



Science and Technology in Advanced Manufacturing

Cold Spray: over 30 years of development toward a hot future

Prof. Rocco Lupoi

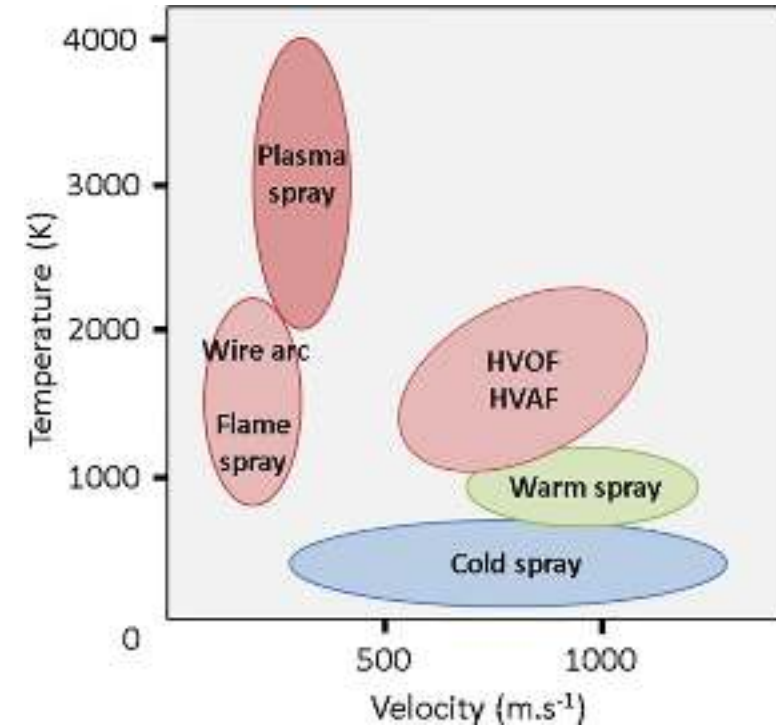
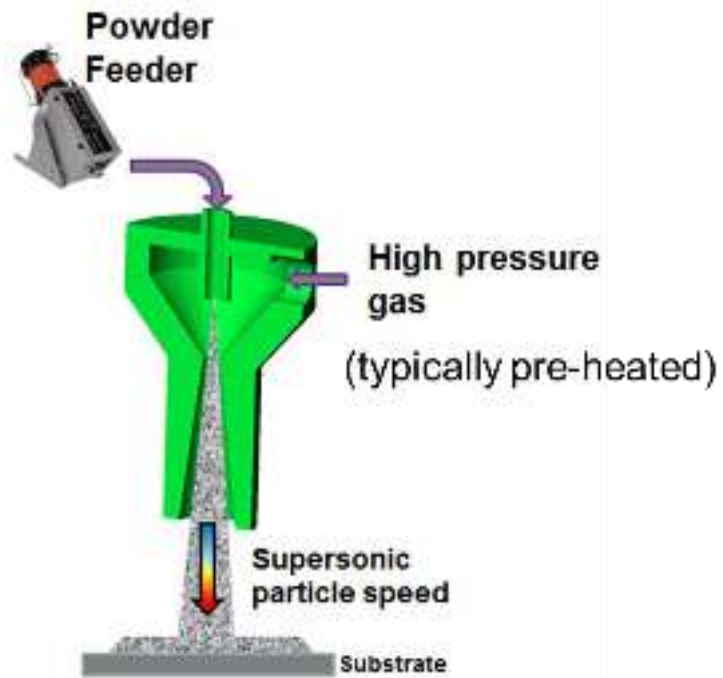
Trinity College Dublin, The University of Dublin, Department of
Mechanical, Manufacturing & Biomedical Engineering

Cold Spray Club meeting, 25-26 of June 2025,
Gallipoli (Italy)

<https://www.stamlab.eu/>



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

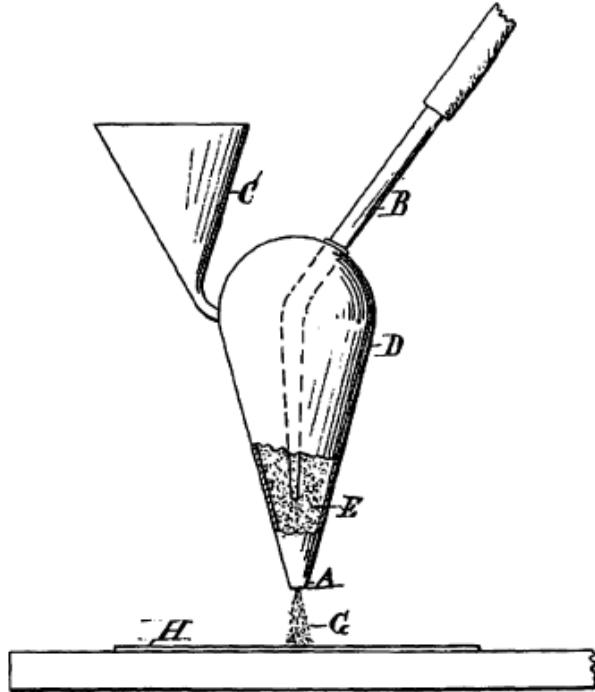


Total papers from 1995? >6000 (Scopus)
...for HVOF a little less, for PS a lot more

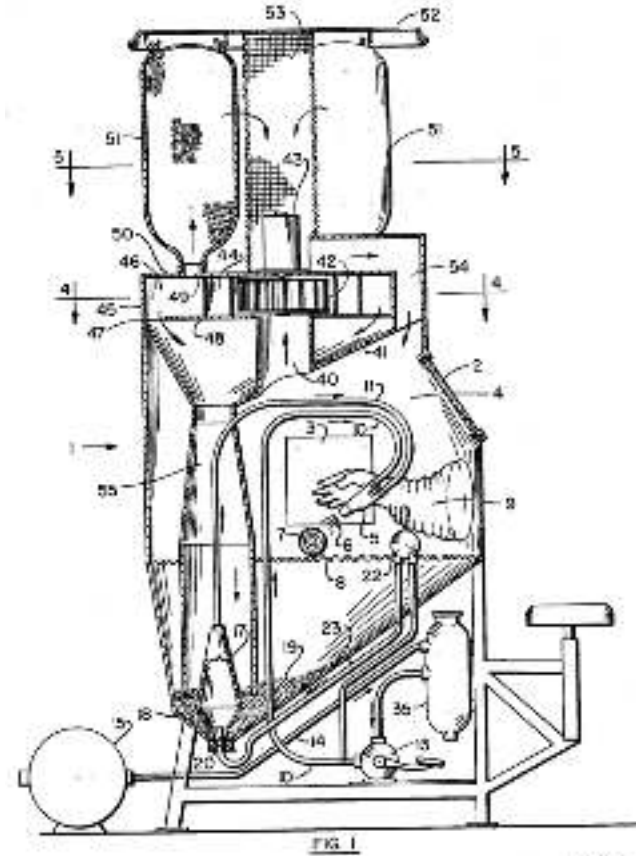
Invention of CS?

