Overview of Cold Spray Technology

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Materials Joining and Engineering Technologies

TWI Limited

- Research & Technology Organisation
  - Welding and joining
  - Materials performance
  - Corrosion
  - NDT
- Established in 1946
- Independent
  - Not government funded
  - No shareholders; any profit is used to build/maintain capability
- Nuclear pedigree

TWI Headquarters at Granta Park, Cambridge

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- **≈£80m turnover p.a.**
  - ≈700 Single Client Projects
  - ≈50 Joint Industry Projects (JIPs)
  - ≈70 Core Research Projects
  - ≈65 Collaborative Projects
- ≈900 staff (≈550 engineers)
- **700 Industrial Members**
  - 4,500 locations in 80 countries
  - Over 15,000 visitors per annum
- TWI influences over 120 International **Codes and Standards**

The Thermal and Cold Spray Section

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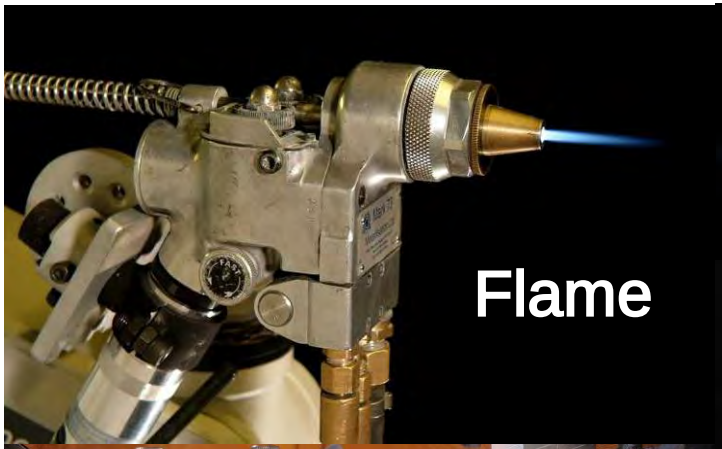
Ten different thermal & cold spray systems (all commercially available)



Four spray booths, two of which can combine to form one large booth (7.5m long x 6m deep x 4m high)

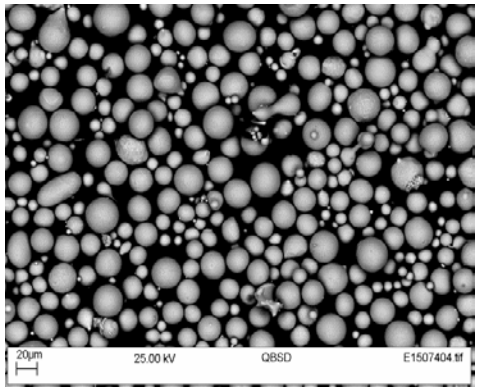
Impact Innovations 5/11 – 6/10
Cold Spray System

