Influence of laser heating on adhesion and coating properties in Laser Assisted Cold Spray

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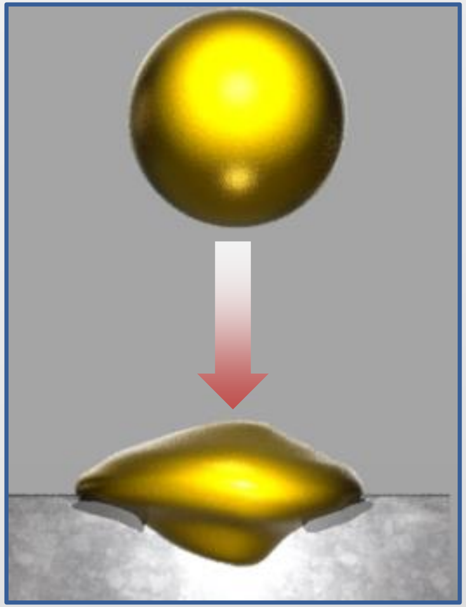
Substrate temperature in cold spray

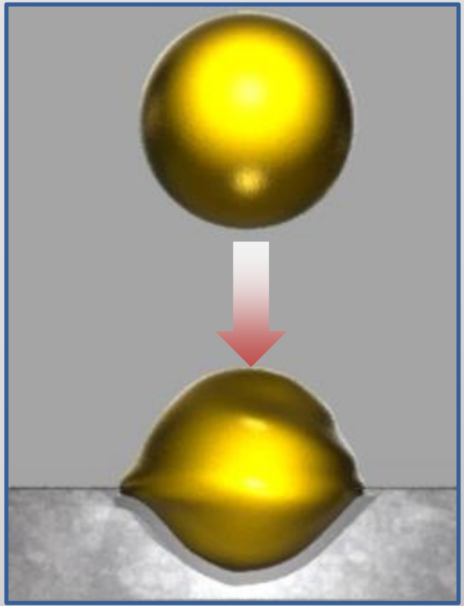
Increased substrate temperature improves deposition



Cold substrate

Increased substrate deformation
Increased flash zone
Increased extent of bond

Higher rates
Better bonding

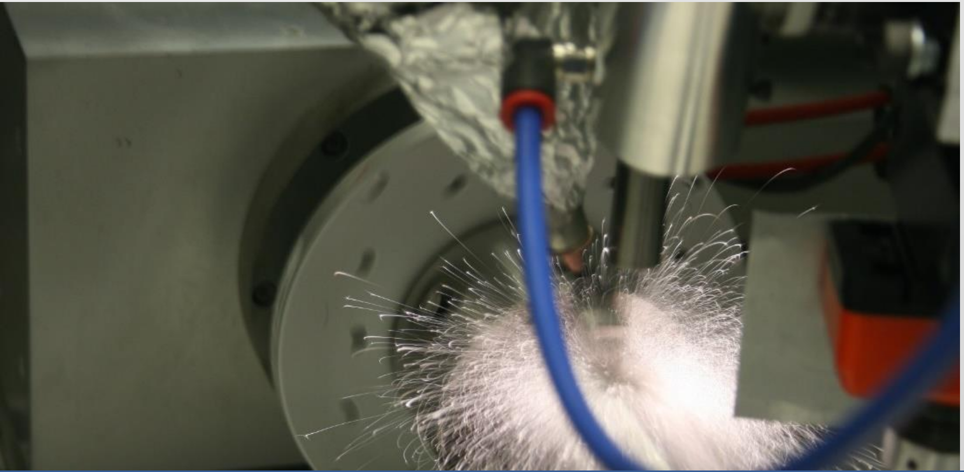


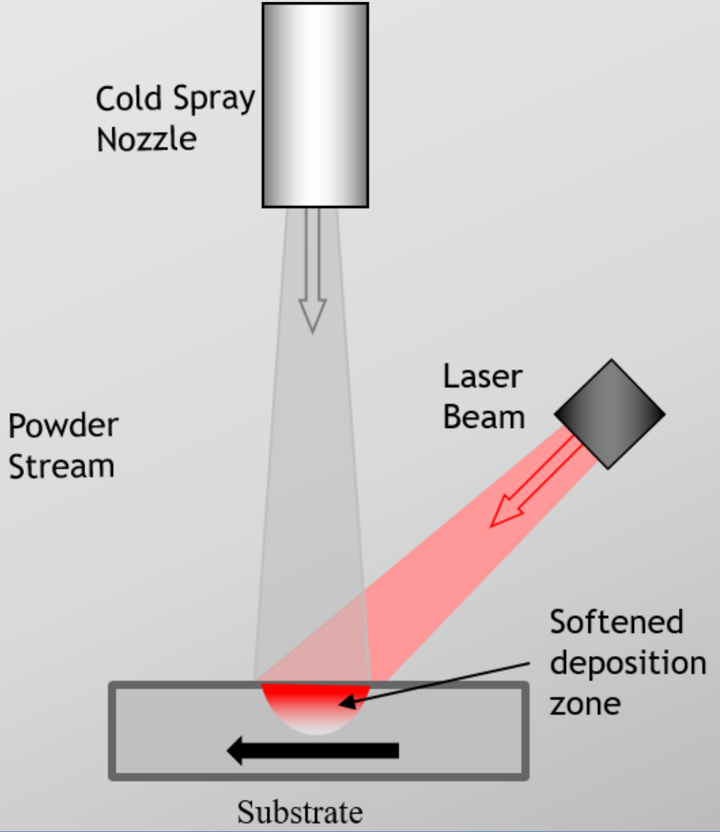
Heated substrate

Laser Assisted Cold Spray (LACS)