Historical contest

Mentioning of this process dates back to 1900



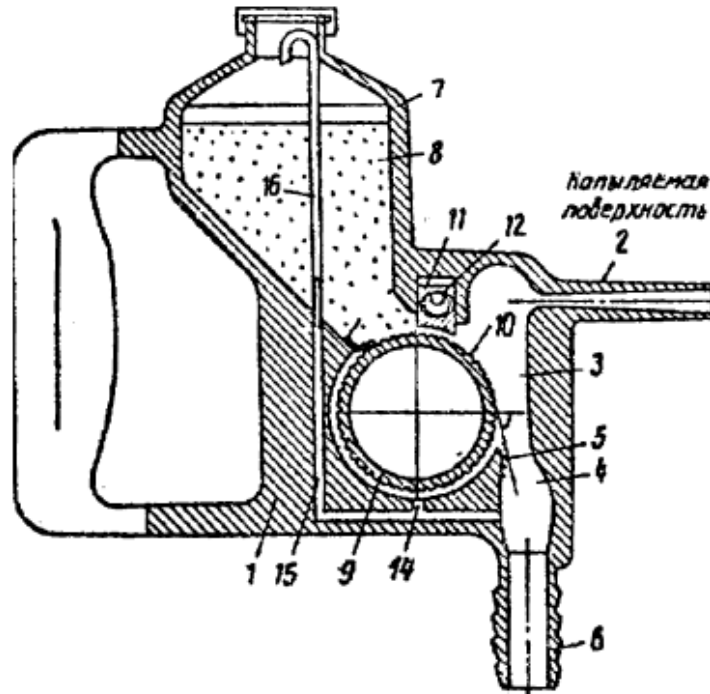
S.H. Thurston, Method of Impacting One Metal Upon Another, US706701, year of priority (issued): 1900 (1902)



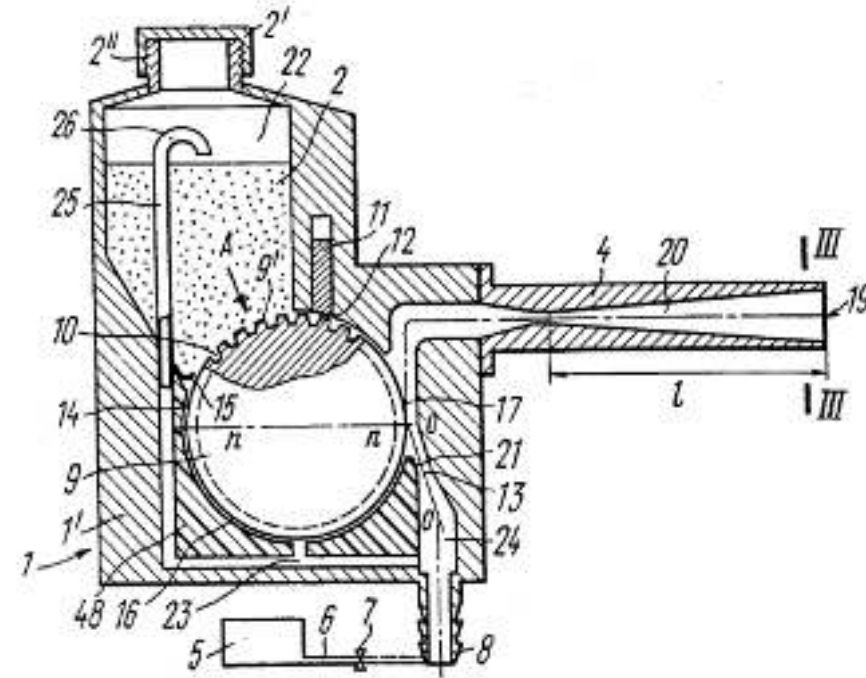
INVENTOR:
CHARLES F. ROCHEVILLE
C.F. Rocheville, Device for Treating the Surface of a Workpiece, US3100724, year of priority (issued): 1958 (1963)

Historical contest

...but the process (the “modern” version) started around 1986



A.P. Alkhimov, N.I. Nesterovich, A.N. Papyrin, V.F. Kosarev, and M.M. Shushpanov, Device for Applying Coatings, SU1618777, year of priority (issued): 1986 (1991)



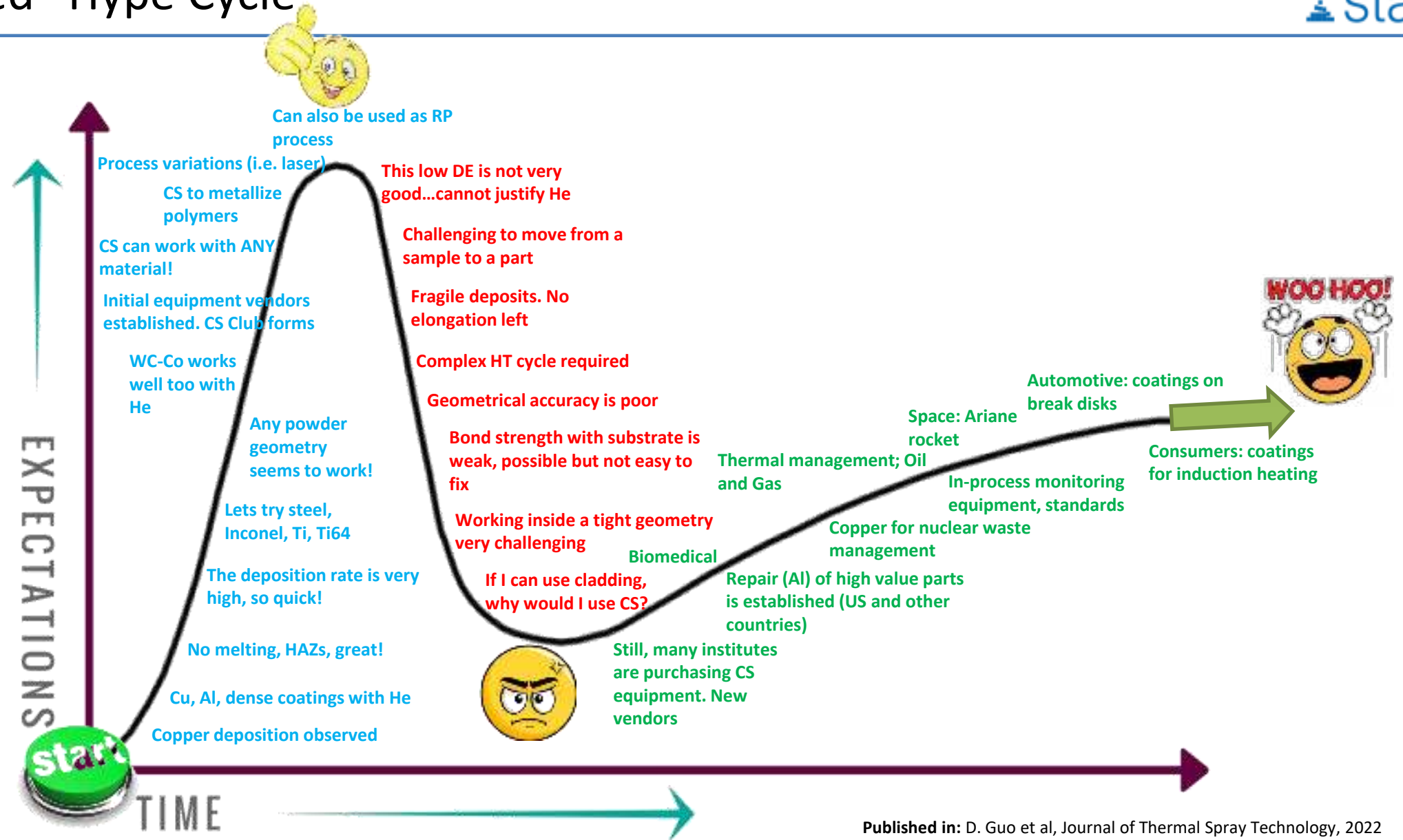
A.P. Alkhimov, A.N. Papyrin, V.F. Kosarev, N.I. Nesterovich, and M.M. Shushpanov, Gas-Dynamic Spraying Method for Applying a Coating, US5302414; WOWO9119016; EP0484533, year of priority (issued): 1990 (1994)