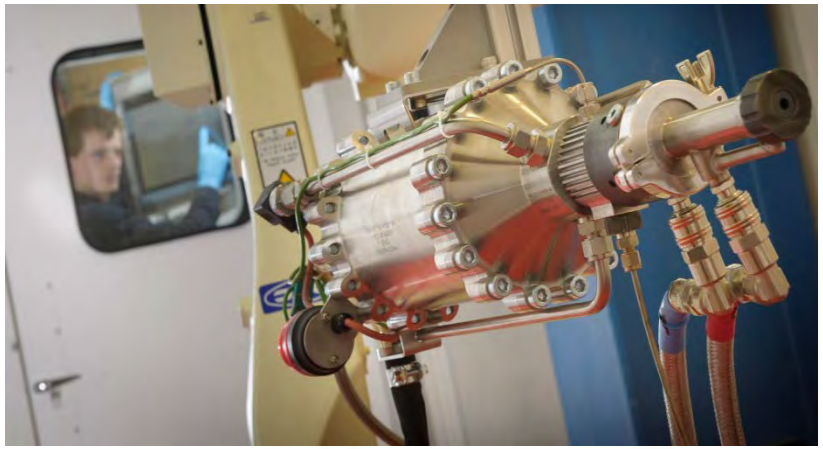
Large mechanised grit blasting room

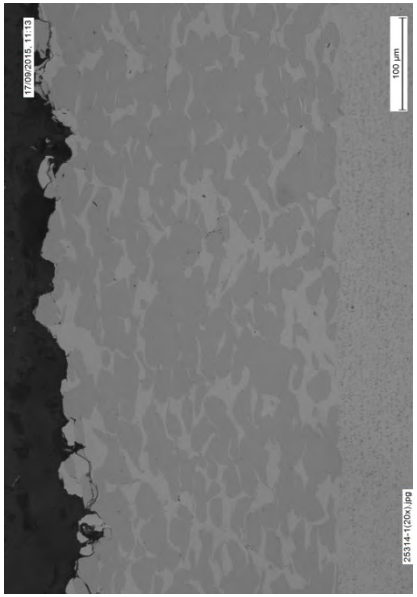
The Cold Spray Process

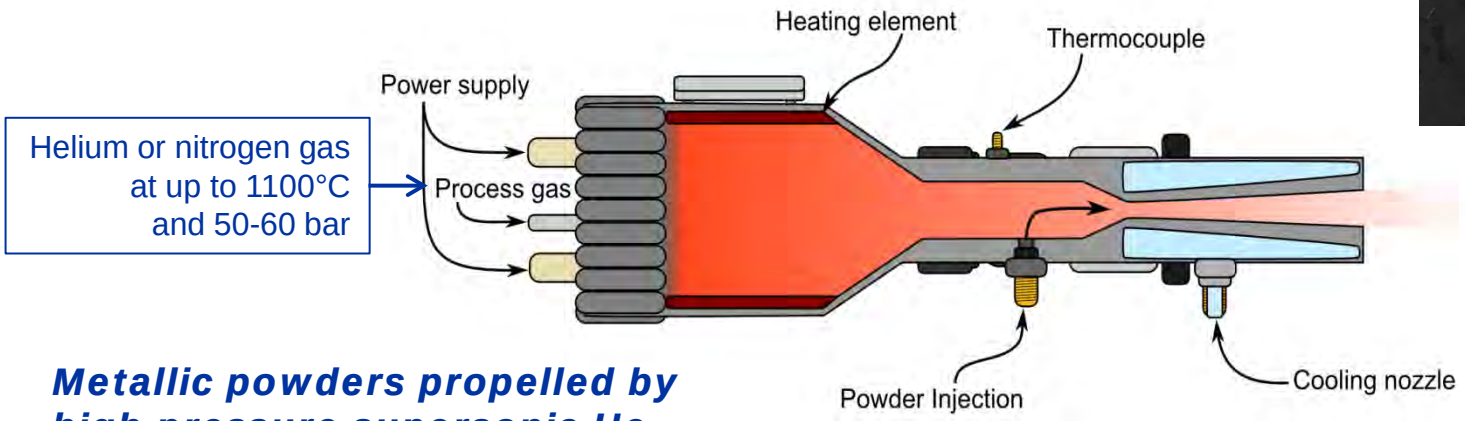
Materials Joining and Engineering Technologies

Cold Spray: A solid state deposition process





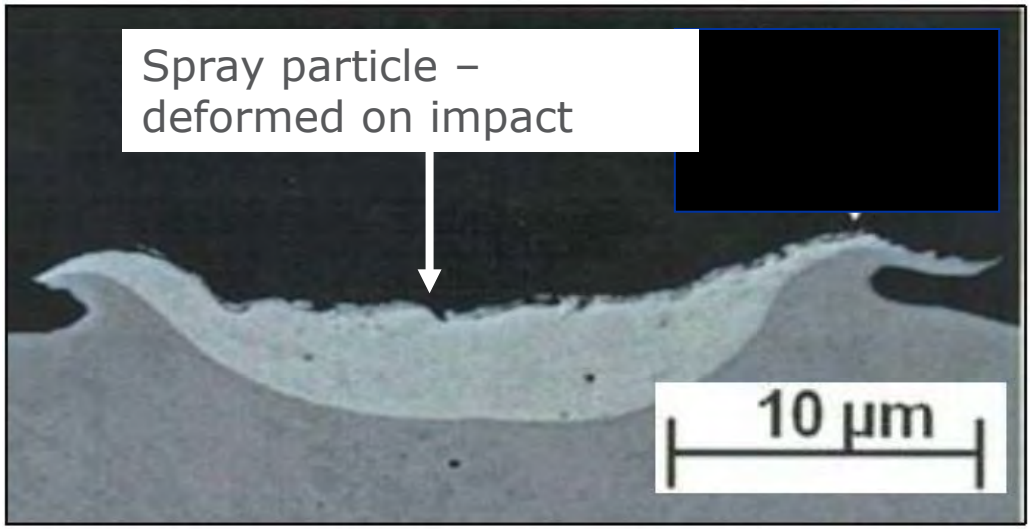


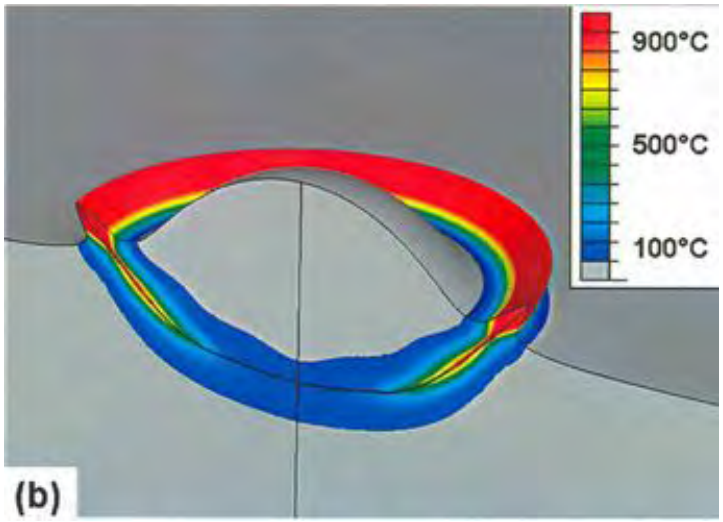


Metallic powders propelled by high pressure supersonic He or N_2 gas stream to reach a critical velocity

Solid particles propelled on to substrate where they impact and plastically deform to build up a coating.