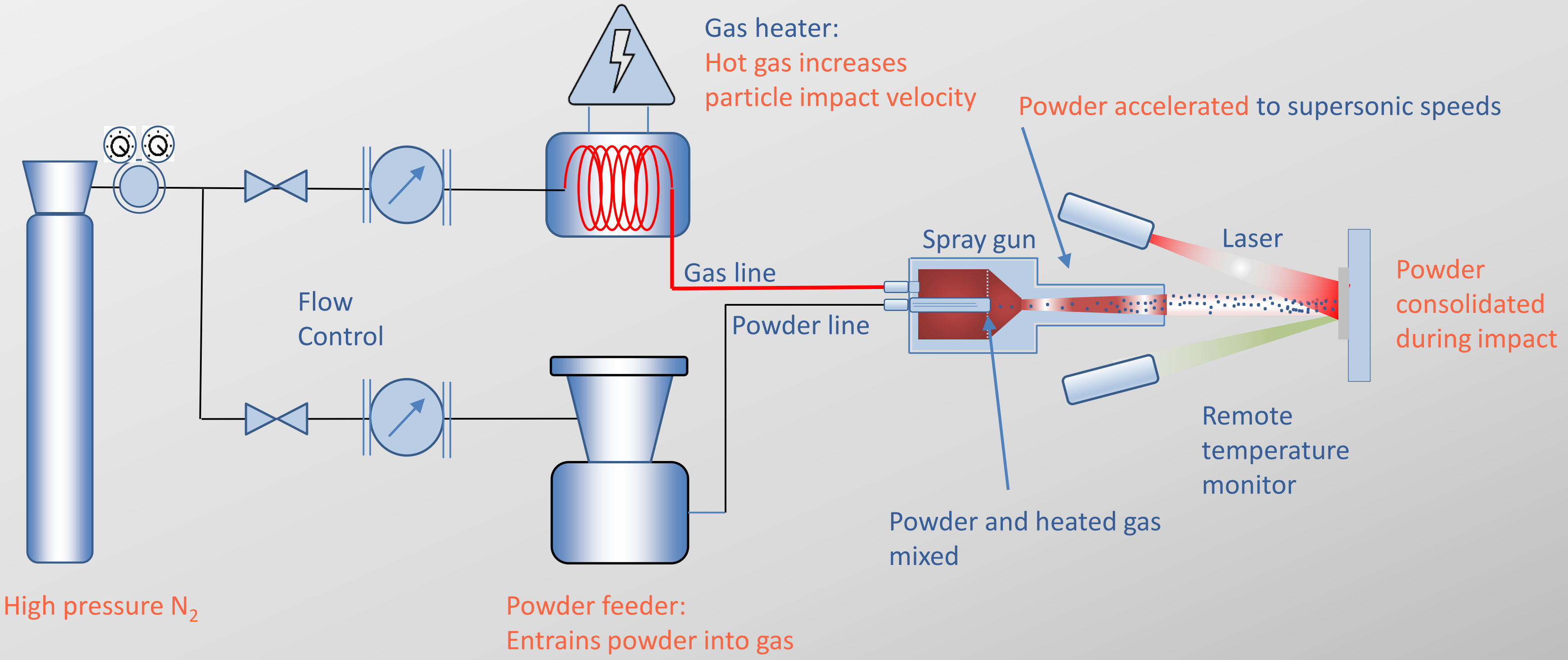
Laser heating softens the deposition site

- Increased deformation and bonding
- Deposition at reduced particle velocity
- Bulk substrate heating avoided
- Better coatings and wider range of materials
- Few materials need helium



