Liquid Accelerated Cold Spray

CSAT Meeting Presentation 10/30/12

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Phase II SBIR Contract # W911QX-11-C-0002

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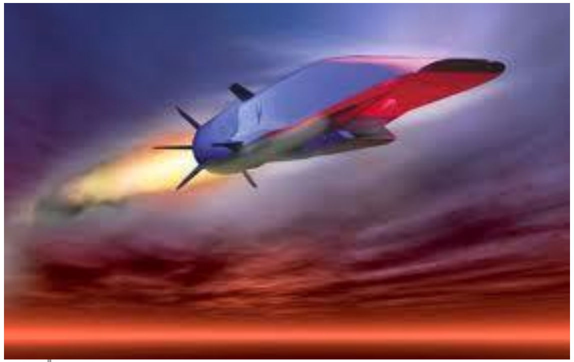
Presentation Summary

- Introduction to Ormond
- Introduction to Liquid Accelerated Cold Spray
- Summary of early work
- Progress since last CSAT
  - Importance of fluid selection
  - Coupons
  - Very high deposition rates at low cost
  - Design of complete system
- Future Work
- Summary

About Ormond

- Ormond engineers have been developing ultra-high pressure waterjet technology for 20+ years
- Peening, Milling, precision cutting, coating removal, machining ceramics
- Developed and implemented waterjet processes for aerospace, nuclear, oil field, food processing, automotive
- Customers include DoD, NASA, Pratt and Whitney, Sikorsky, Boeing, Rolls-Royce, Baker, Bell, Avure, Sandvik, etc.



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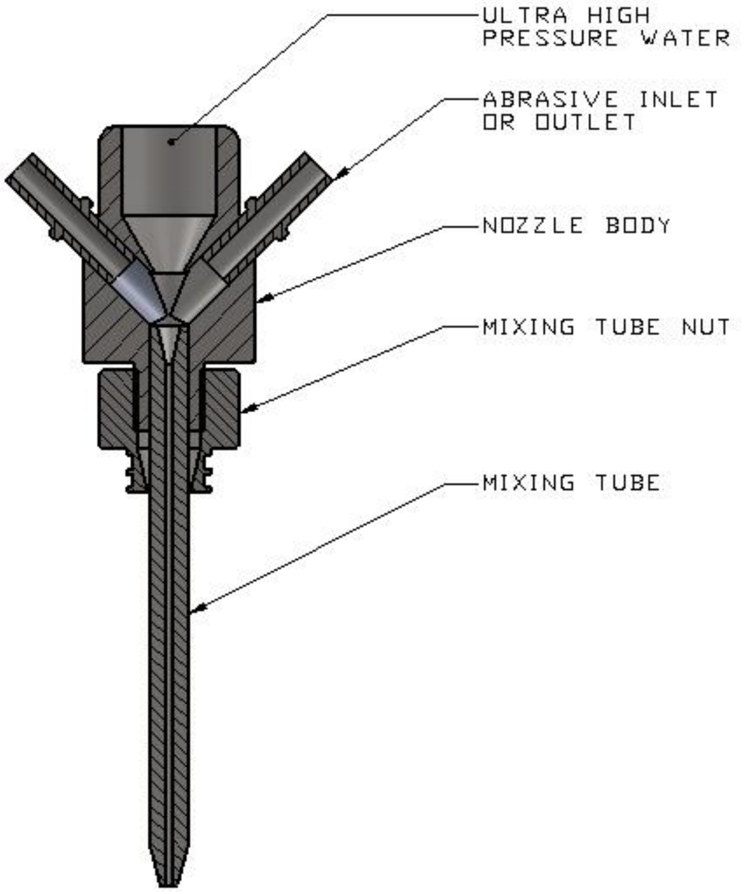
Ultra-high Pressure Waterjet Industry

- 40,000 waterjet shops world wide
- Typically use 60-90,000 psi pumps and multi-axis robots
- Entrain abrasives into fluid jet
- Particle velocities of around 850 m/s
- Particle size typically 180 microns (.007”)
- Particle flow rate up to 1,000 g/min.



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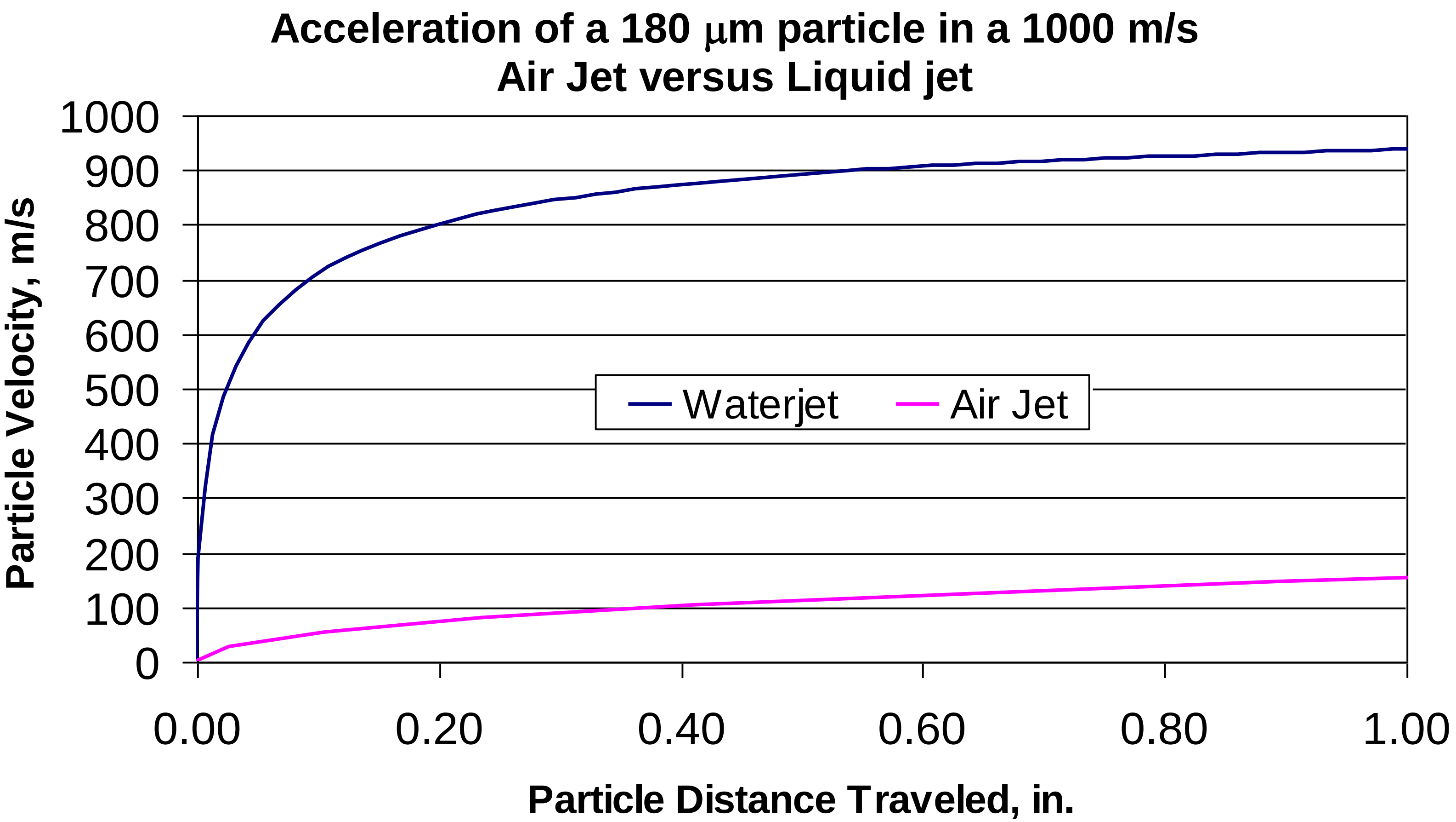
What is Liquid Cold Spray?