...and many more after this
covering equipment, materials,
applications

What has been the
development journey for the
past 30 years?

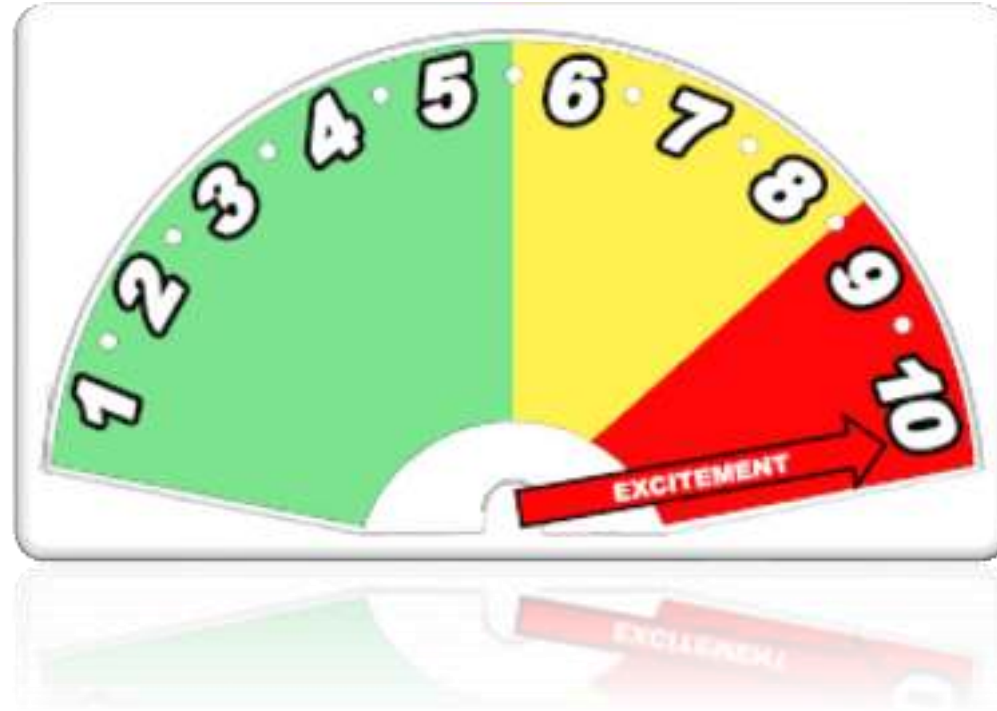


This is called "Hype Cycle"

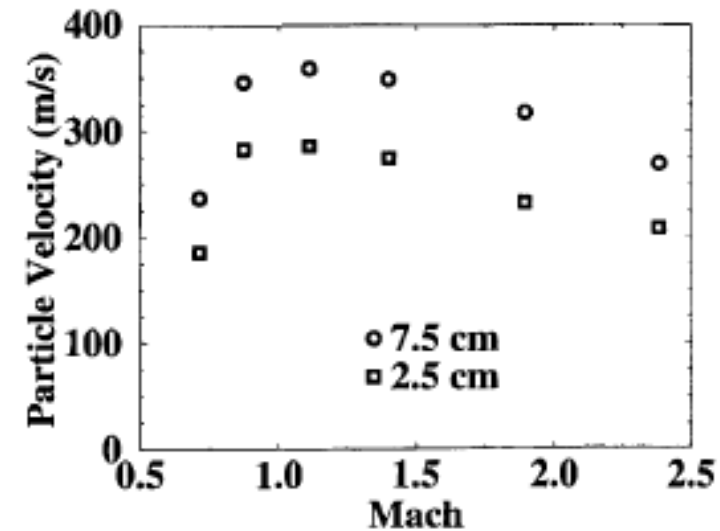
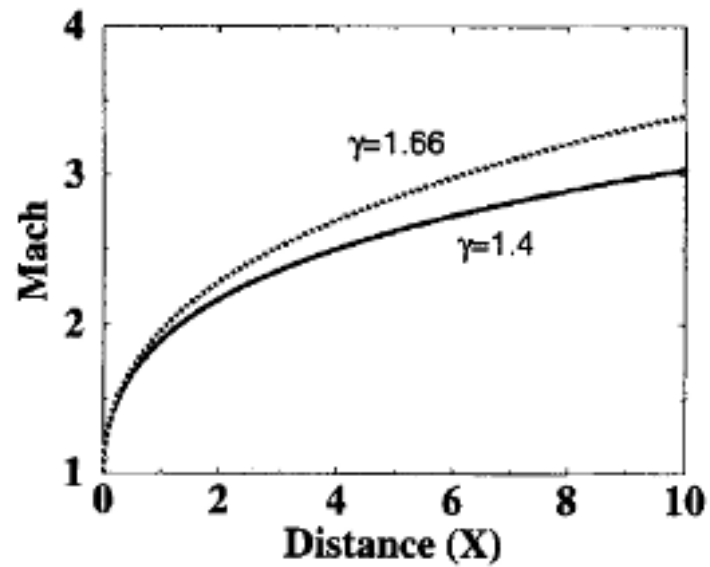
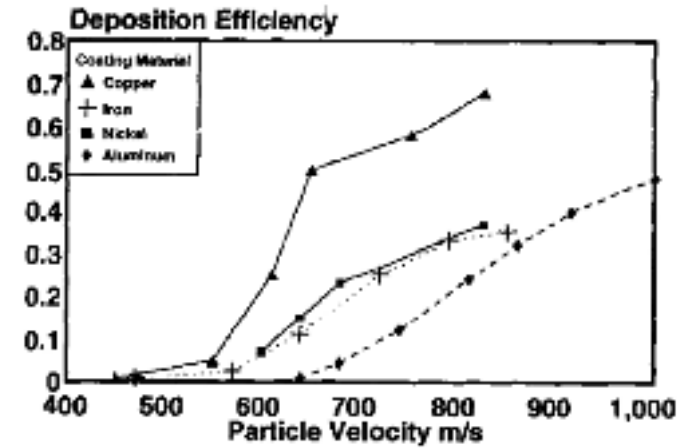
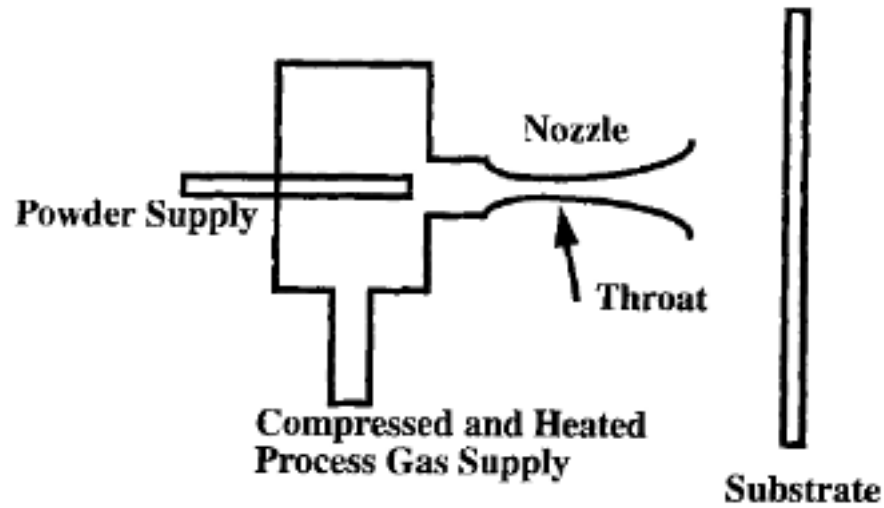