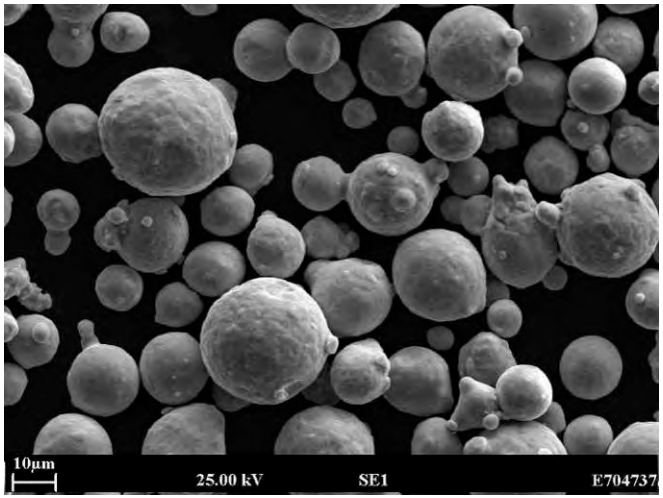
Cold spray principle

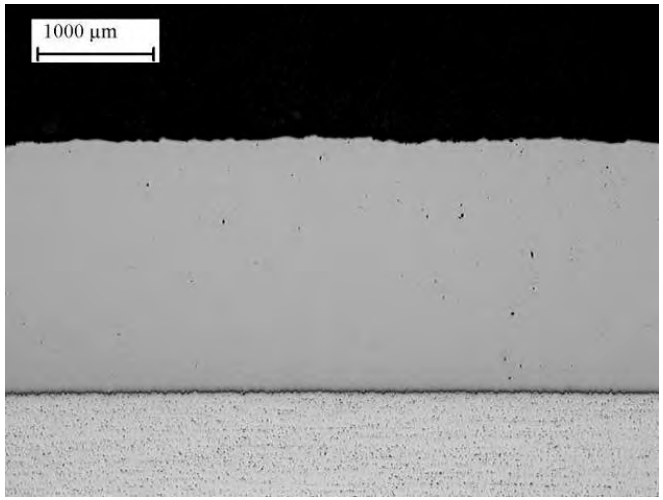


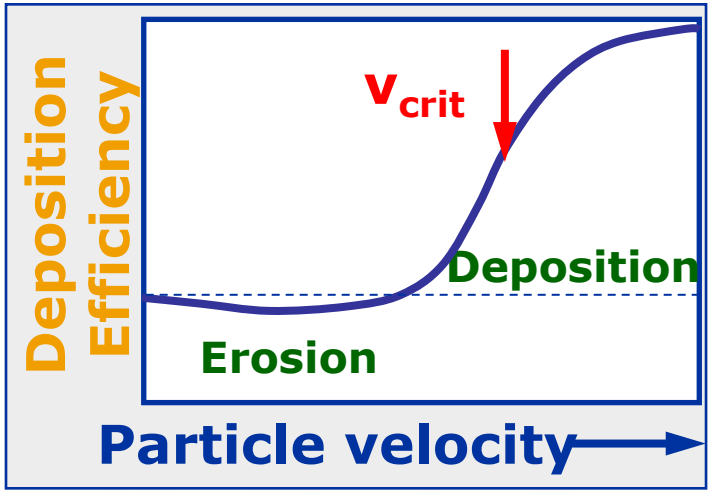


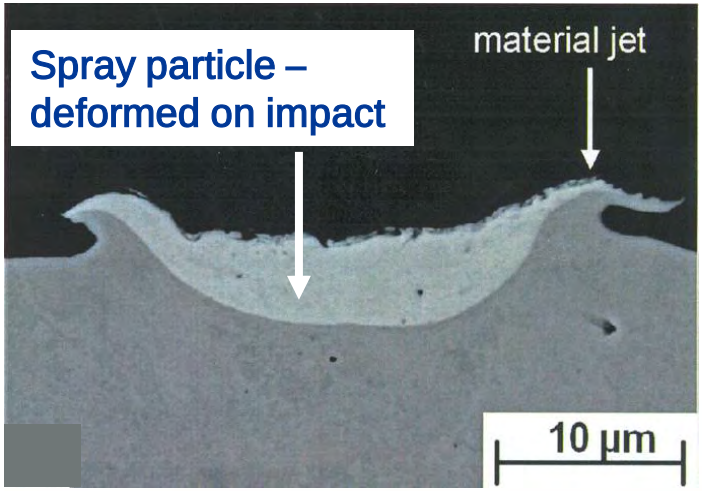
- **Localised, transient adiabatic shear instabilities at the interface**:
- Kinetic energy converted to deformation and thermal energy
- Rapid, highly localised, transient temperature increase at interface → drop in yield strength at interface (YS=f(T))
- Brief and highly localised plastic flow of particle and substrate leads to bonding