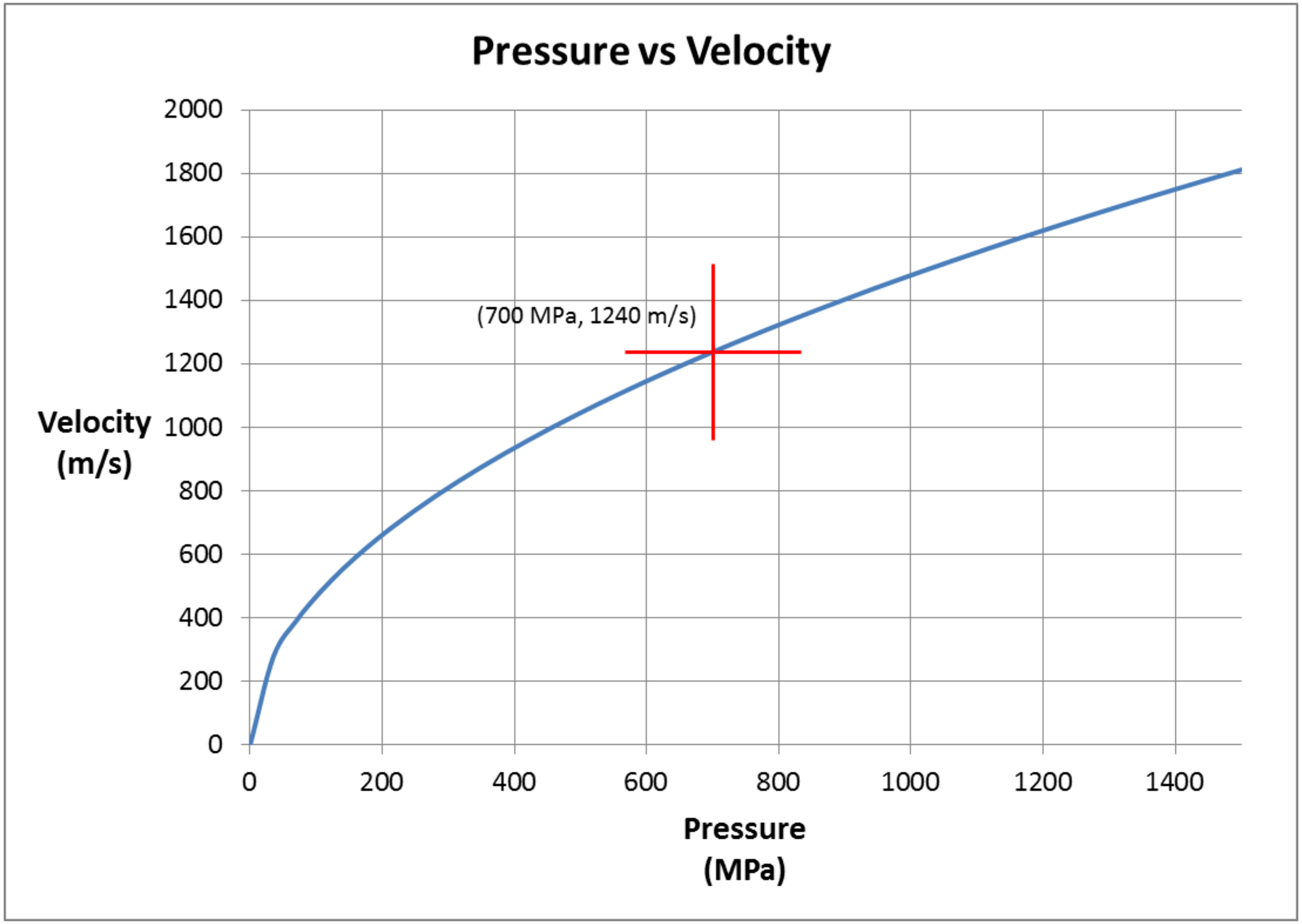
- Liquid accelerated cold spray uses high pressure liquid jets to accelerate ductile powders to high velocities so they can form coatings and build-up parts
- Commercially available pumps and robots can be modified to accomplish cold spray.

Why Liquid not Gas?



Liquids are much more effective at accelerating particles because they are typically 1,000 times denser than gas. Larger, denser particles can be accelerated to higher velocities.

Jet Pressure Versus Velocity



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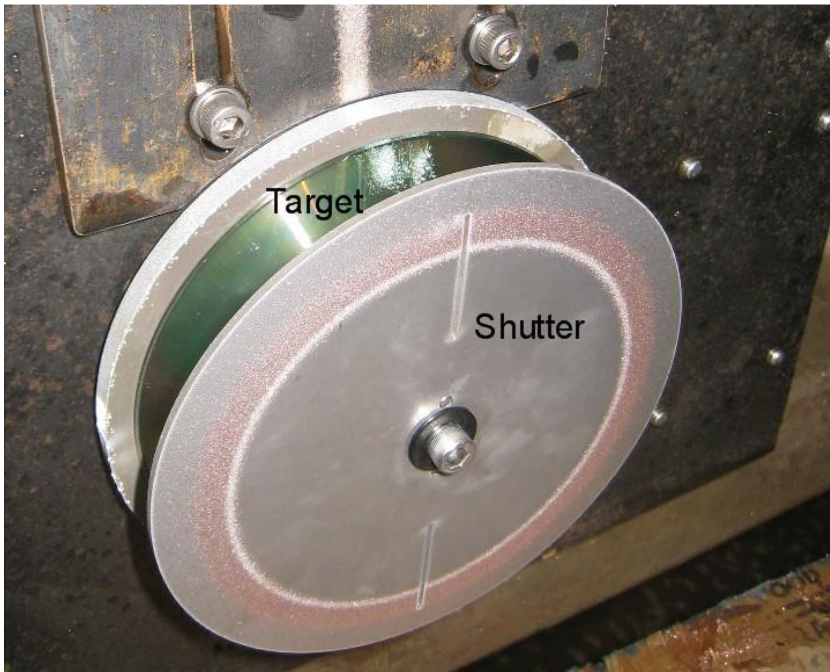
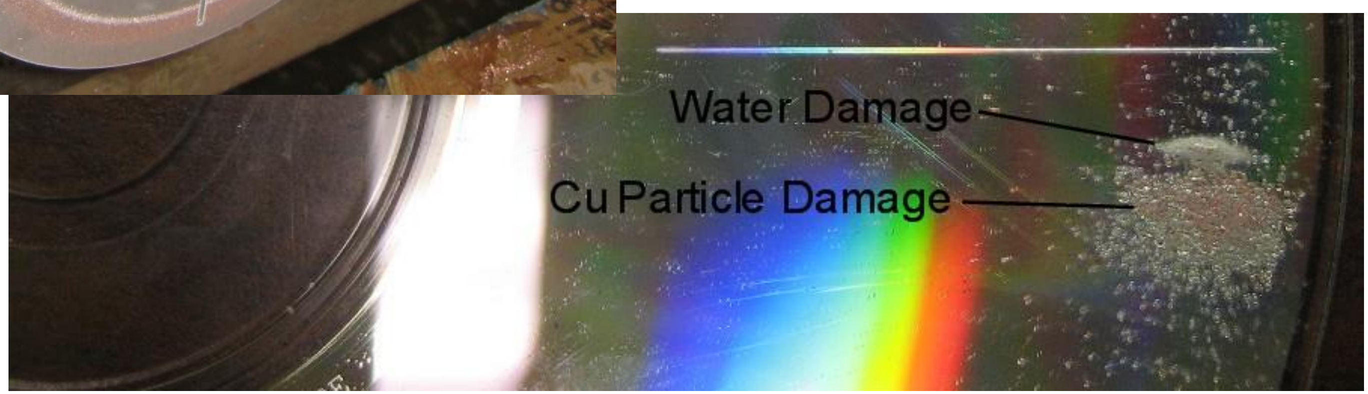
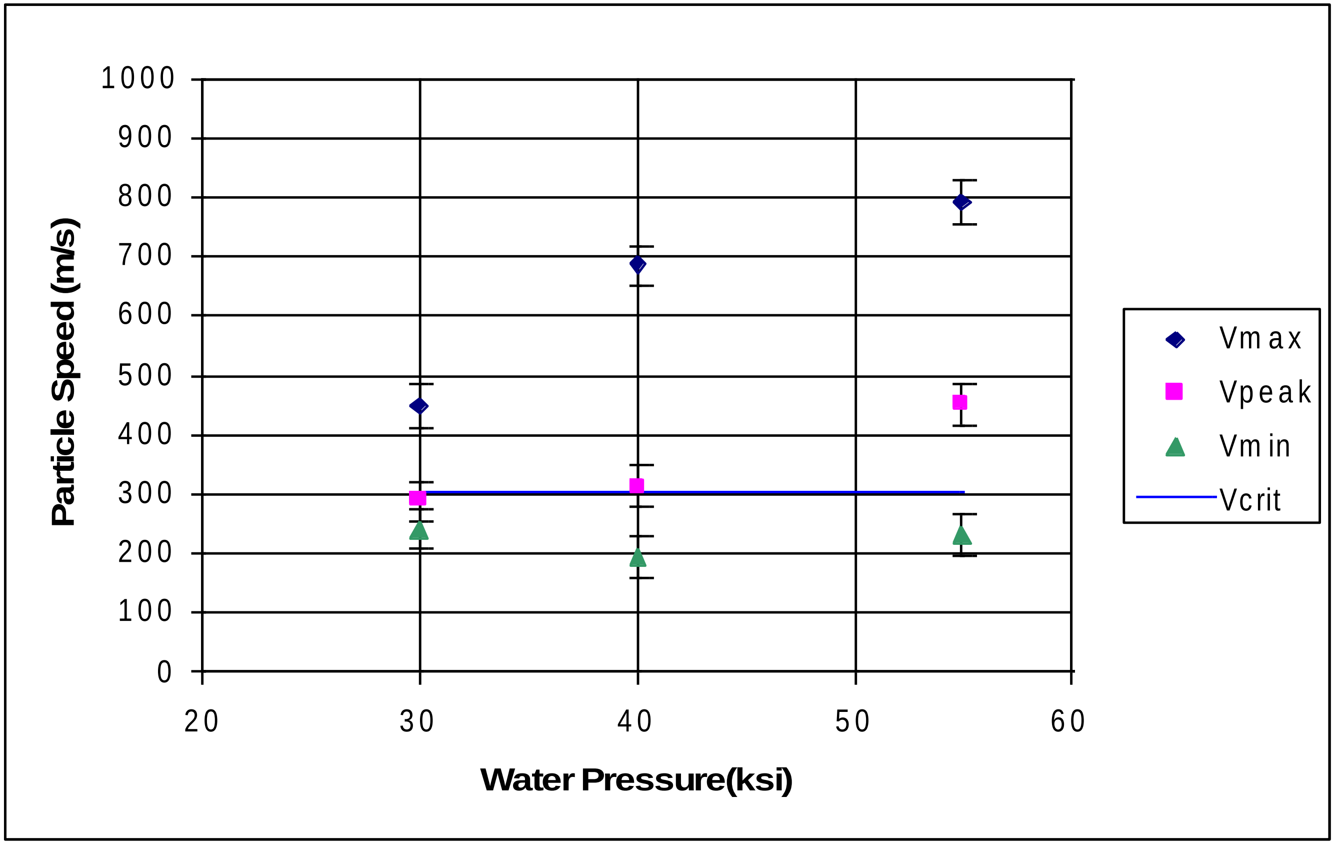
Particle velocity