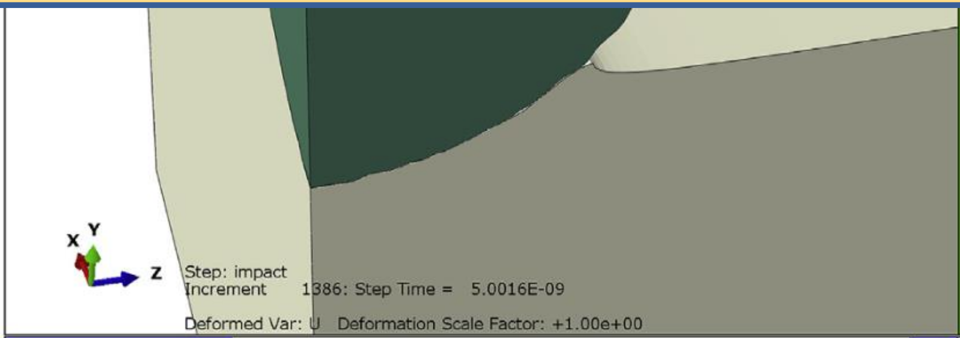


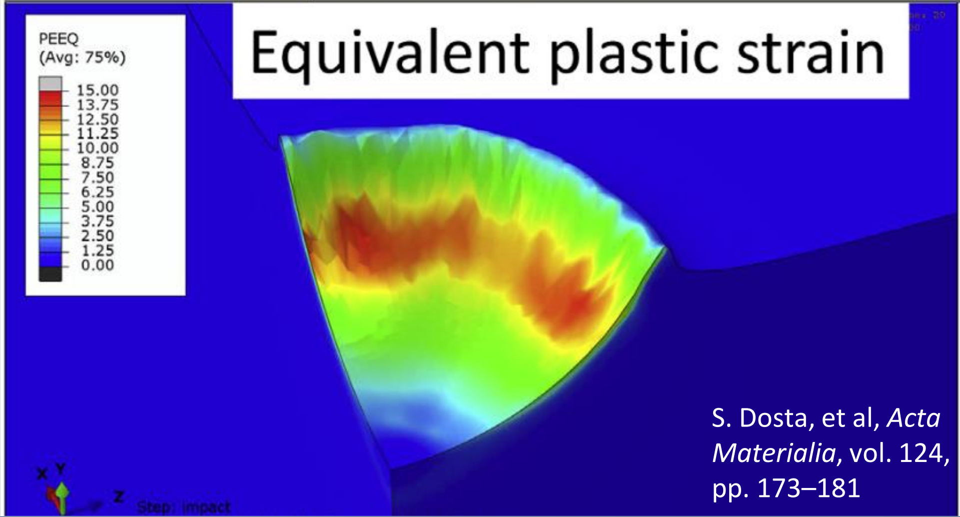
LACS Deposition System



How far do we need to heat?

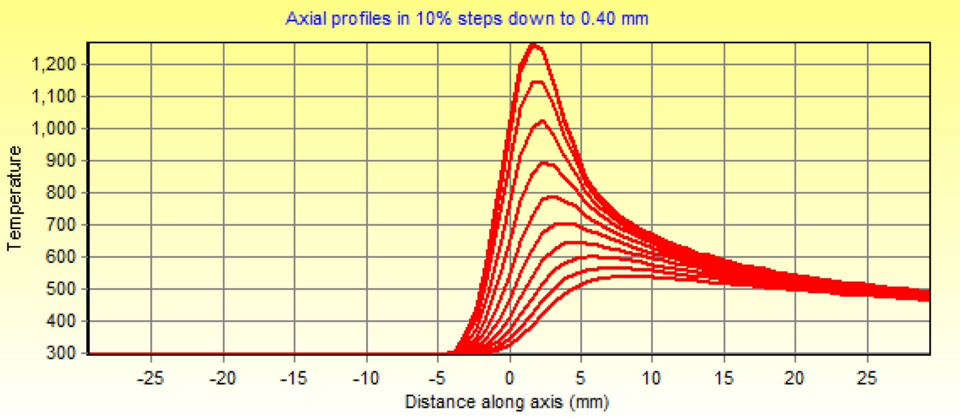
- There are competing requirements from laser heating of the substrate surface
  - Increase temperature in the region of the substrate which deforms during deposition.
  - Avoid overheating substrate to prevent unwanted phase changes and/or overaging.
- Unlike the plastic zone beneath a spherical indenter, the plastic zone beneath a cold sprayed particle is of the order of a few μm beneath the impacting particle.
- In LACS temperature distribution in the top 20-40 μm of the substrate will influence deposition and adhesion.





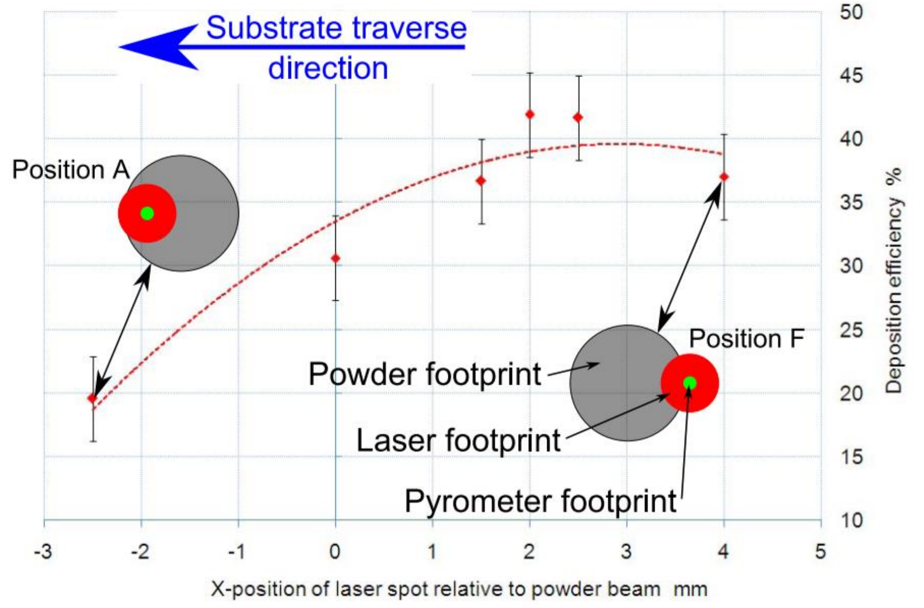
S. Dosta, et al, *Acta Materialia*, vol. 124, pp. 173–181

