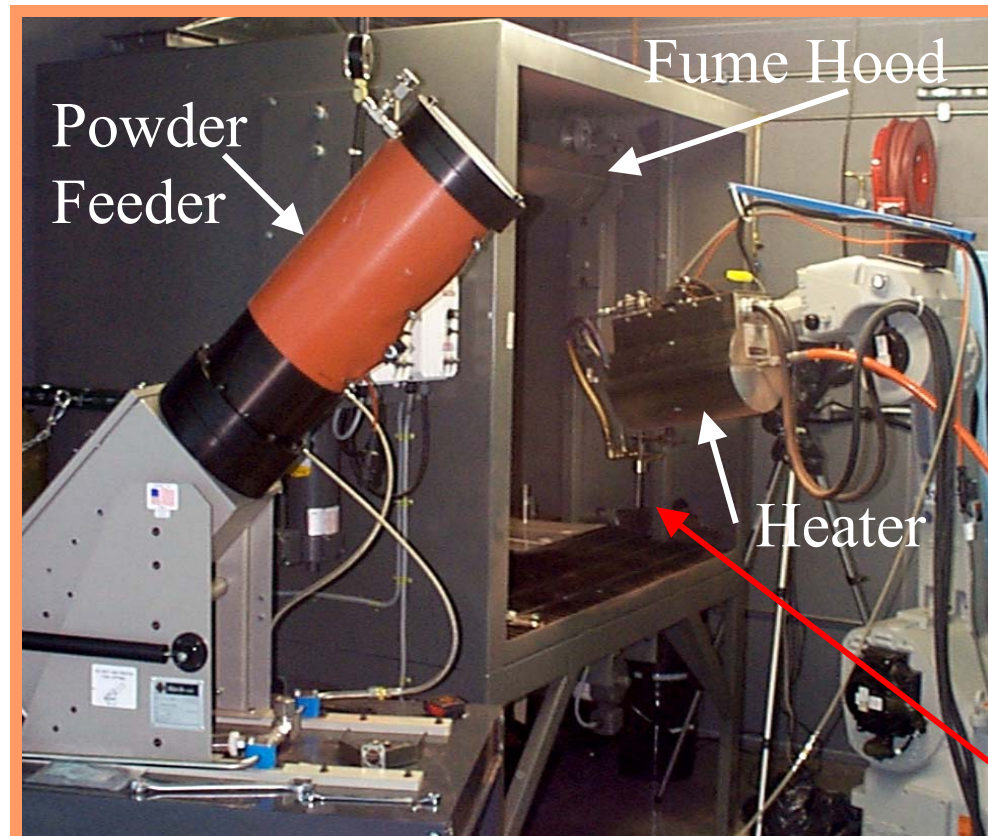


Cold Spray Advantages

- **High deposition rates**
- **Deposition efficiency greater than 70%**
- **Porosity less than 1%**
- **Low temperature deposition**
- **Solid state bonding**
- **High density, low oxide content**
- **Young's modulus 85% of bulk material**
- **High thermal & electrical conductivity**
- **Electrical conductivity near bulk material values**
- **Low residual stress**
- **Compressive residual stress**
- **Produces free-standing structures**