- Measured particle velocity with spinning disks



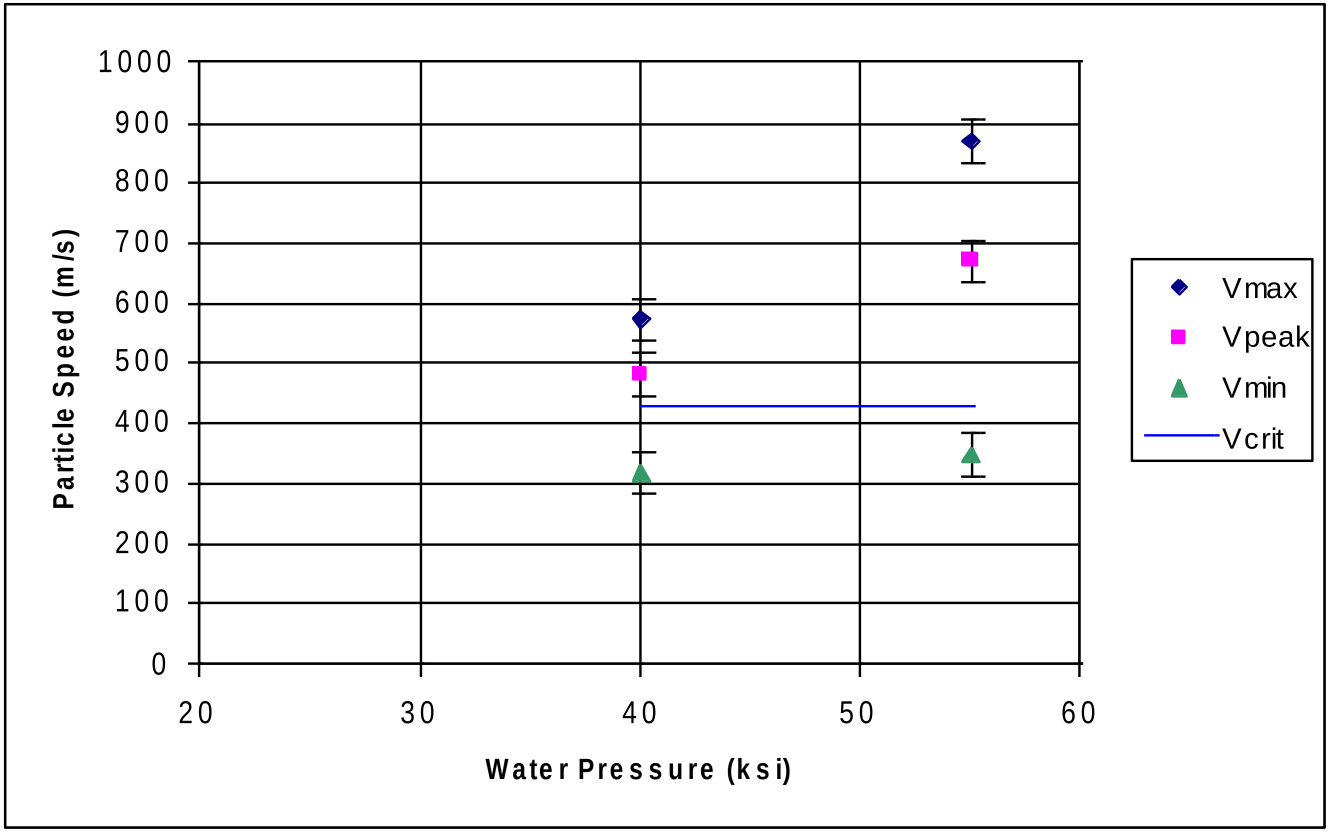


Pressure vs Particle Velocity



Particles 300 micron copper

Pressure vs Particle Velocity



Particles 180 micron copper

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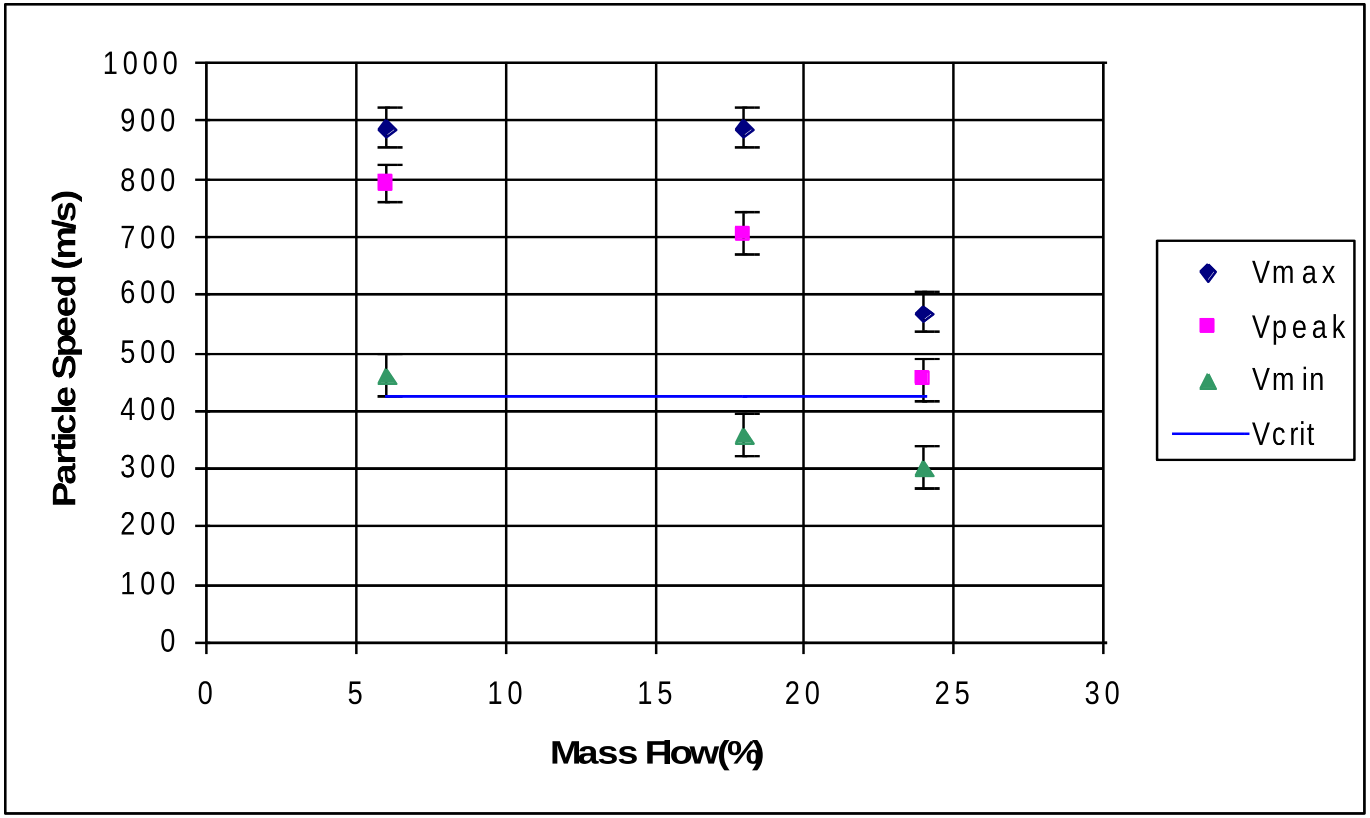
Potential for high deposition



18% mass flow of powder means 1.5 lbs per minute!

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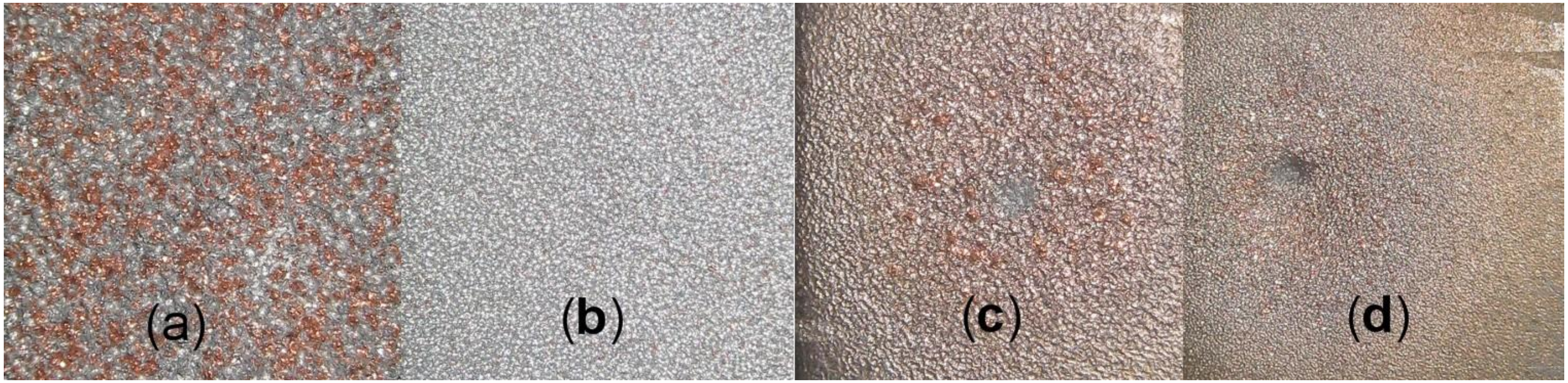
Water -Coupon testing poor deposition



a) Al- large particles, b) Al-small particles, c) Steel-large particles, d) Steel-small particles - all copper particles

Water is problem fluid

- Water is simple, cheap and safe working fluid.....
- ...but it interferes with the coating deposition
- Even a 0.0001" layer of water around a particle is enough to absorb the impact energy as it flashes to steam
- Attempts to draw off the water were 99%+ successful - but not good enough