Critical Velocity: A key concept in cold spraying

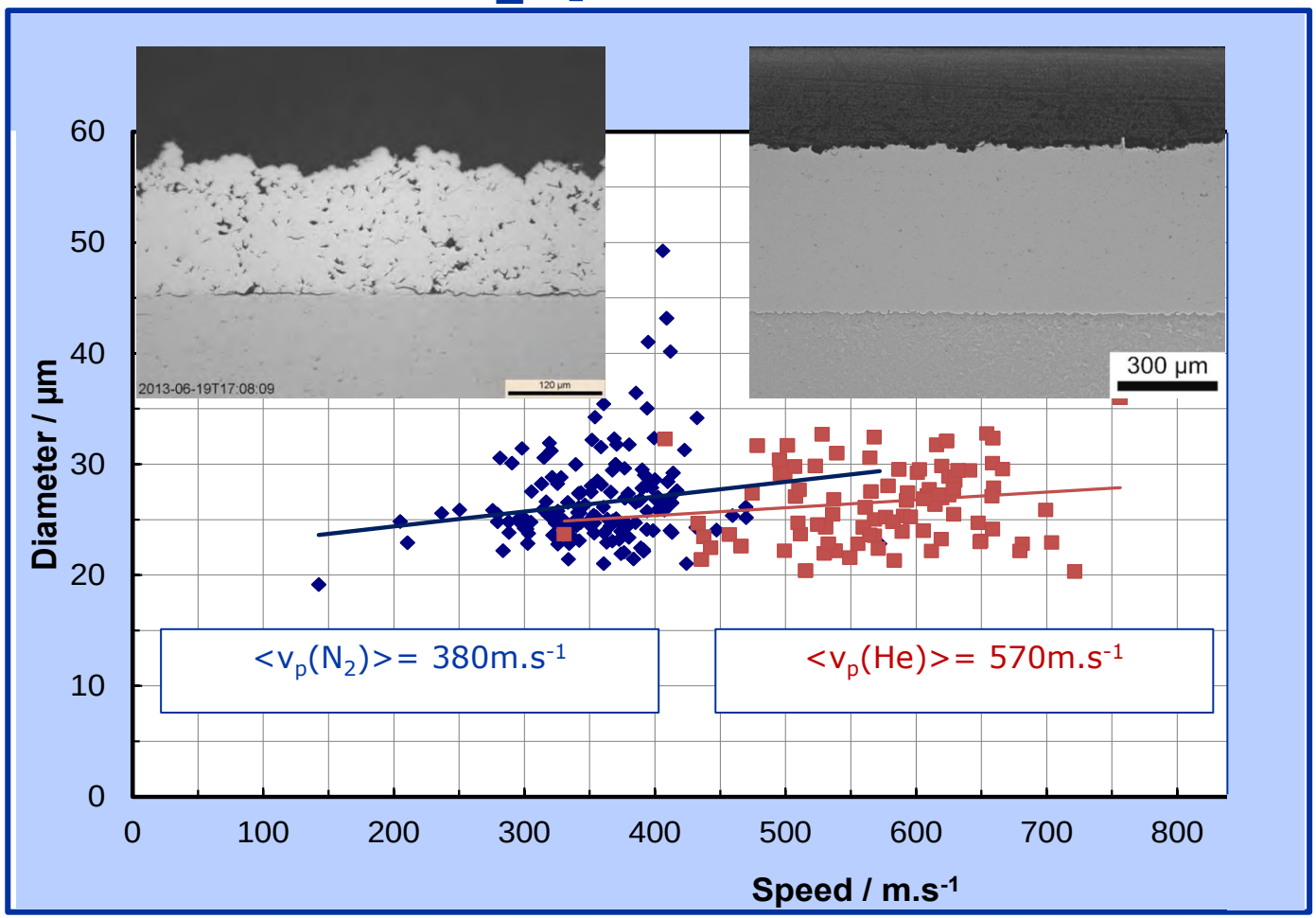






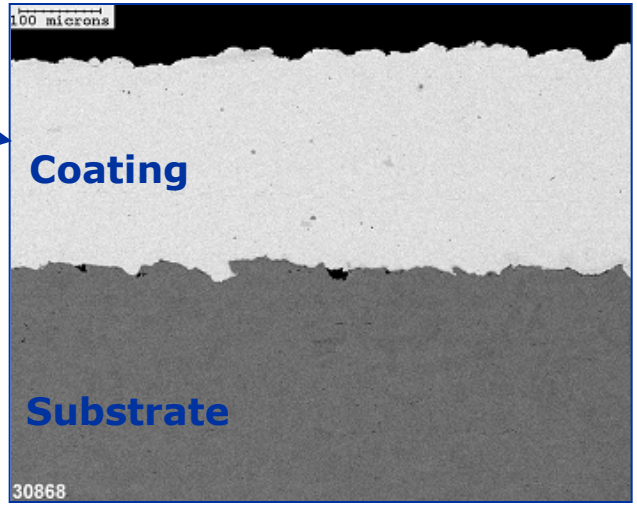


Powder particle velocity (ms^{-1}) He vs N_2 (CGT Kinetiks® 4000/47)