ARL SPD System

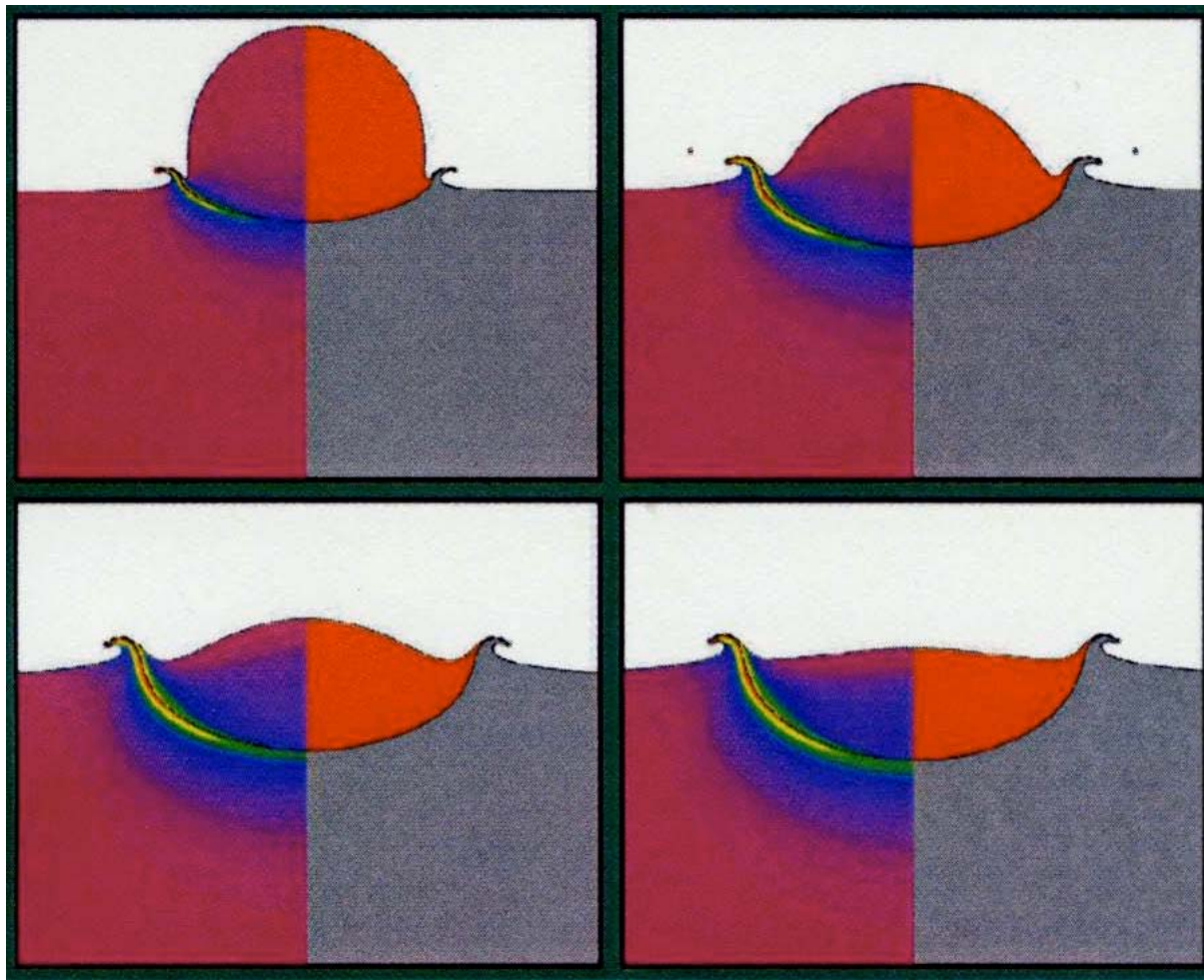


Robotically Controlled

Spray Nozzle