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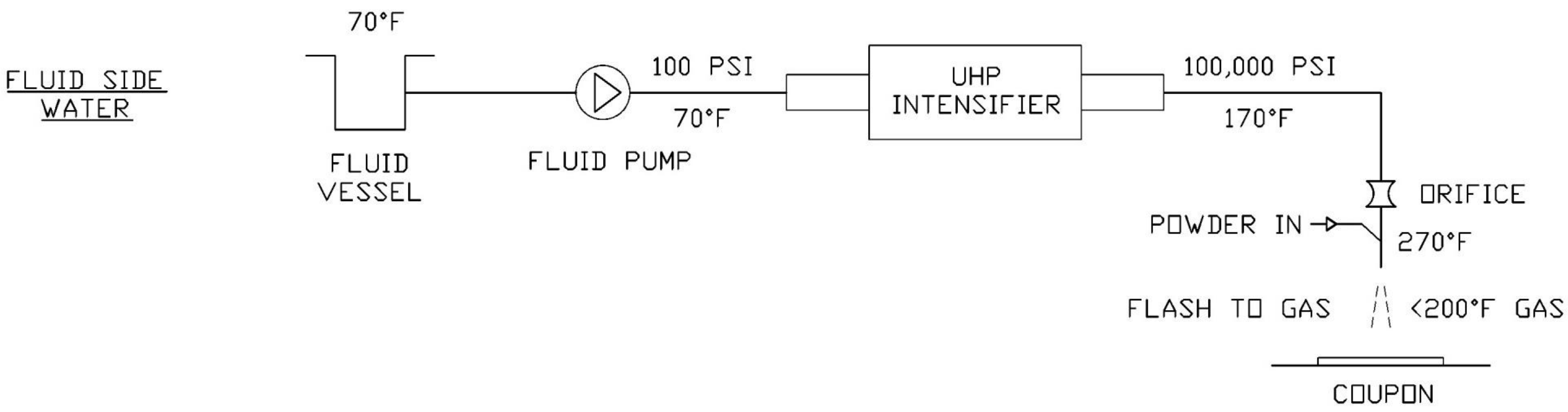
Water-Steam Temperature



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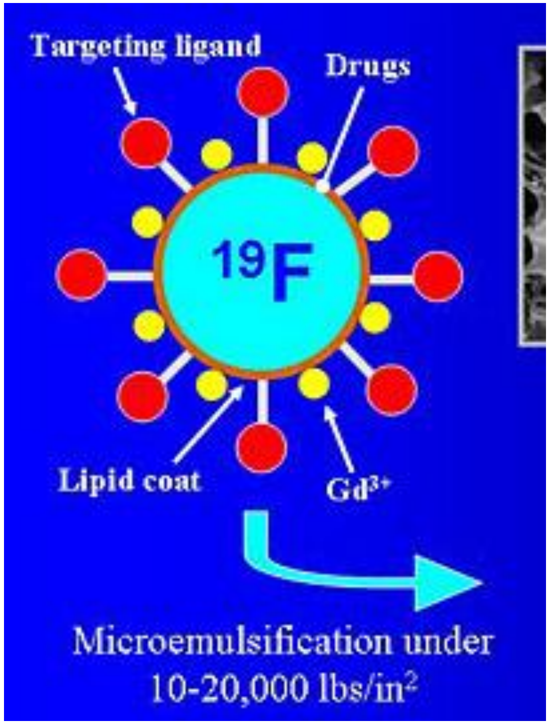
Fluid Requirements

- Safe at high temperatures and pressures
- Environmentally benign
- Can be pressurized without solidifying
- Reasonable cost
- Low latent heat of vaporization
- Non-reactive with powders, pumps and seals
- Low specific heat capacity
- Can be recycled in closed loop

Alternate Fluid

- Fluorocarbons have very low latent heat of vaporization – easily flash to gas after exiting nozzle without cooling particle/substrate interface
- High volume gas high speed could be used to further accelerate the particles



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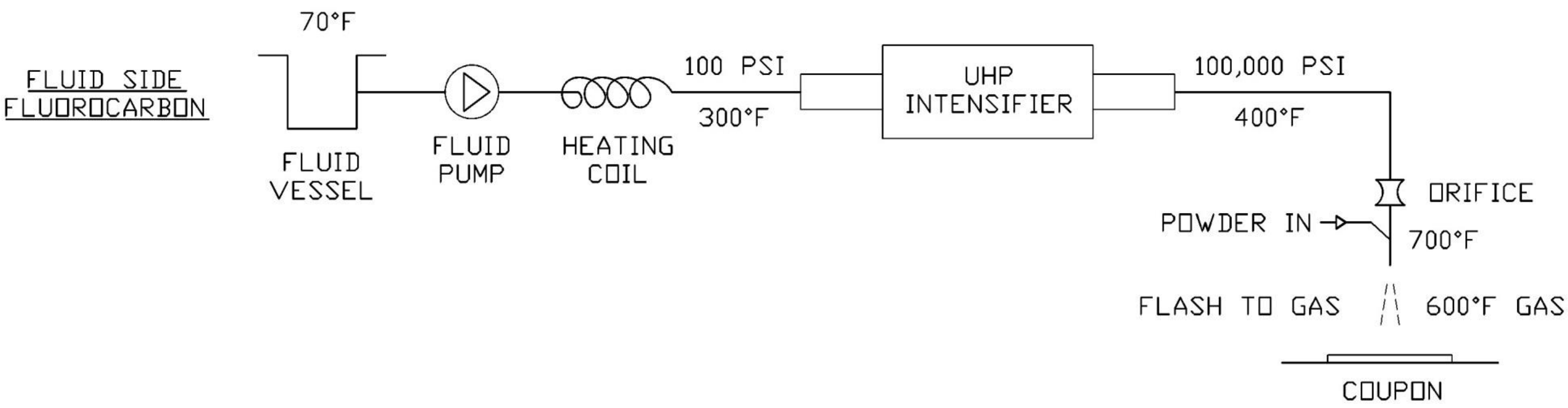
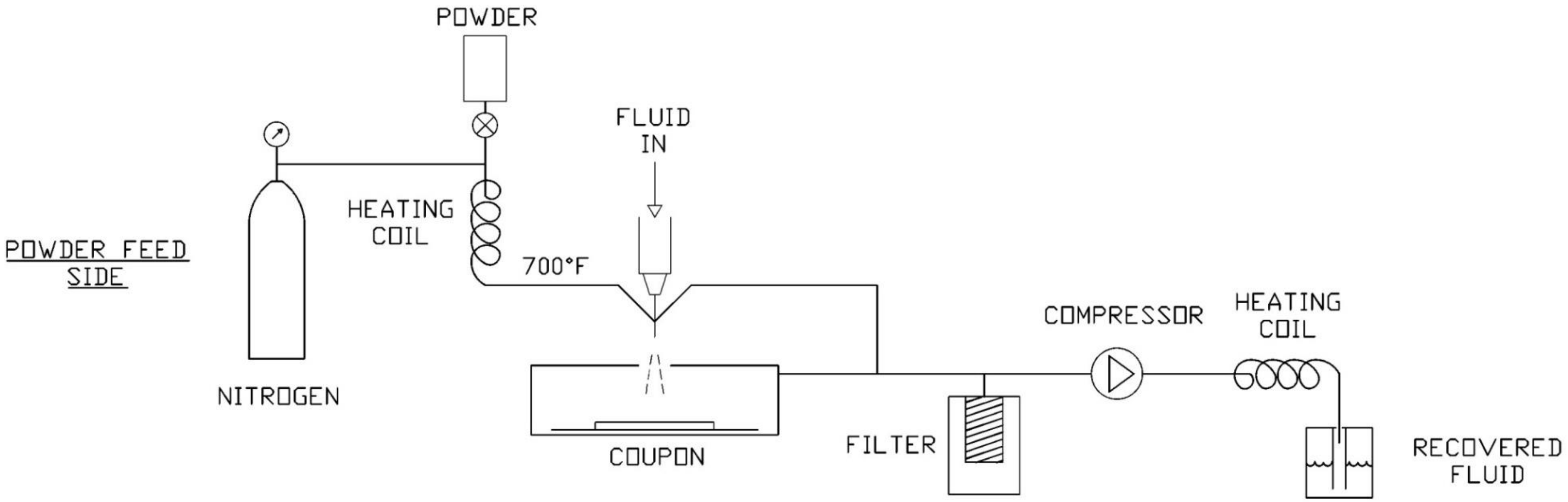
Heated Fluorocarbon as work fluid



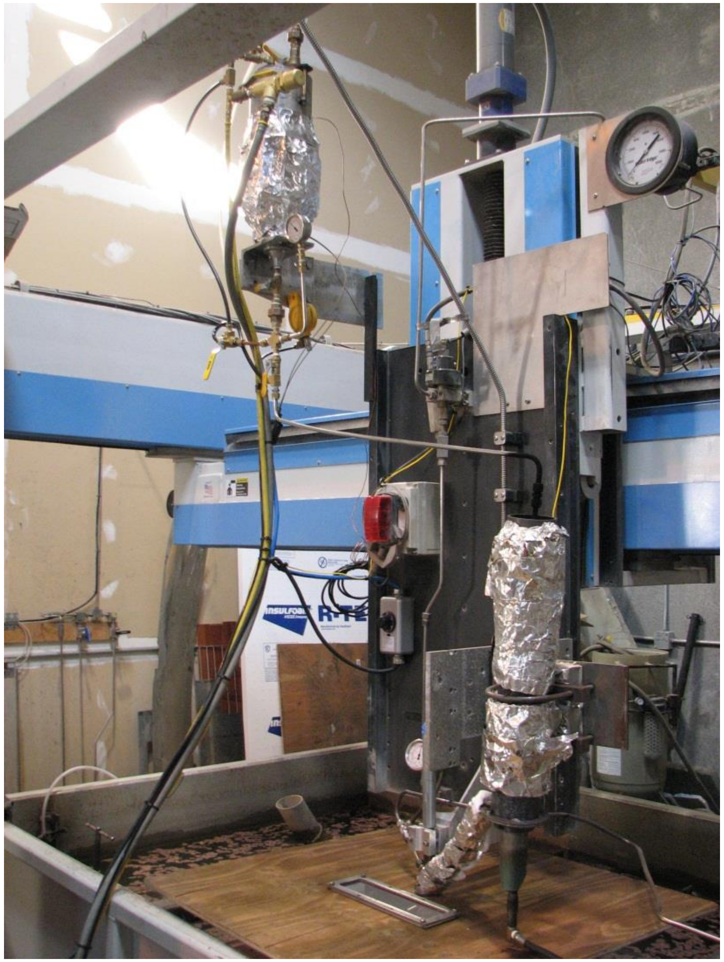
Powder path and fluid recovery



100,000 psi Test Setup

Recent Progress

- Direct pumping of fluorocarbons at 100,000+ psi.
- Fluid velocity at 1,200 m/s, median particle velocity of 800 m/s
- Nozzle mounted on 3-axis robot
- Have deposited copper, aluminum and titanium (Ti-6-4).