The influence of laser position

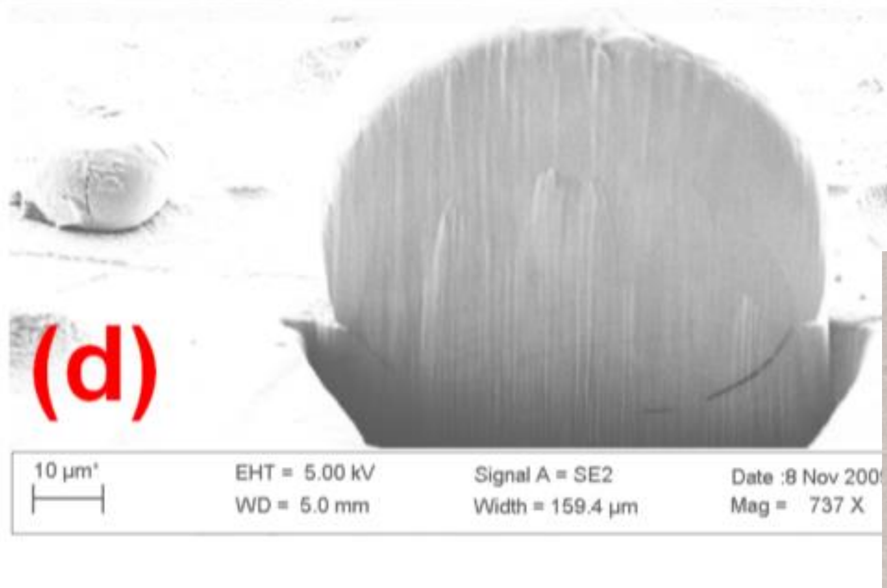


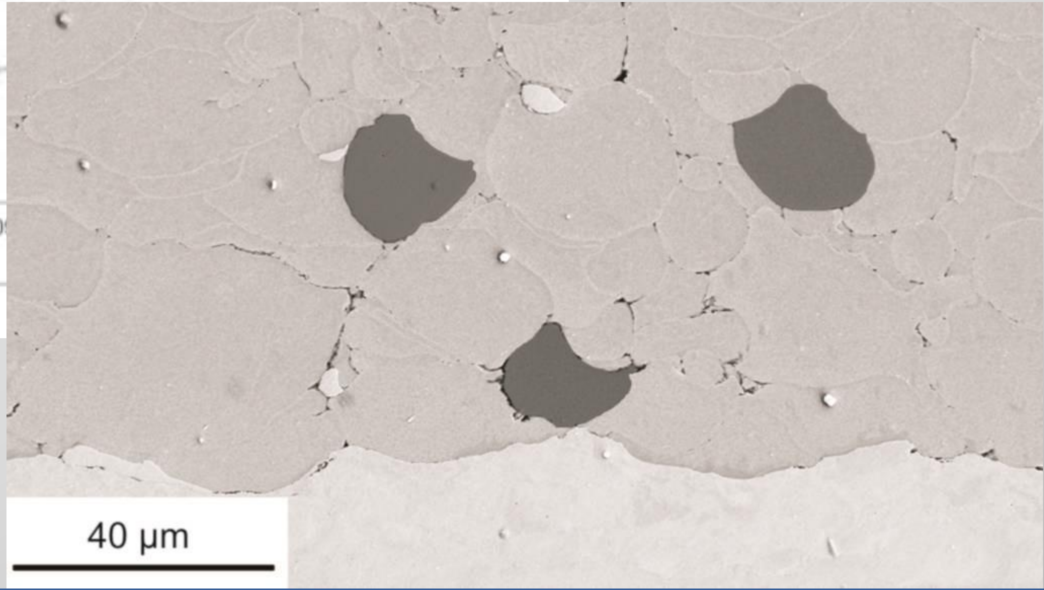
- Peak temperature at a given depth moves back as depth increases.
- The heat input should lead the powder footprint.

- Laser spot leading has been shown to increase deposition efficiency.



Influence on particle impact



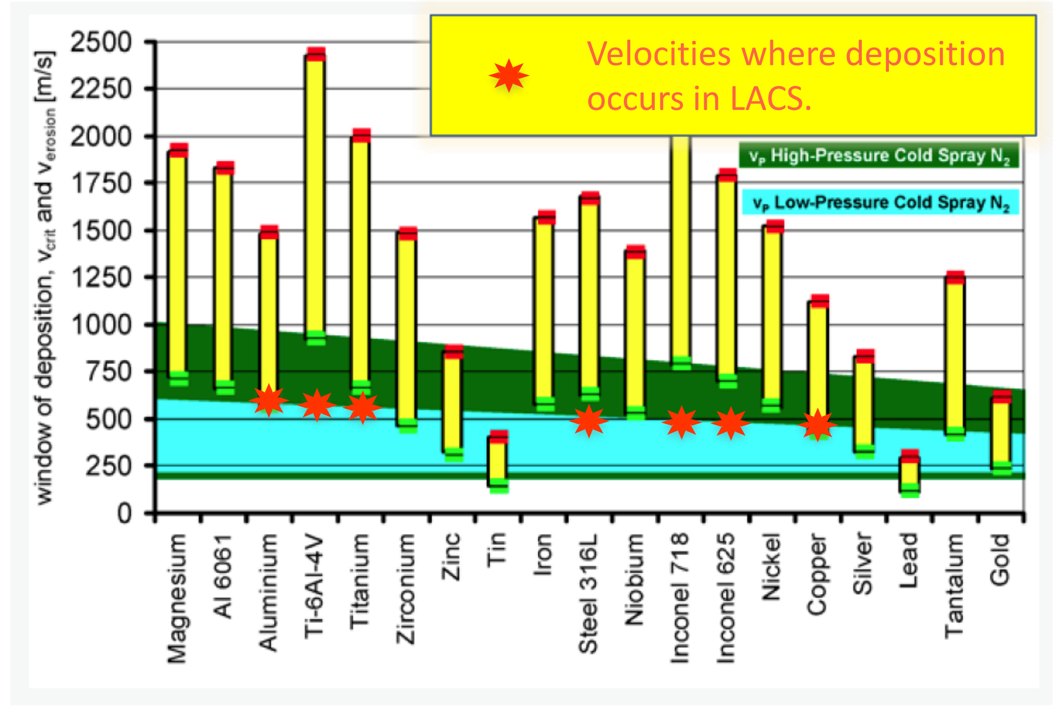


Critical Impact Velocities:

Effect of laser in LACS

- Deposition velocities for various materials are well established for CS.
- With the addition of laser heating, LACS has demonstrated deposition at velocities below the cold spray deposition window for many metals.