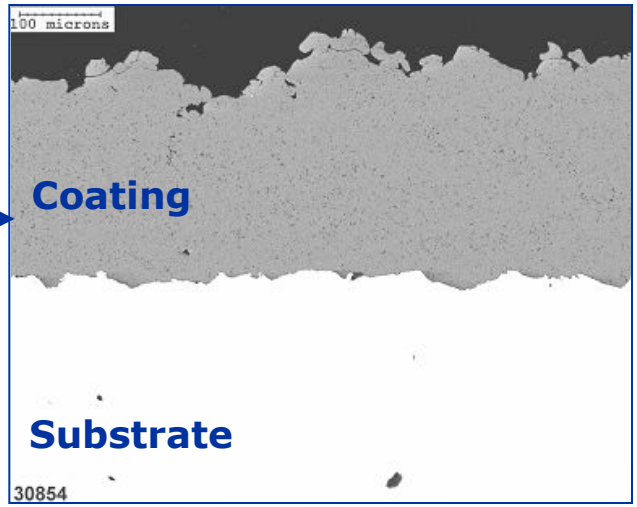
Typical cold spray coatings

- Cu coating
- Oxygen level, wt%
  - Powder 0.05
  - Coating 0.05



There is usually minimal oxidation of the powder in cold spraying

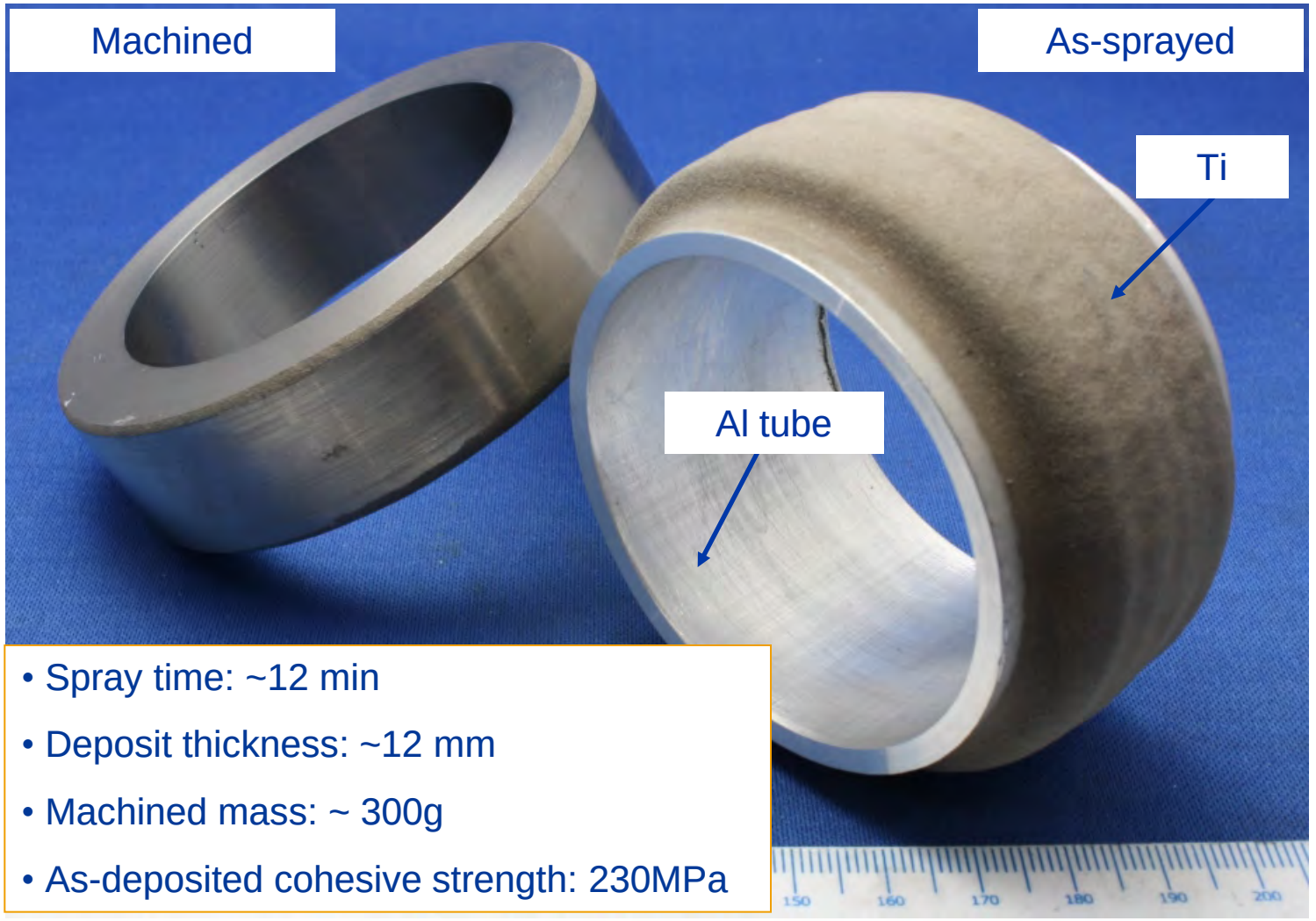
- Al coating
- Oxygen level, wt%
  - Powder 0.20
  - Coating 0.20