Published in: D. Guo et al, Journal of Thermal Spray Technology, 2022
<https://doi.org/10.1007/s11666-022-01366-4>

Lets move on to the “excitements”...

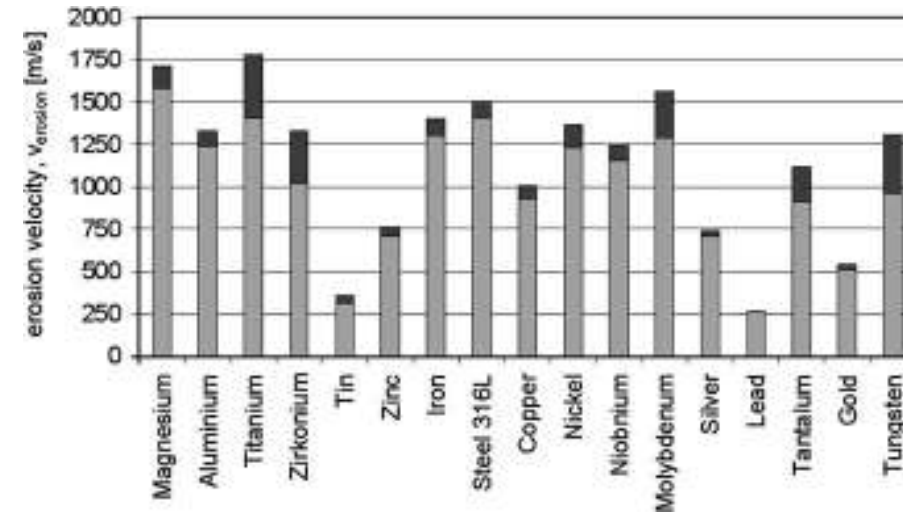
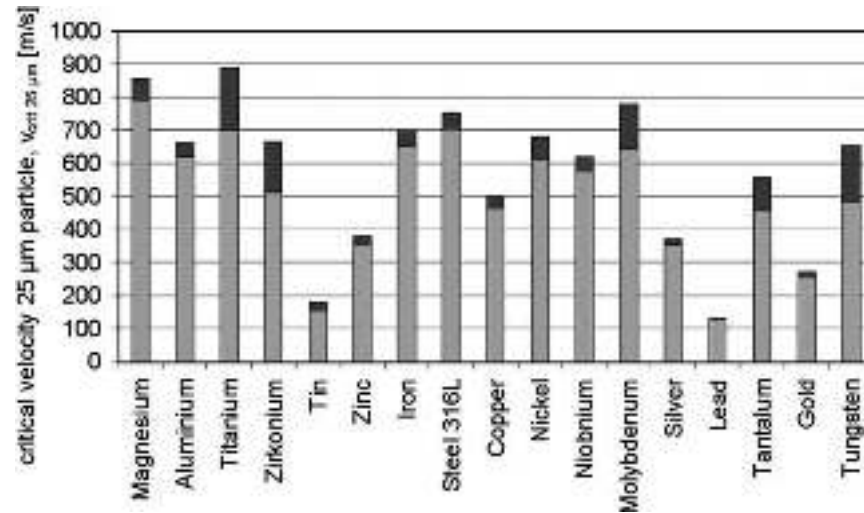
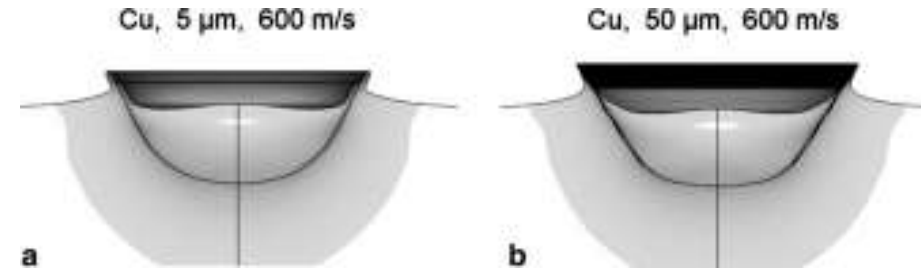
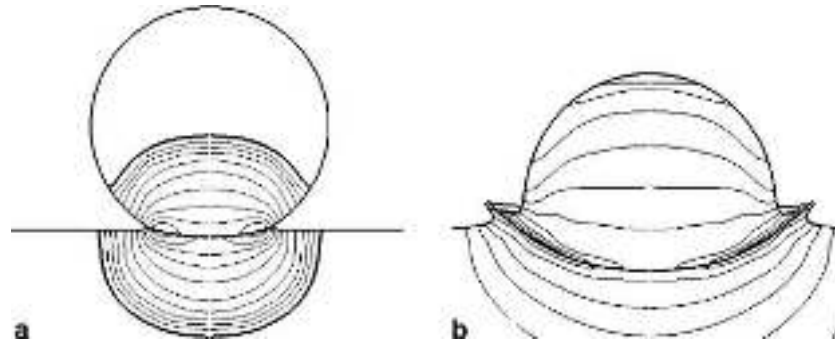


- ☐ I have shortlisted **MY top 12** in the CS journey
- ☐ This is mainly based upon academic papers and presentatios (not necessarily commercial applications). Citations or journal IF has NOT been a metric
- ☐ Subjective to my scientific taste (agree or disagree)
- ☐ Disclaimer: I have included some references, there are many more!