Thick Deposits at high speed

- High rate deposition of metallic powders
- So far, deposited copper, Aluminum and Titanium Ti-6-4
- Larger powders are easier and faster to deposit 250 g/min
- Smaller powders result in denser deposits 120 g/min

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Large plates built up quickly

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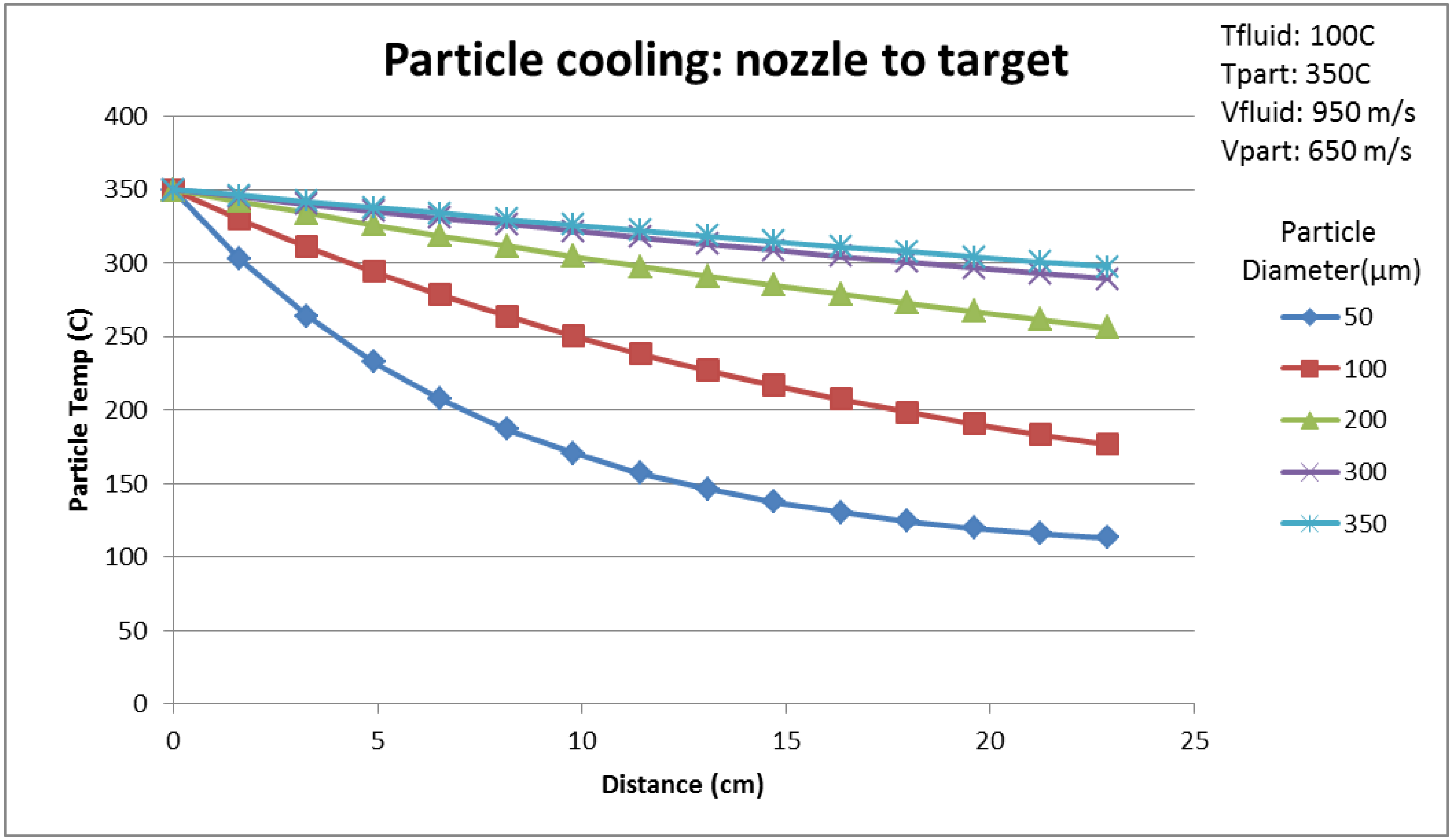
Cooling of particles by liquid



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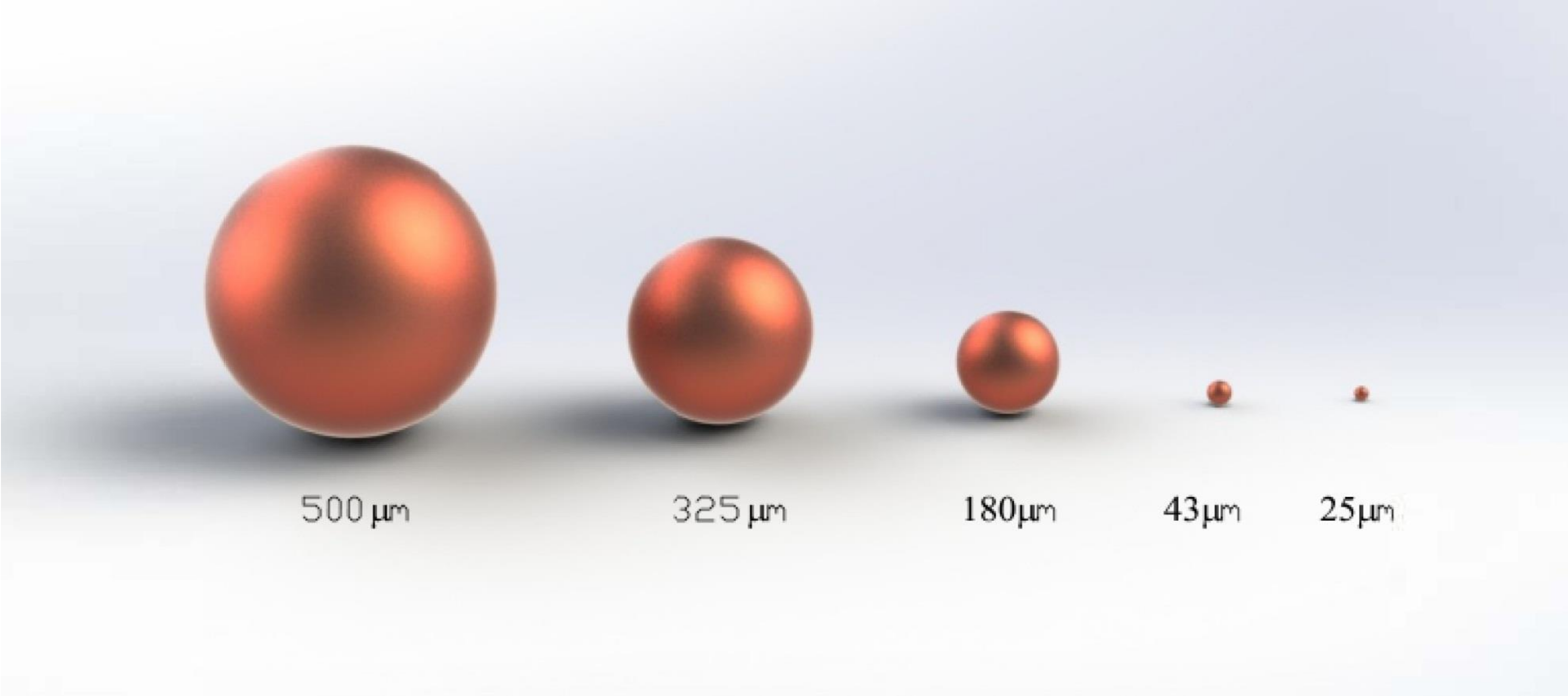
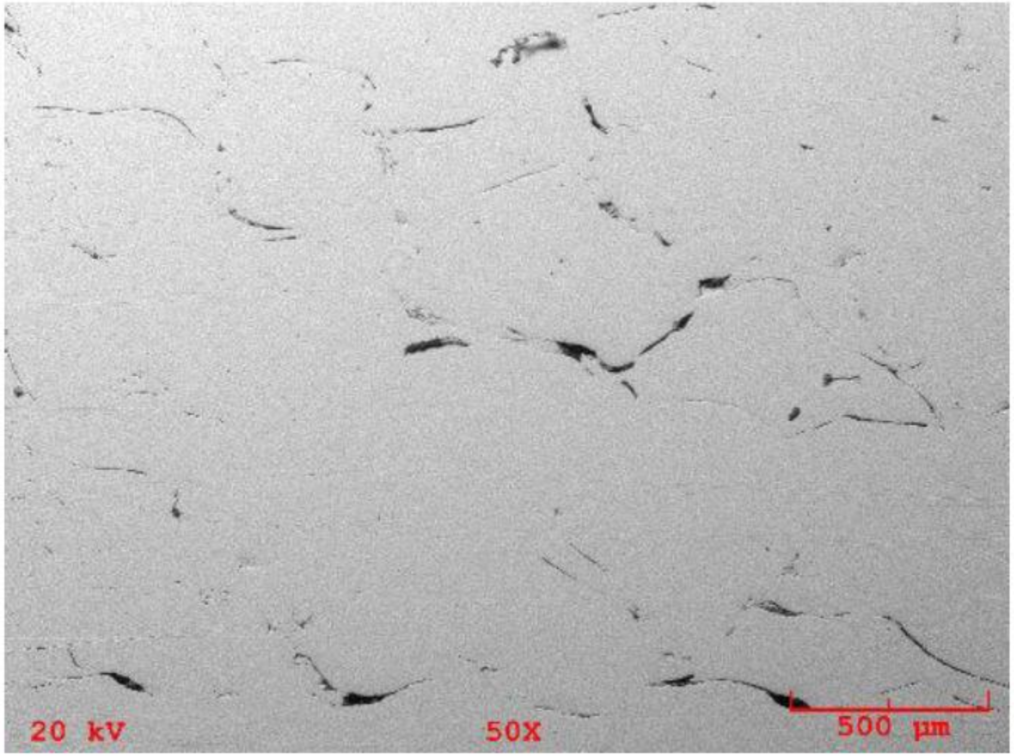
Particle size comparison