Cold Sprayed Cu-Sn on Al

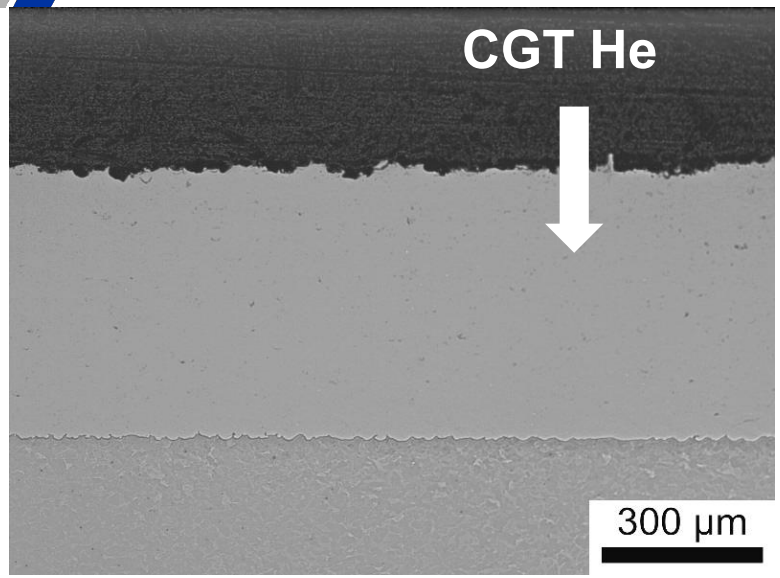
Spray-Formed Ti

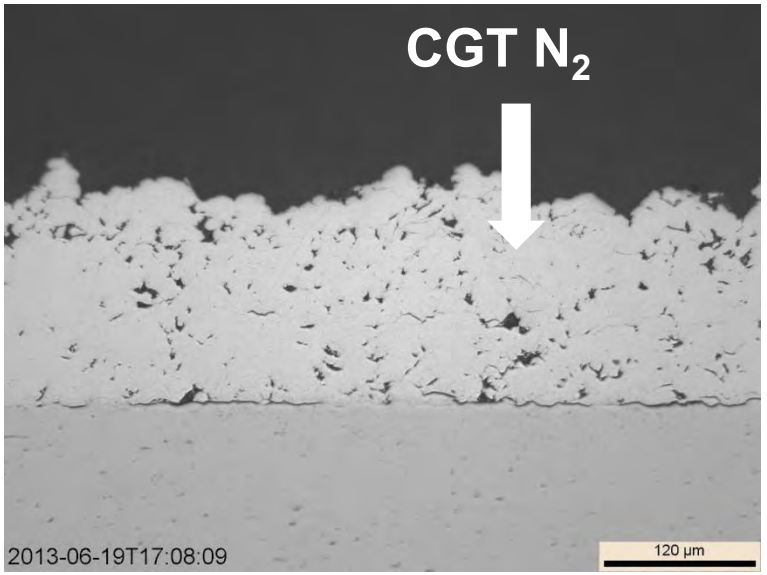
Spray-Formed Ti

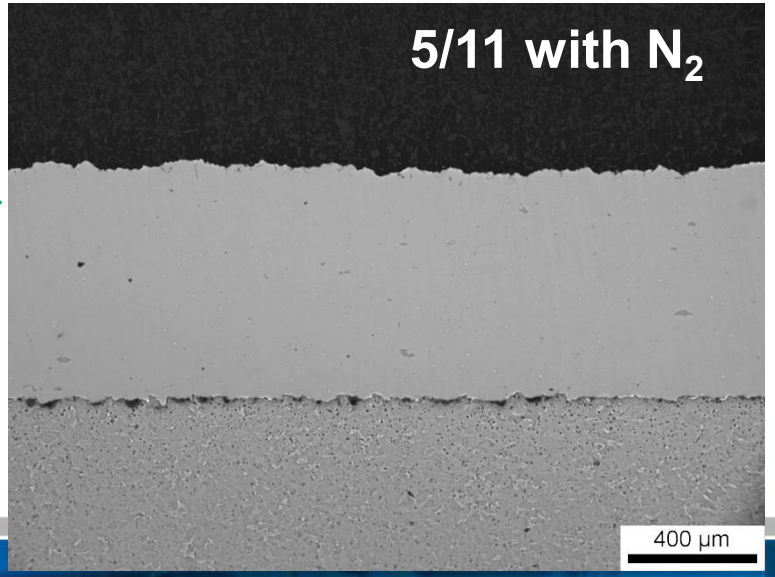


- Spray time: ~12 min
- Deposit thickness: ~12 mm
- Machined mass: ~ 300g
- As-deposited cohesive strength: 230MPa