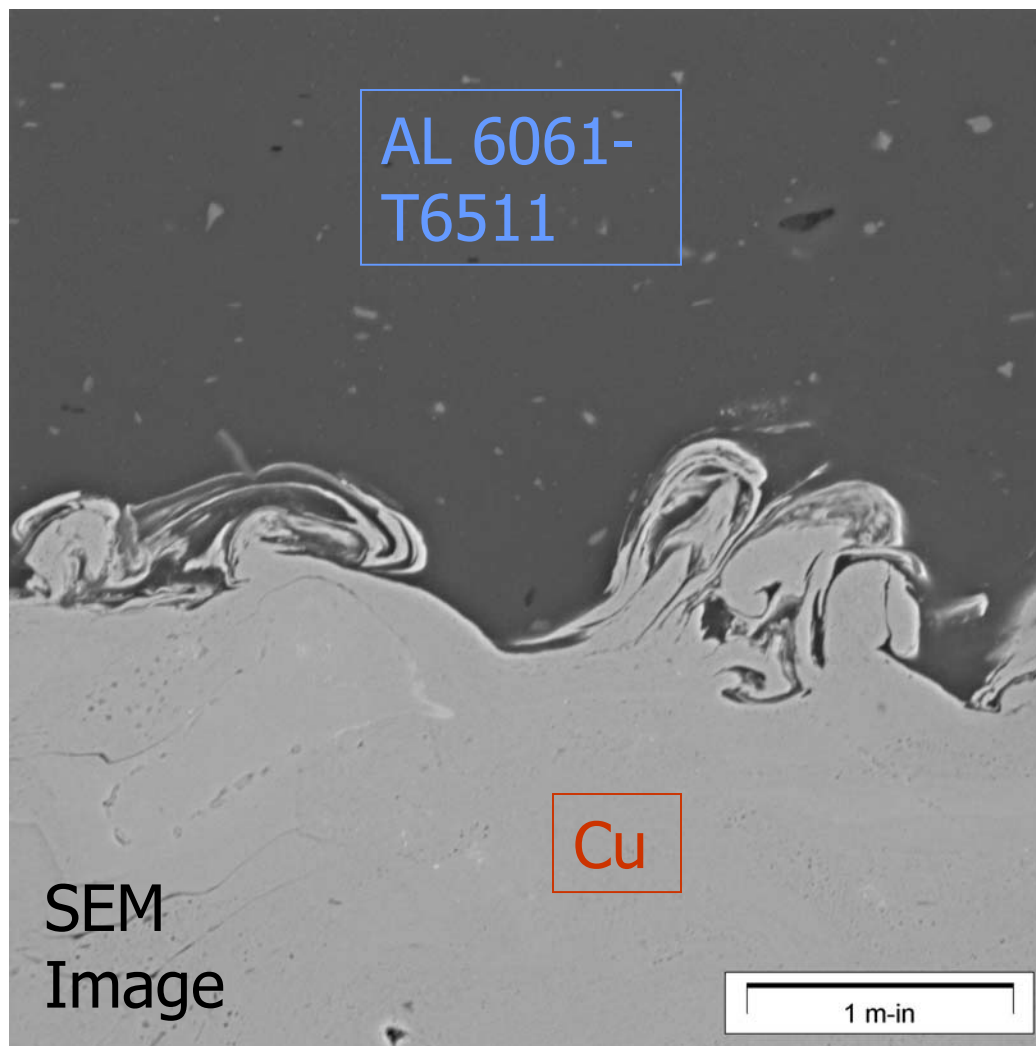
Particle Impact



From Dykhuizen et al, J. Thermal Spray Tech, Dec 1999.