Source: R.C. Dykhuizen "Gas Dynamic Principles of Cold Spray", Journal of Thermal Spray Technology, Volume 7(2) June 1998

Excitement N. 2: Deposition window concept

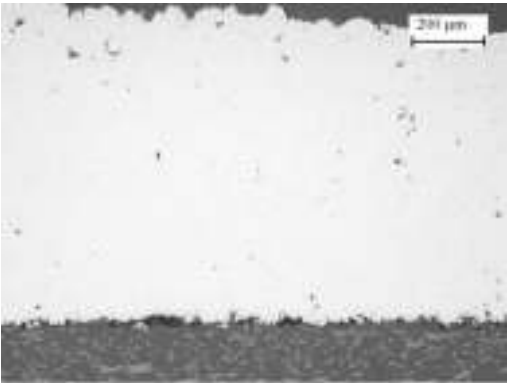


Source: T. Schmidt et al "Development of a generalized parameter window for cold spray deposition", Acta Materialia, Volume 54, Issue 3, February 2006

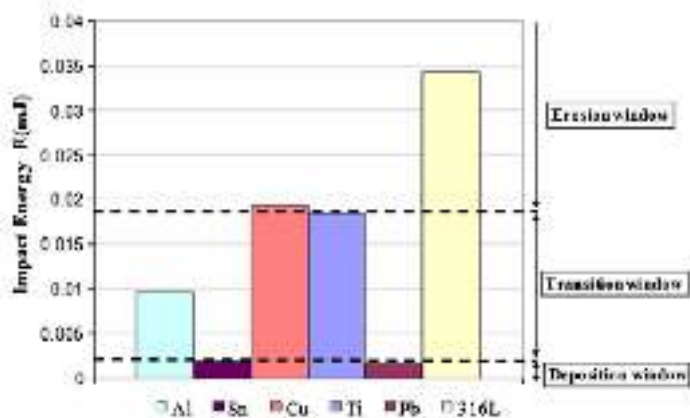
Excitement N. 3: Polymer surfaces are possible



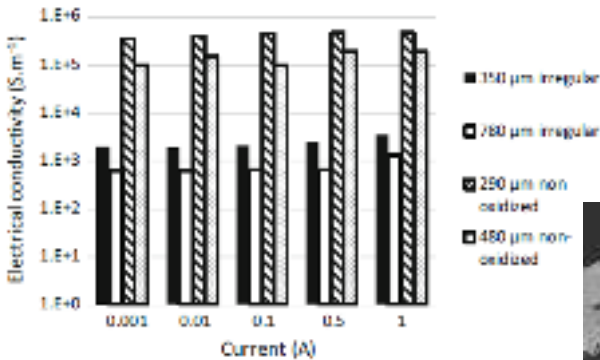
Source: D. Zhang et al “Cold Gas Dynamic Spraying of Aluminum: The Role of Substrate Characteristics in Deposit Formation”, Journal of Thermal Spray Technology, Volume 14(1) March 2005-109



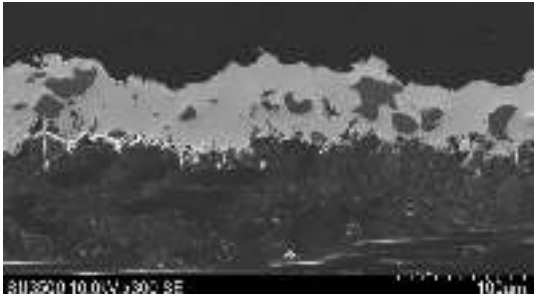
Source: A Sturgeon et al “COLD SPRAYED COATINGS FOR POLYMER COMPOSITE SUBSTRATES” European Space Agency, (Special Publication) ESA SP, n 616, September, 2006



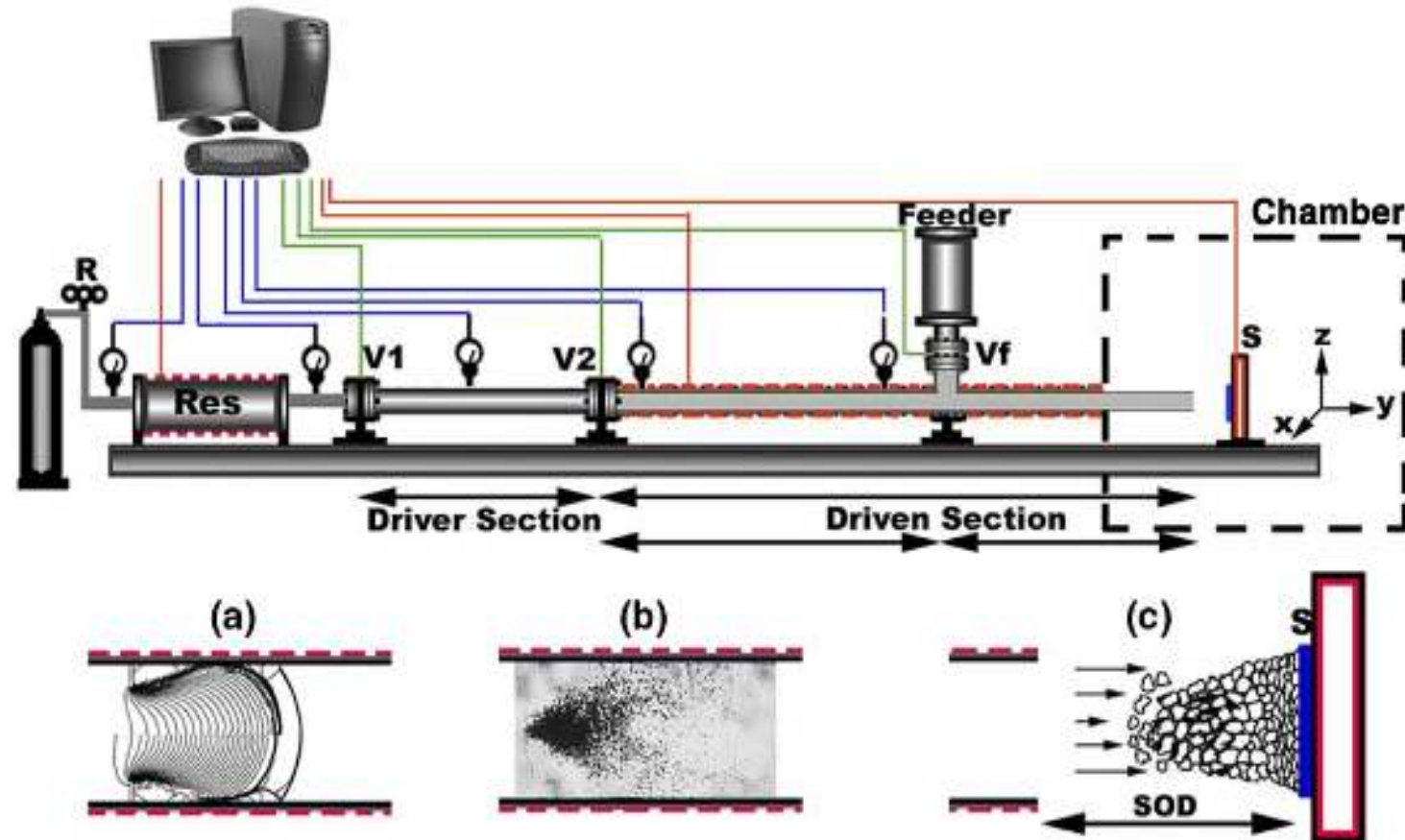
Source: R. Lupoi, W. O'Neill “Deposition of metallic coatings on polymer surfaces using cold spray”, Surface & Coatings Technology 205 (2010) 2167–2173