Cold Sprayed Alloy 718







Oxygen pickup during deposition

System	Powder	P	Temp.	Thickness (avg.)	Porosity (avg.)	O_2	Bond strength	Tensile cohesive strength
Kinetiks® 4000/47	TWI	40 bar	800°C	≈ 150 µm	3.6-4.0%	0.03% (300 ppm)	28 MPa	n.d.
Kinetiks® 8000/52	SM	40 bar	1000°C	≈ 130-145 µm	2.0%	0.05% (500 ppm)	>70 MPa	n.d.
PCS-1000	PG (N_2 gas)	50 bar	1000°C	≈ 715 µm	1.8%	0.08-0.09% (800-900 ppm)	Disbonded	n.d.
Impact 5/11	TWI	46 bar	1000°C	≈ 700-740 µm	0.3-0.9%		34 MPa	289 MPa
	IMP	46 bar	1000°C	≈ 585-610 µm	0.6-0.8%		>72 MPa	266 MPa

Powders were 300 ppm. There is up to 600 ppm oxygen pickup during coating deposition with 1000°C N_2

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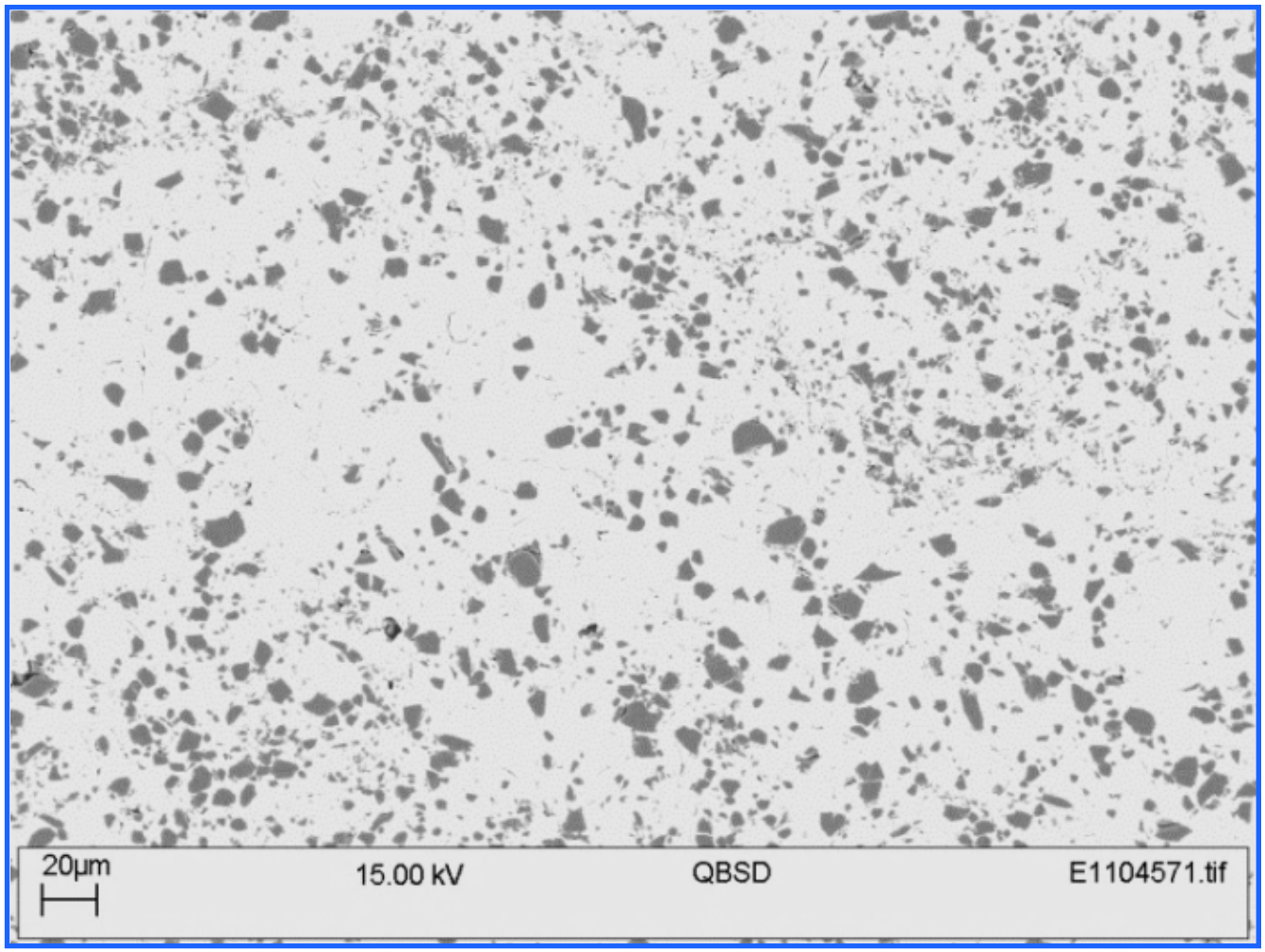
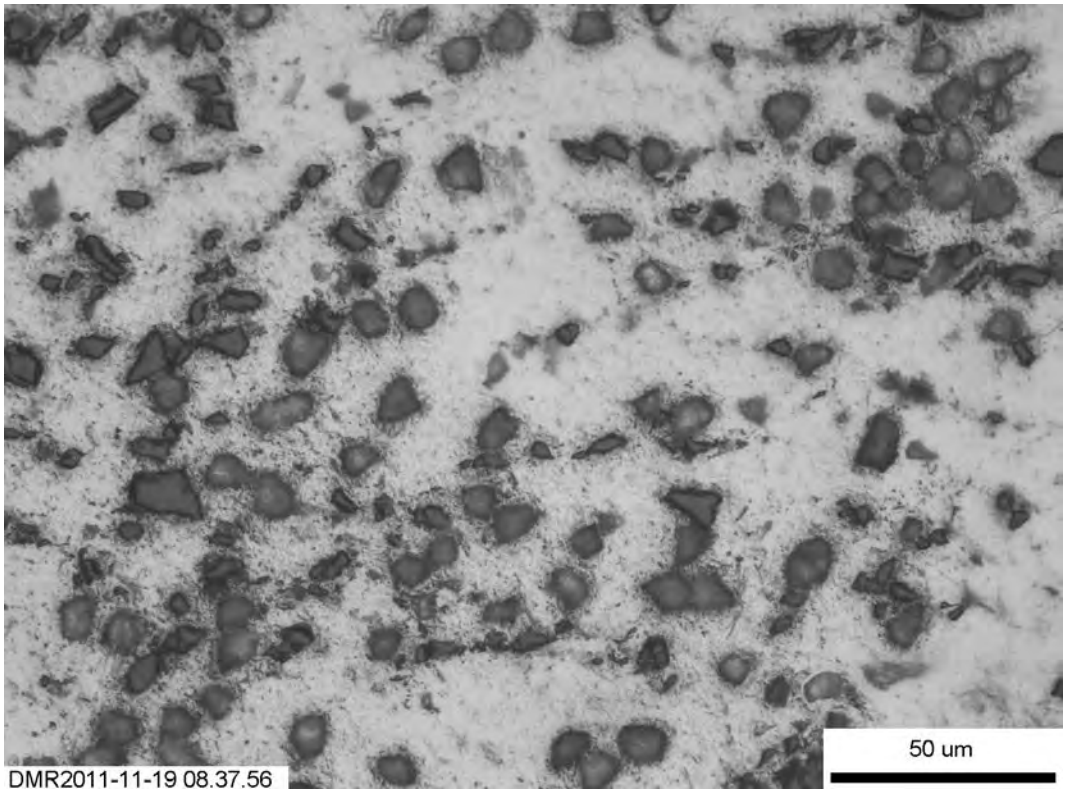
Marrocco *et al*, **Proc. ITSC 2006** p.265-270:
HVOF-deposited Alloy 718 contains ≈0.26% oxygen