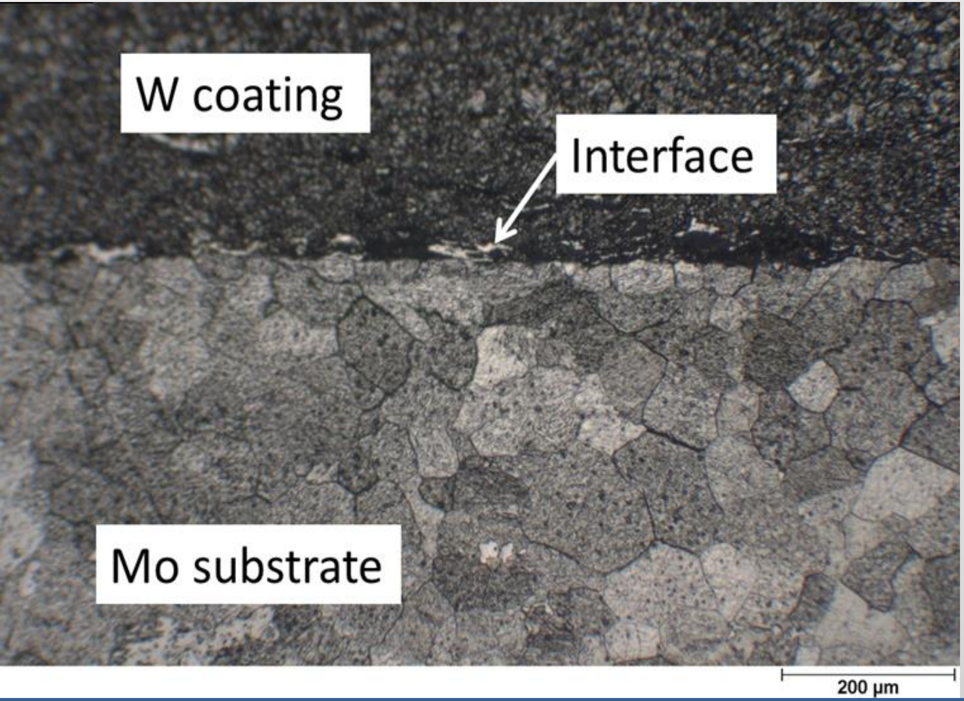
Velocity windows for deposition in CS.



T. Schmidt, F. Gärtner, H. Assadi, and H. Kreye: Development of a Generalized Parameter Window for Cold Spray Deposition, *Acta Mater. 54, 2006, p 729-742.*

LACS example: Tungsten

Tungsten's high melting point makes Laser cladding difficult.
High DBTT inhibits Cold Spray LACS enables coating formation