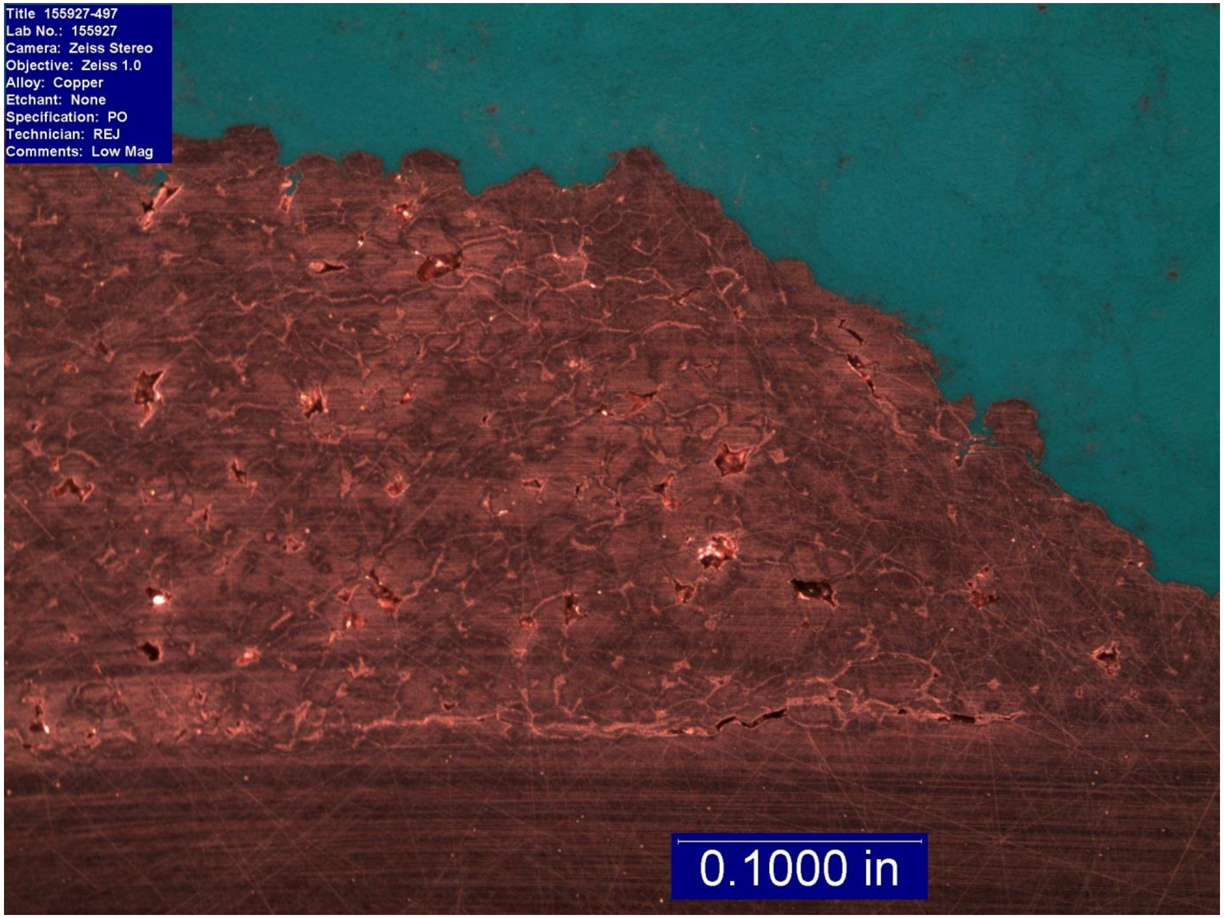


SEM of 325 micron copper



Estimated 3% Porosity, incomplete bonding

Optical view of 325 micron copper



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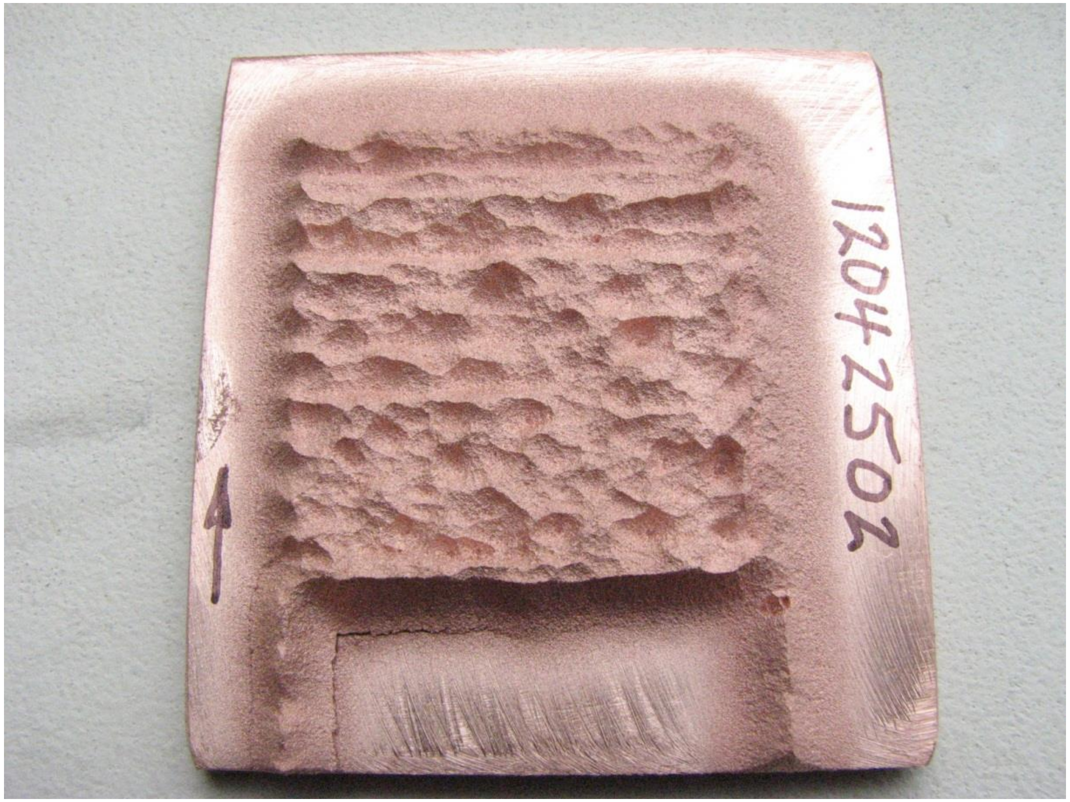
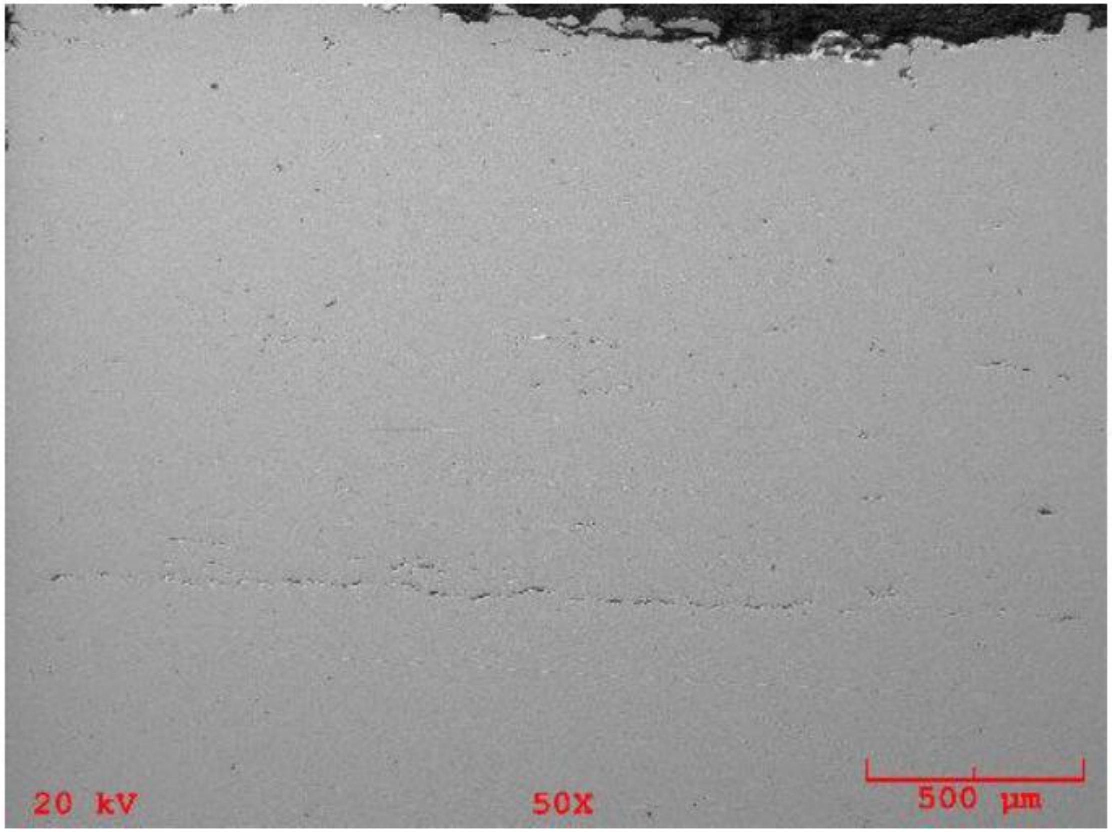
43 micron copper much denser