Al-B_4C composite NucleoStore™ coating



20 vol% B_4C in an aluminium matrix

Al-B_4C composite NucleoStore™ coating



Almost unlimited thickness

Al-B_4C composite NucleoStore™ coating

Property	BORAL® Composite	BORTEC® MMC	TWI NucleoStore™
Description	Flat shapes fabricated from 1100 Series Al alloy plates, separated by a core of Al + B_4C powder	Flat, rolled plates of metal-matrix composite consisting of Al alloys (or Al) containing B_4C particles	An MMC coating that can be deposited onto a wide variety of fabricated metal shapes
Minimum thickness	1.905 mm	1.905 mm	≈ 200 µm
Maximum thickness	6.858 mm or more	9.525 mm or more	Potentially no limit.
Max %B_4C by mass	≈ 61% in the core	**≈ 32%**	Currently **≈ 18%**
Max %B_4C by volume	≈ 65% in the core	**≈ 34%**	Currently **≈ 20%**
Relative density	N/A	>98%	> 98%
Tensile strength approx.	≈ 10 ksi (≈69 MPa)	21-31 ksi (145-215 MPa)	> 16 ksi (> 110 MPa) Parallel to substrate
Adhesion strength of NucleoStore™ coating to AISI 316 S/S substrate:			≈ 23 MPa
Adhesion strength of NucleoStore™ coating to duplex steel substrate:			≈ 18 MPa

Summary

- Nuclear engineering experience
- Large scale, state-of-the-art cold spray facility
  - Can handle large parts (cranage)
  - Offline programming of coating toolpaths
  - Full process: Grit blasting, machining, coating, NDT
  - HIP consolidation
  - Laser assisted cold spray
  - Laser surface consolidation
- Full suite of coating evaluation and characterisation capabilities
  - Corrosion
  - Wear
- Highly experienced engineers and technicians

Contact Details

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