Source: V. Bertolussi et al “Electrical Conductivity of Metal-Polymer Cold Spray Composite Coatings onto Carbon Fiber-Reinforced Polymer”, J Therm Spray Tech (2020) 29:642–656

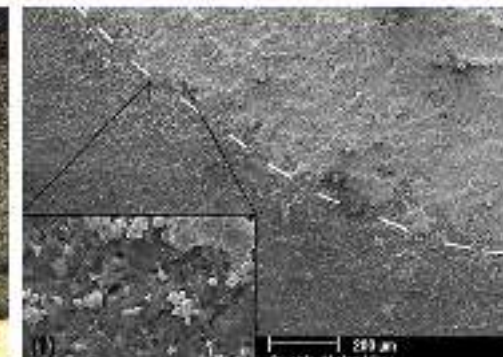
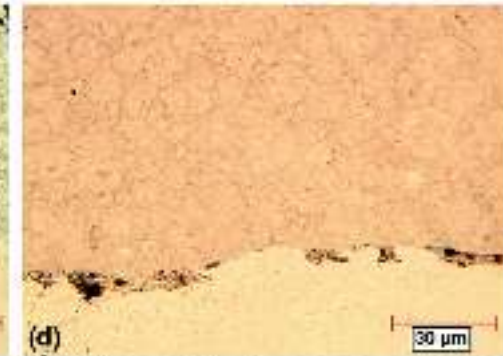
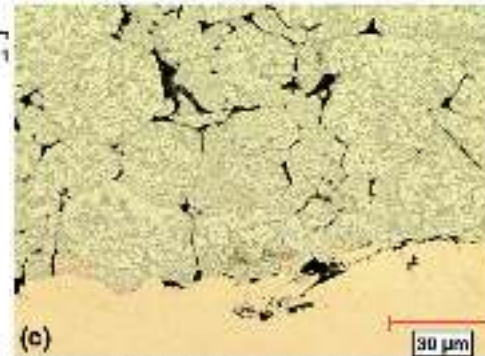
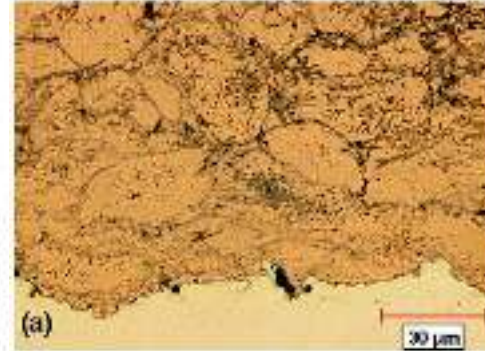
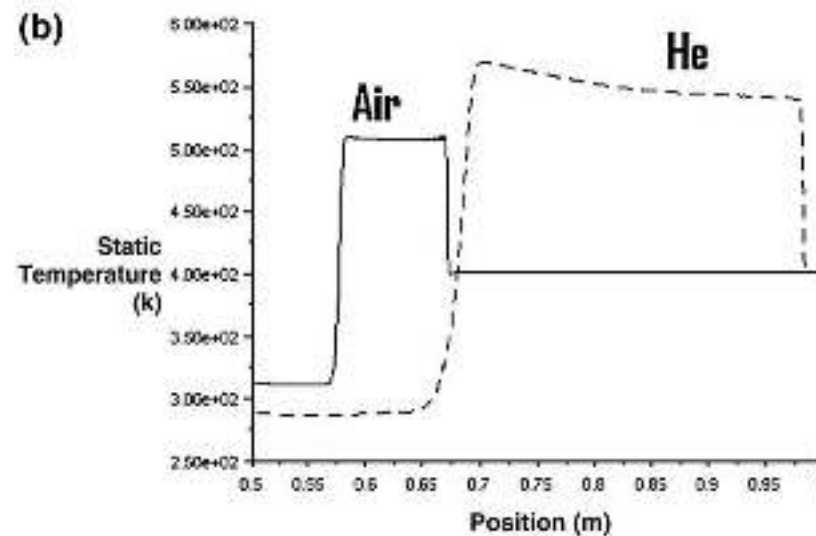
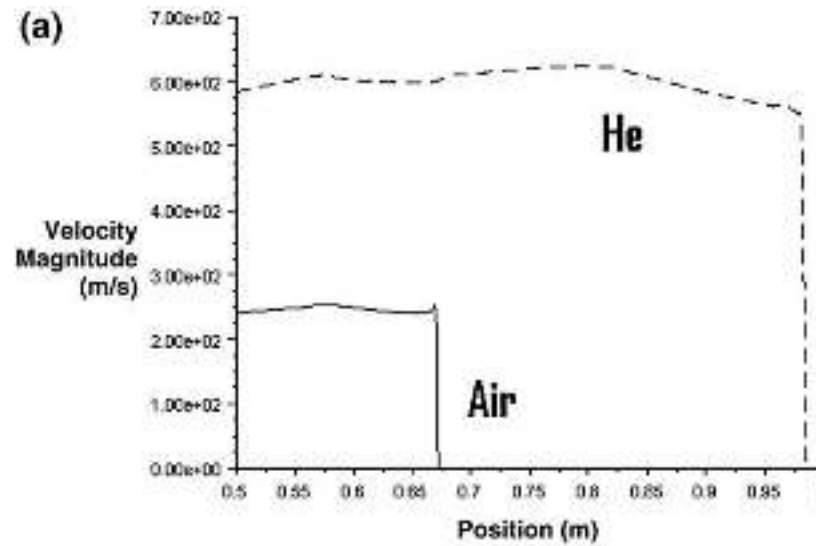