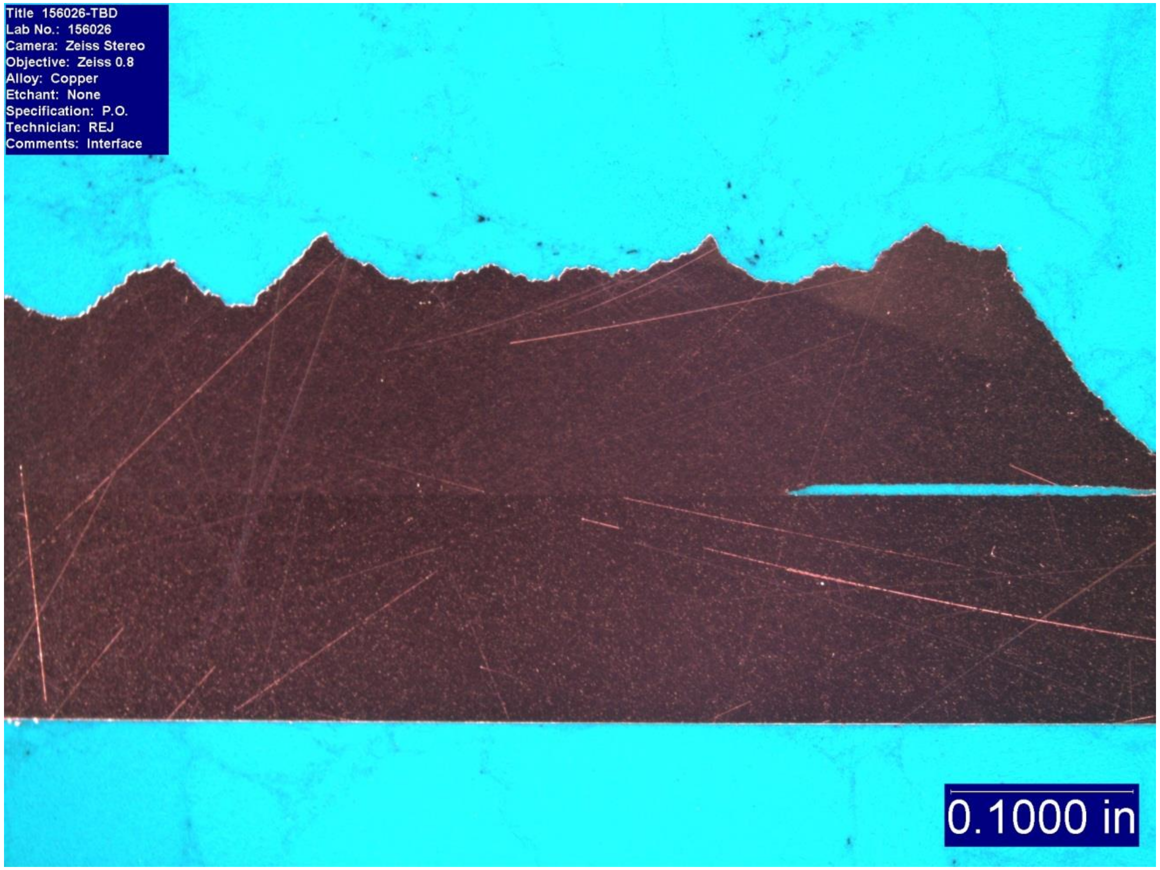


SEM of 43 micron copper



Estimated 0.16% Porosity

Optical view of 43 micron copper



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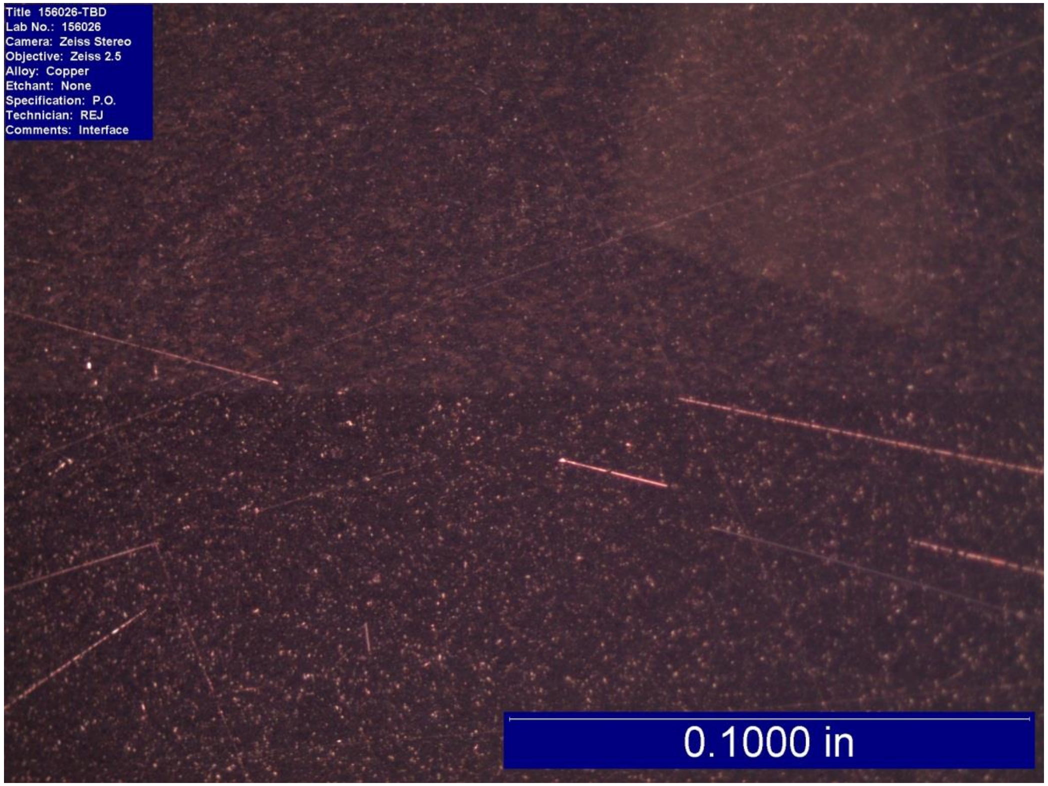
Optical close-up of copper-copper joint – 100% dense



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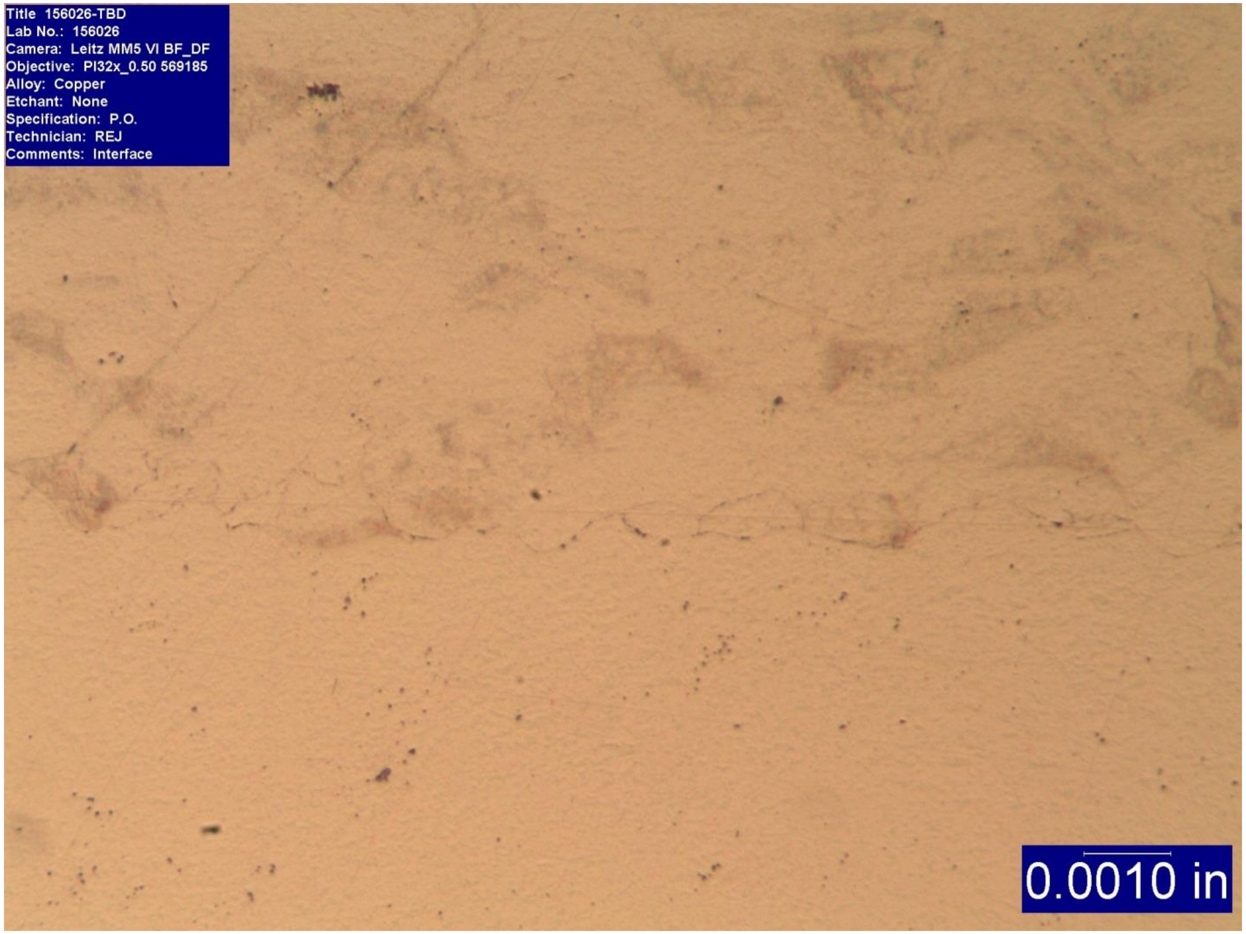
Optical close-up of fine copper joint