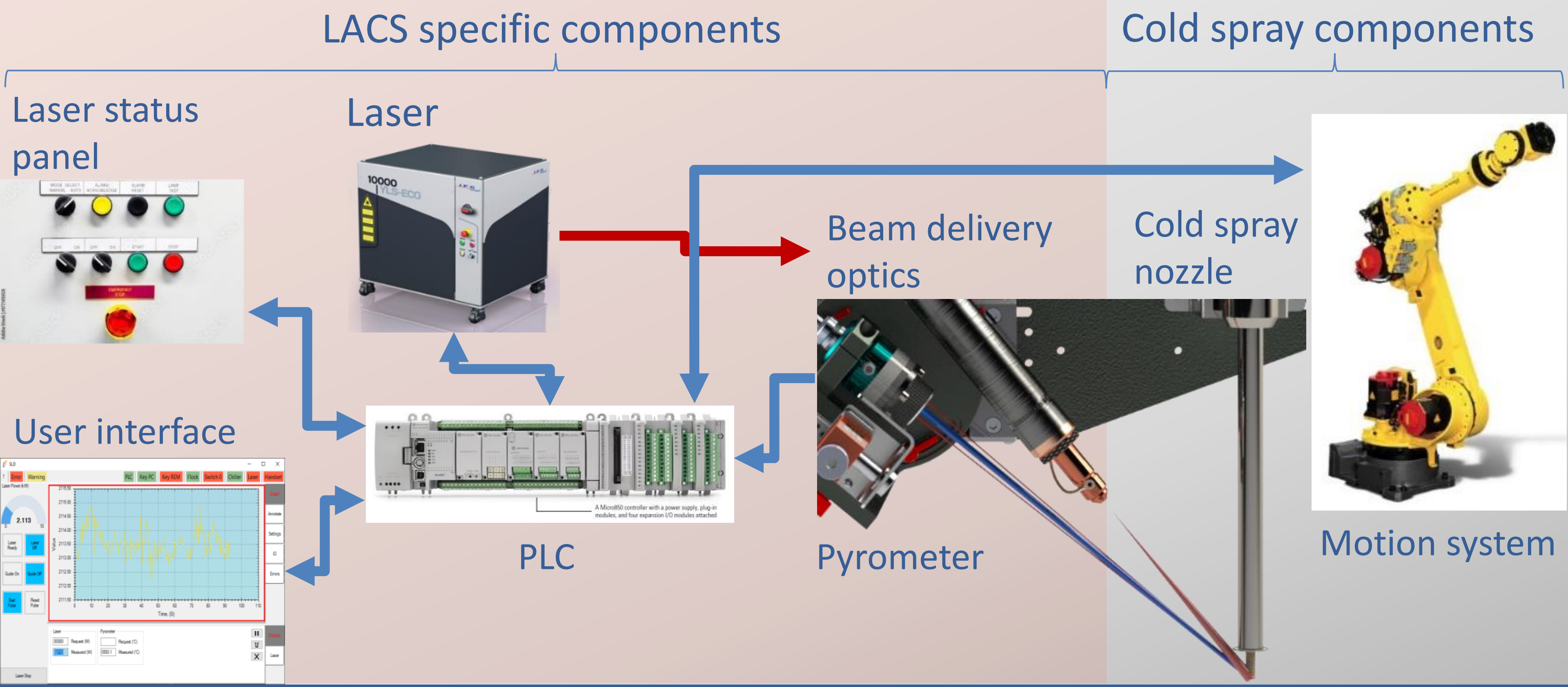


- LACS deposits without melting
- Density > 95%
- Demonstrated strength comparable with wrought material in 3 point bend test of free standing deposit

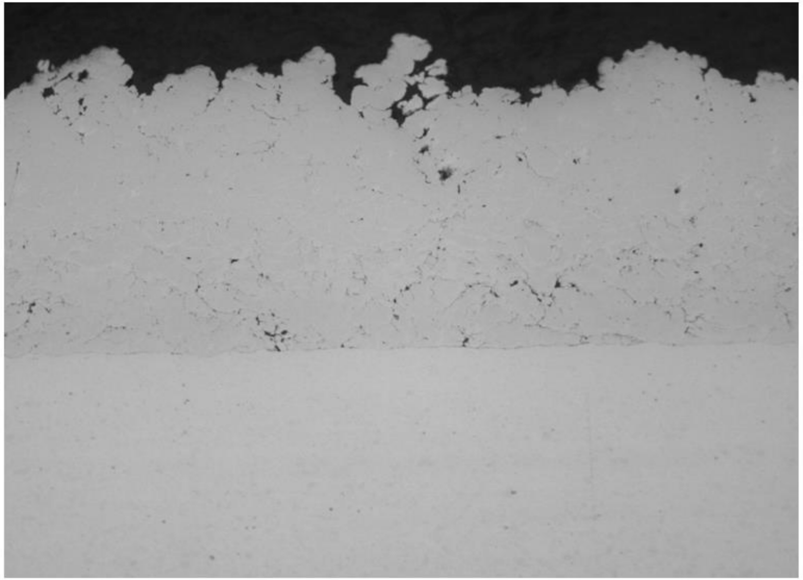
LACS in repair: ES3 GA, USA

- LFT have Upgraded the VRC Gen III at ES3's Georgia Technical Operations Center (GTOC) with a 4 kW IPG laser
- Materials: CP Ti on Ti-6Al-4V, 6061 on 2024-T3, and 6061 on EZ33A-T5.
- Performing testing & comparing Ellsworth AFB baseline parameters to LACS
- Metallurgical (Micro/Hardness/Almen/Bend/Porosity/Adhesion) –
- Tensile
- Triple Lug Shear
- PATTI Pull Test
- Impact/Drop
- Wear