Source: A. Liberati et al “Cold Spray of Mixed Sn-Zn and Sn-Al Powders on Carbon Fibre Reinforced Polymers”, ITSC 2018

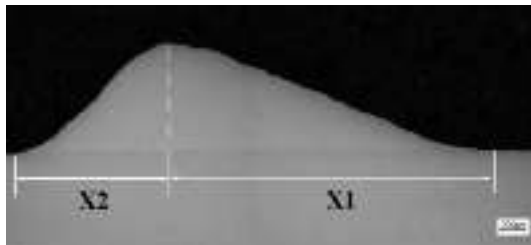
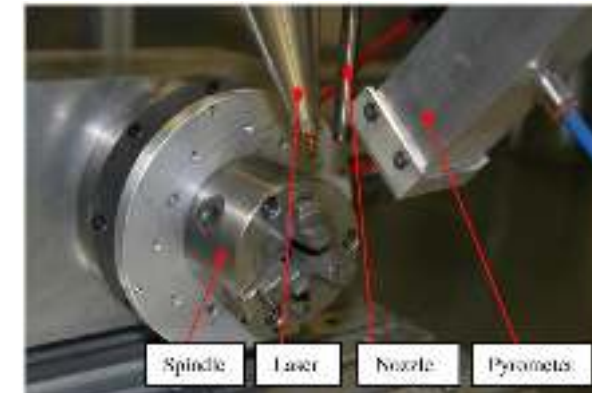
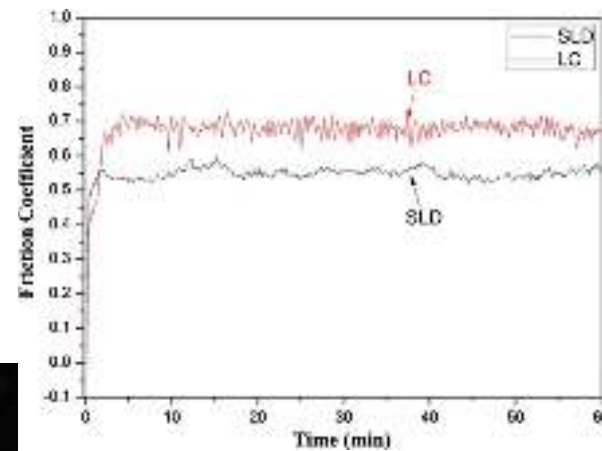
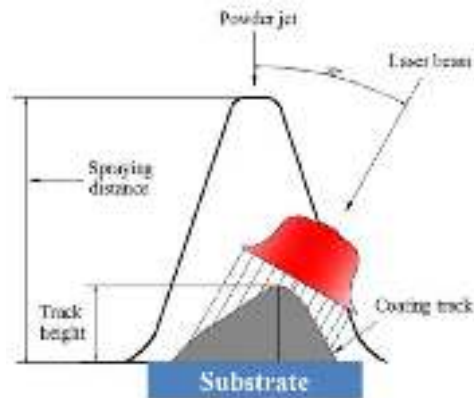
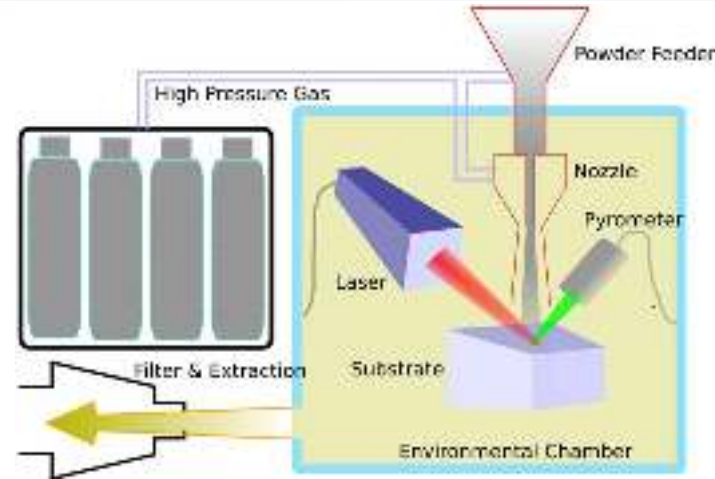
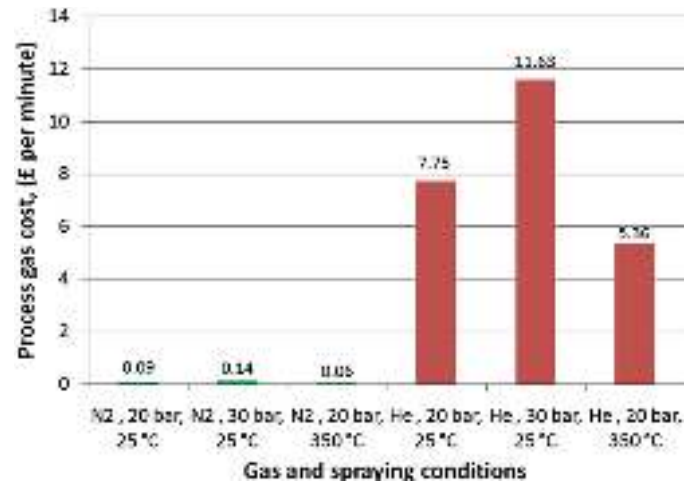


Source: B. Jodoin et al "Pulsed-Gas Dynamic Spraying: Process analysis, development and selected coating examples", Surface & Coatings Technology 201 (2007) 7544–7551

Cu, Zn, Al, Al-12Si and nanocrystalline WC-15Co respectively)