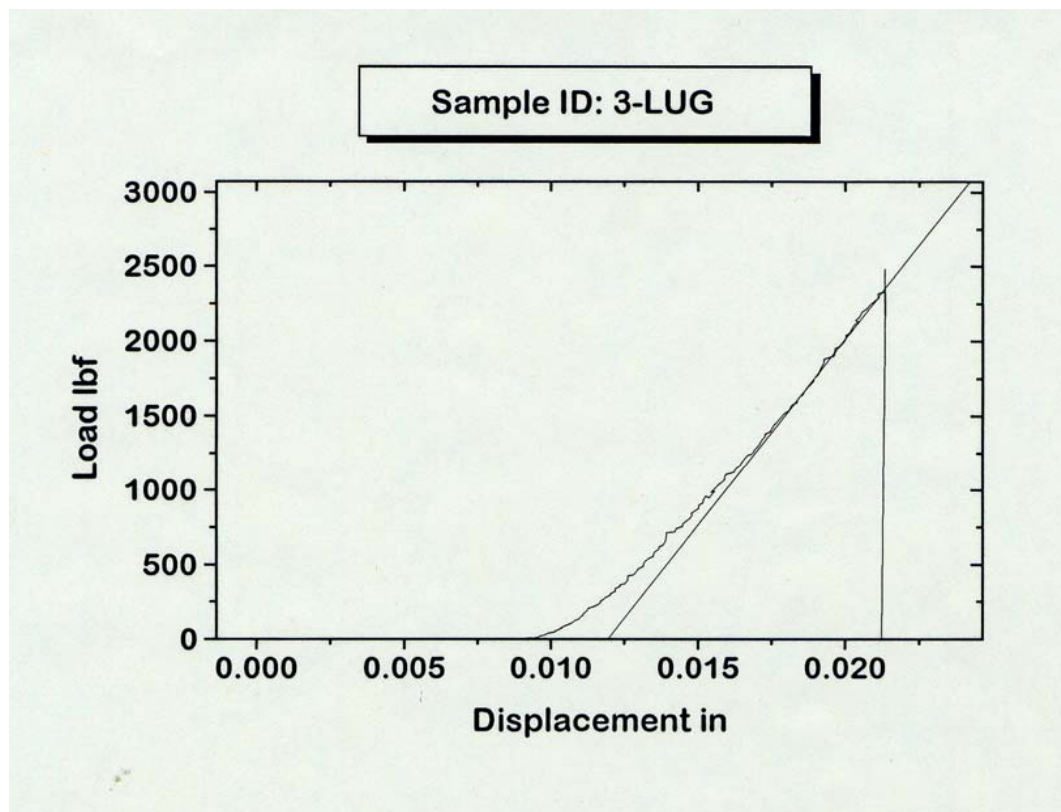


Copper Deposition on Aluminum





Copper on Aluminum



Shear Test Bond Strength = 11,650 psi



Typical Process Parameters

Carrier Gas

Gas Pressure

Temperature

Standoff

Traverse Speed

Powder Size

Powder Feed Rate

Nitrogen

300-400 PSI

400-450 °C

25 mm

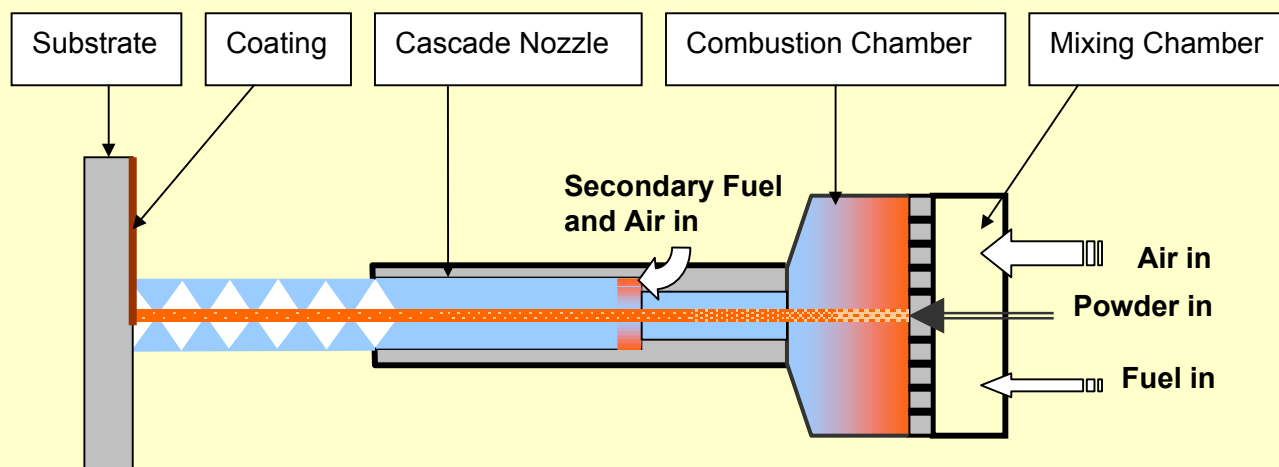
100mm/sec

5-45 microns

20-40 g/min



HVAF Gun Assembly





Benefits of HVAF

- Expands metal, alloy and carbide coating capability while retaining benefits of Cold Spray
 - High Productivity Rate and Increased Coating Thickness
 - Low Porosity, Non-Oxidized Coatings
 - Coatings are essentially free of residual stresses