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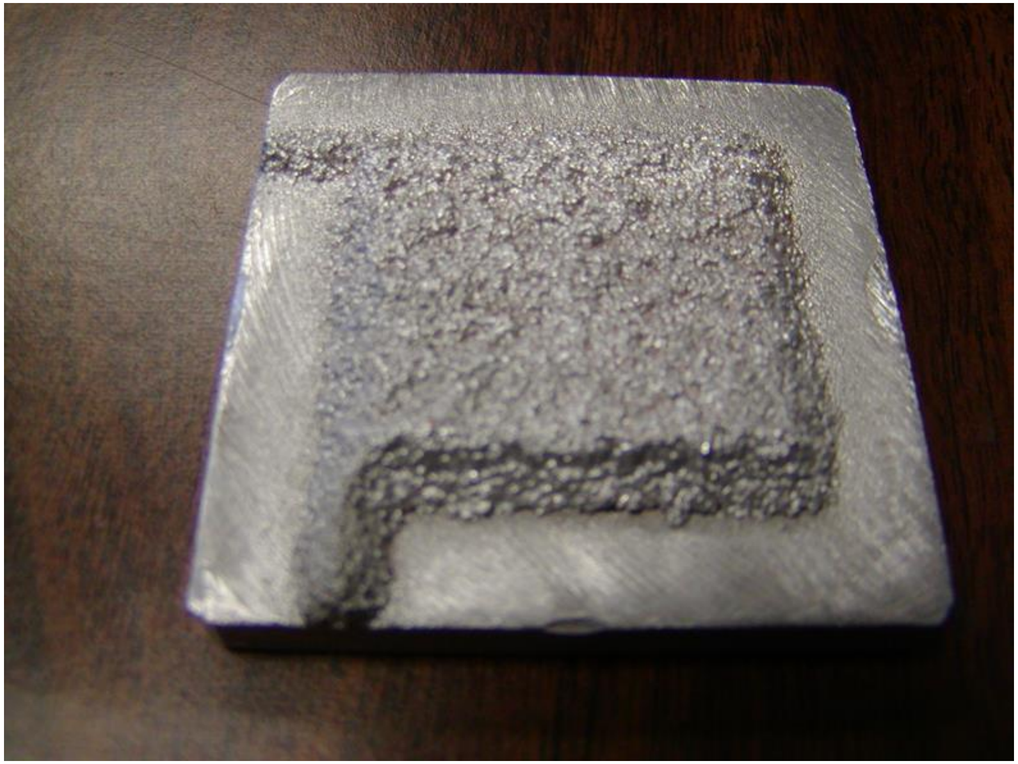
V43 Pure Aluminum



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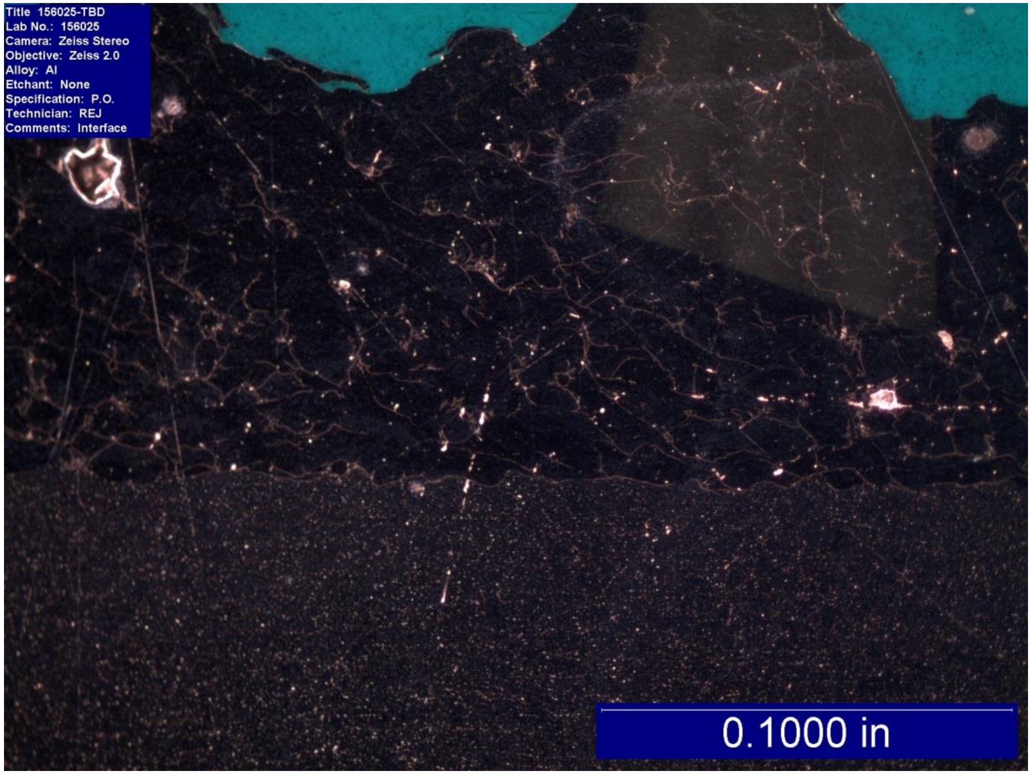
Optical view of Aluminum



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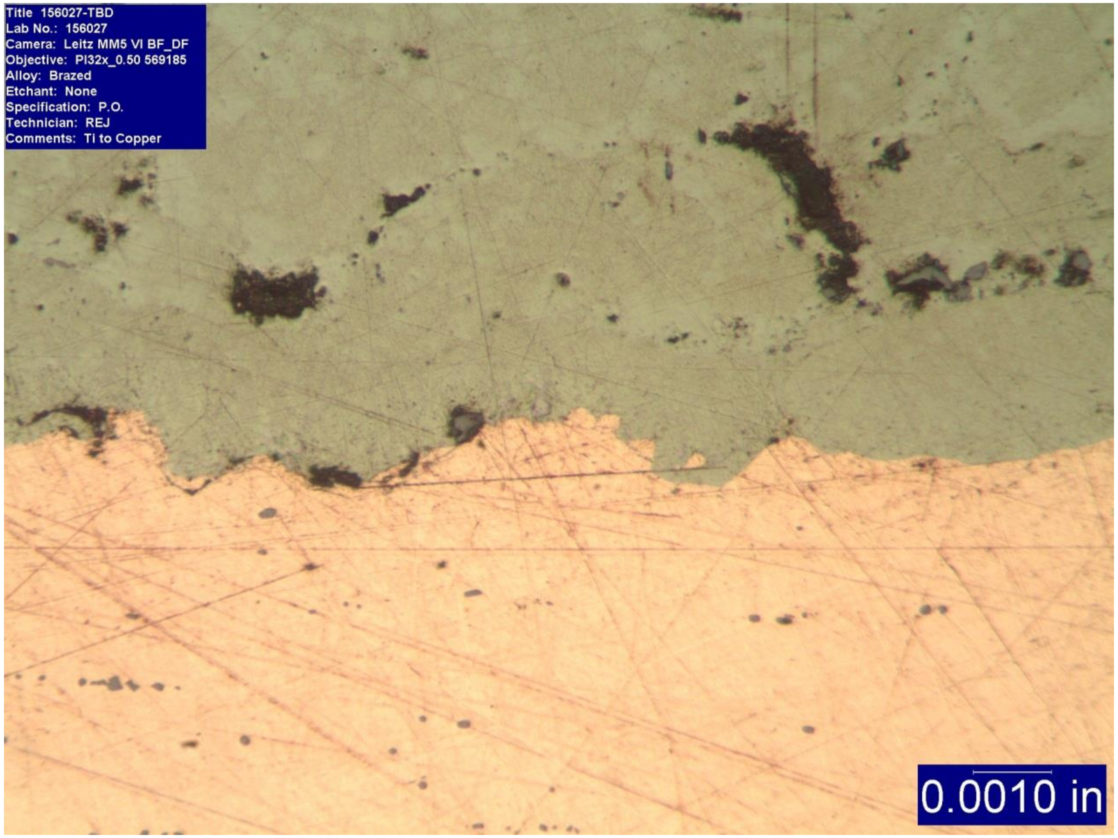
Optical view of Ti-6-4 deposit



Large titanium on copper substrate

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Potential for low cost

- Liquid cold spray has potential to be low cost deposition process
- Deposition rates as high as 250 g/min for 325 micron powder, 120 g/min for 43 micron powder
- Power requirements of 5 kW for fluid, 5 kW for heating powder, gas and fluid
- 75% of fluid is recovered in current setup
- Wide range of powder sizes and types can be deposited
- Particle speeds greater than 1,000 m/s are possible

Issues

- Technology is still at coupon level (TRL 4)
- Equipment is R&D level – not robust
- Need to improve particle feed and heating

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Future Plans

- Address coating density by increasing particle temperature
- Redesign heater and nozzle to handle small (<50 micron) particles
- Characterize aluminum and Titanium deposits

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Summary

- Liquid cold spray is a promising low cost, high deposition rate coating method.
- Copper, aluminum and titanium have all be successfully deposited
- Technology readiness is still at coupon level
- Improvements needed to for large particle deposition
- Small particle deposition fully dense