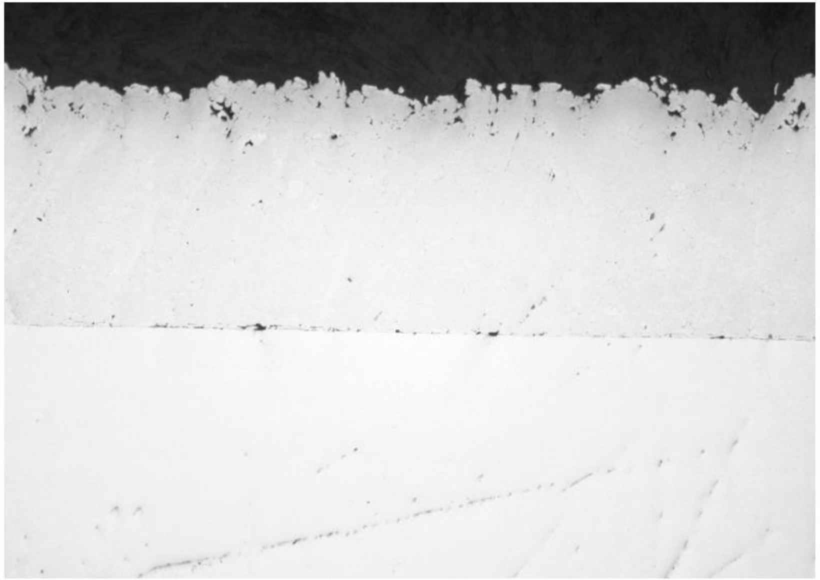
System provision: Architecture



CS Baseline compared to LACS



1200W LACS Parameter Op



Baseline Parameters

CP Ti on Ti-6Al-4V

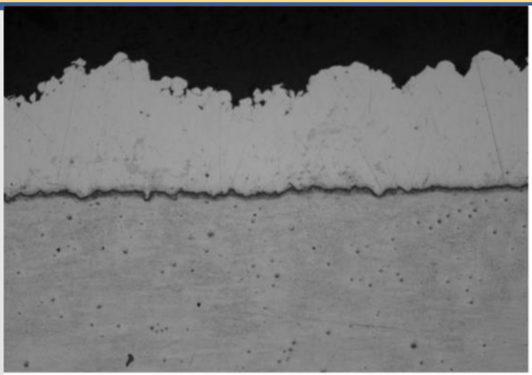
Result summary for Ti on Ti-6Al-4V

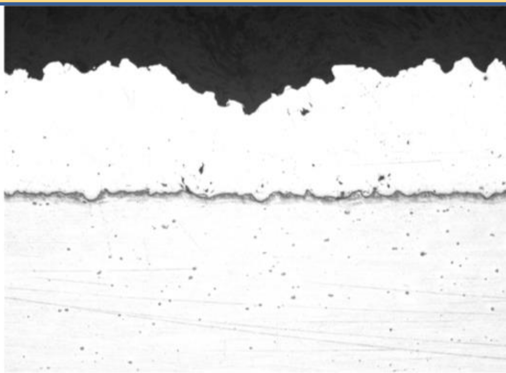
Laser Power	Bend Test	Coating Thickness (in.)	Average Hardness (HV300)	Adhesion Bond Strength (psi)	Porosity
0 W	Fail	0.007	136	3,817	0.50%
2000 W	Pass	0.008	178	3,748	6.9%
1000 W	Pass	0.011	180	5,781	0.78%
1200 W	Pass	0.011	201	11,776	0.46%
1400 W	Fail	0.011	256	5,933	5.7%
1400 W	Fail	0.008	222	9,165	4.0%

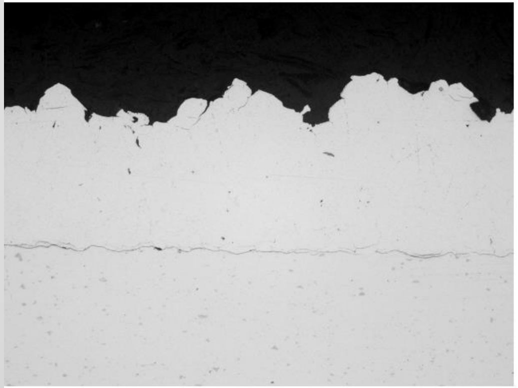
No hardness change across substrate detected for Ti-6Al-4V at optimized parameters

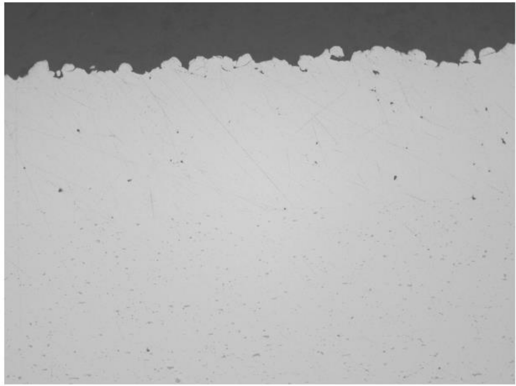
N_2 CS Baseline compared to LACS

- 6061Al on EZ33A-T5 Mg substrates
  - LACS gives 10% greater adhesion values and glue failure rather than cohesive failure.
  - LACS passes the Almen test (Reduced residual stress)
- 6061 Al on 2024-T3 Al
  - 16% increase in adhesion strength
  - Removes obvious bond line in micrographs
  - Reduces porosity to 0.16%
- Substrate hardness is unchanged in both cases.

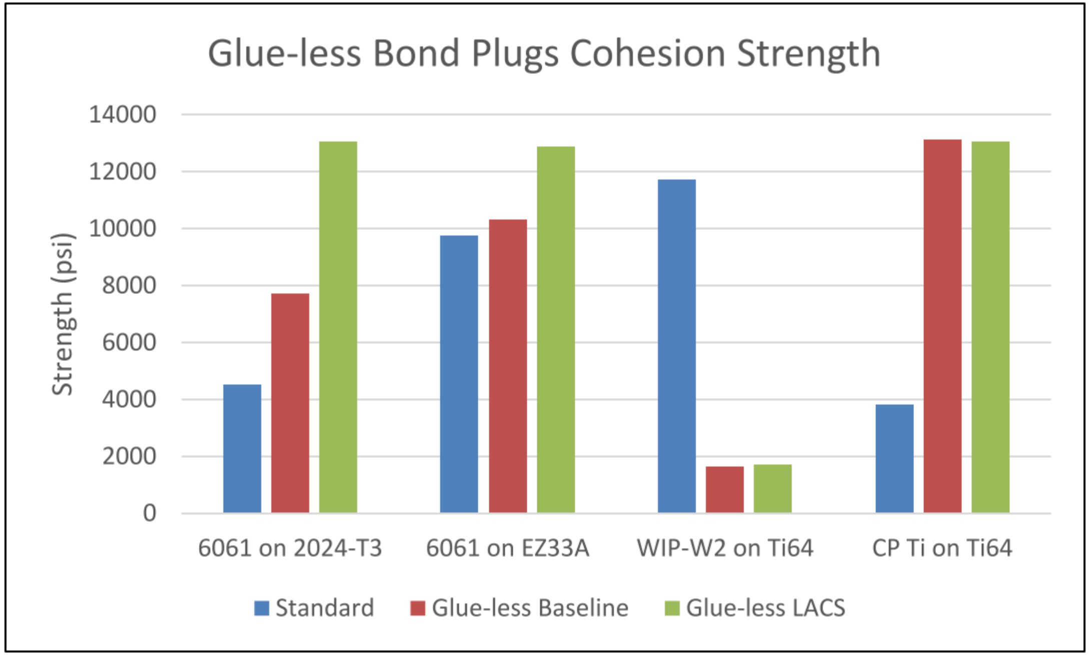

Baseline 6061 on EZ33A-T5


LACS 6061 on EZ33A-T5


Baseline 6061 on 2024-T3


Laser CS 6061 at 1300W on 2024-T3

Coating Cohesion



Typical Ti Glue-Less Bond Coupon

Post-Test, Glue-Less Bond Coupon: Valimet 6061 on EZ33A

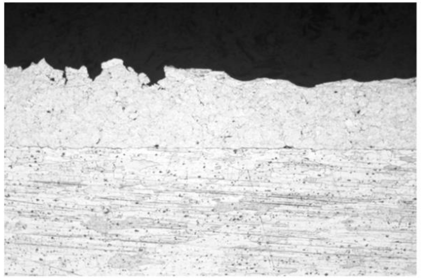
Coating Wear (pin on disc testing)

Project Status

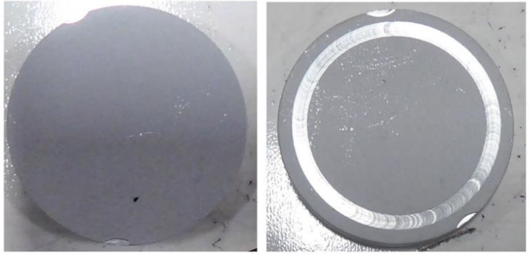
- Wear Test

Substrate	Powder	Pin weight loss (g)	CS Weight Loss (g)	LACS Weight loss (g)
EZ33A-T5	Valimet Grade AM 6061C	0.026	0.253	0.005
Ti-6Al-4V	WIP-BC1, WIP-W2	0.004	0.045	0.039
2024-T3	Valimet Grade AM 6061C	0.0026	0.098	0.004
Ti-6Al-4V	Commercially Pure Titanium	0.004	0.009	0.005

Wear Test Set-up



Cross-section of Valimet 6061 on 2024-T3 wear coupon

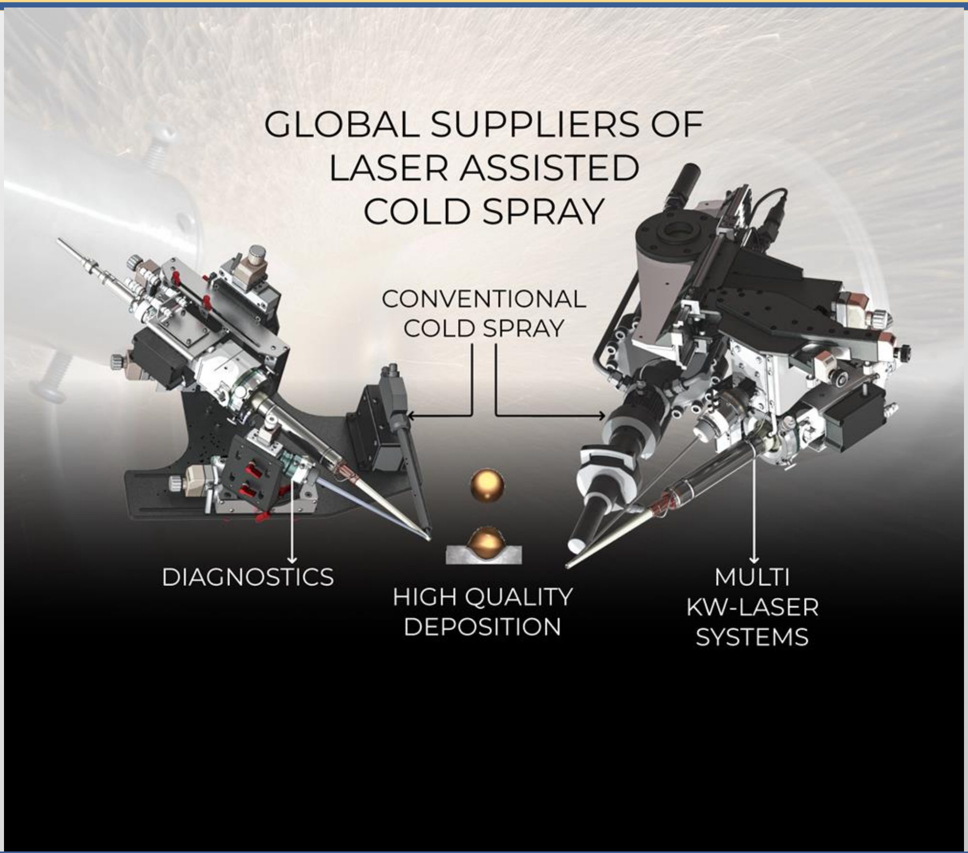


Typical 2024-T3 Wear Coupon Post-test

Summary

- Laser heating of the deposition site allows increased deformation on impact.
- Localised deformation during cold spray impact means that heating is only required for the top ~ 40µm of the substrate.
- LACS enables deposition at impact velocities below v_{crit} for conventional cold spray.
- LACS enables the deposition of refractory coatings such as tungsten.
- LACS can enhance adhesion and cohesion in cold spray coatings.
- LACS is being validated for use as a replacement for helium based cold spray for repair applications on aluminium, titanium and magnesium substrates.

Questions?


GLOBAL SUPPLIERS OF
LASER ASSISTED
COLD SPRAY
CONVENTIONAL
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DIAGNOSTICS
HIGH QUALITY
DEPOSITION
MULTI
KW-LASER
SYSTEMS