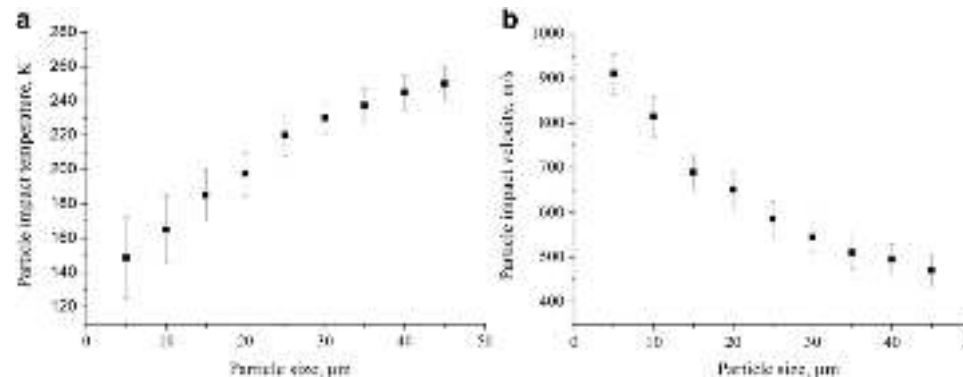
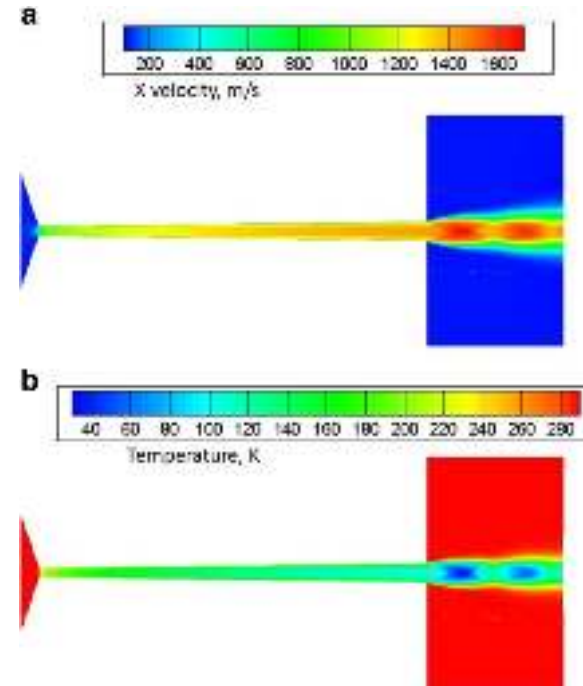
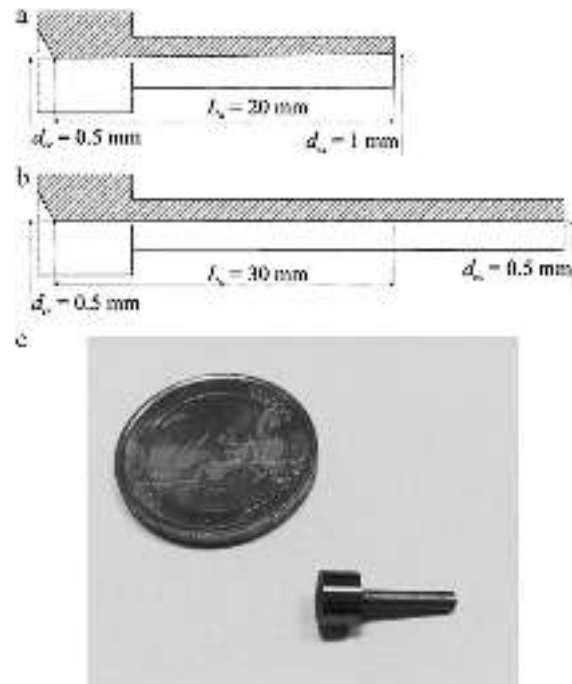


Excitement N. 5: Laser cold spray (it has several names)



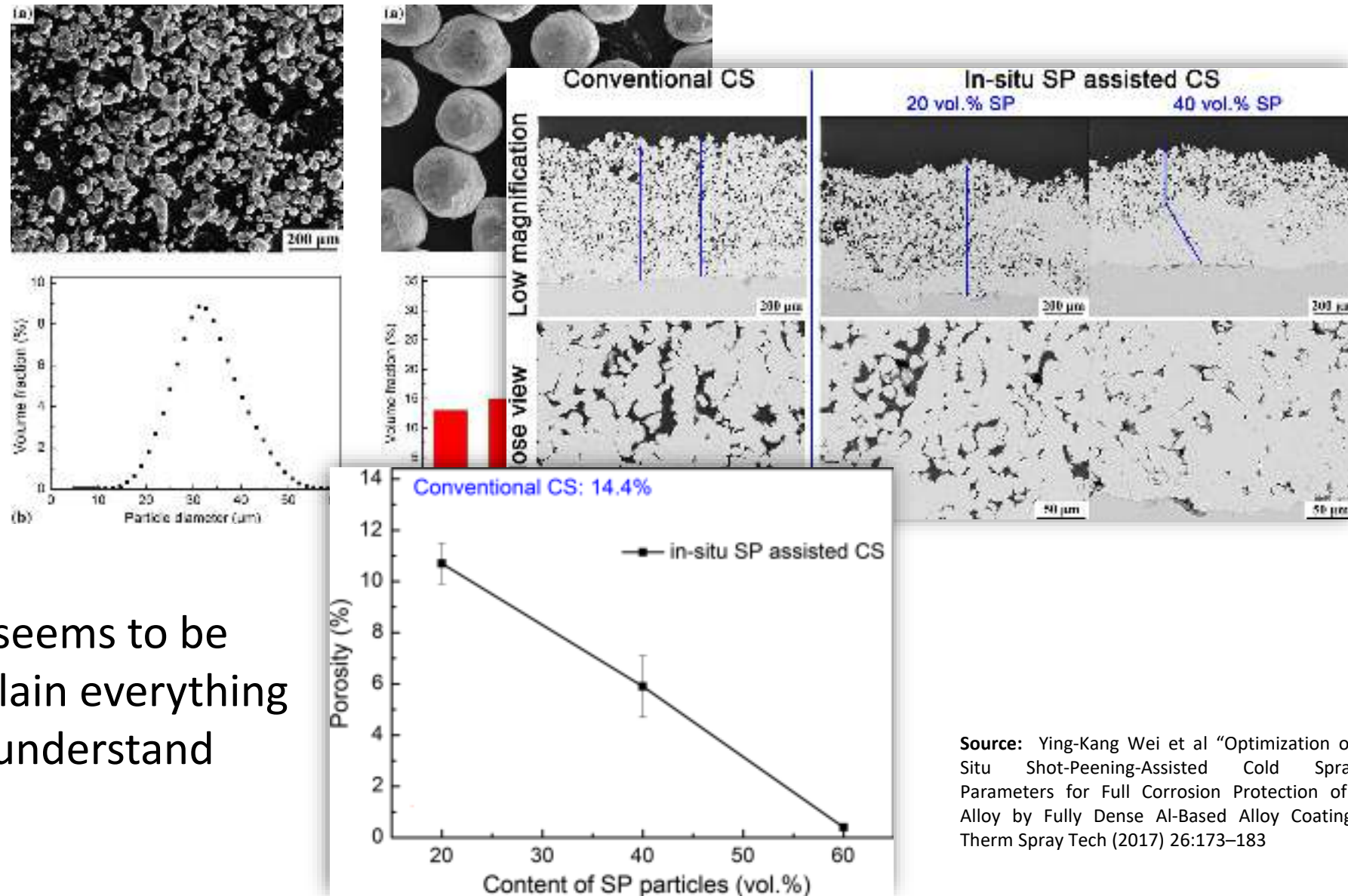
Sources:

- M. Bray et al, Surface & Coatings Technology 203 (2009) 2851–2857.
- R. Lupoi et al, Materials Letters 65 (2011) 3205–3207.
- Bo Li et al, Optics and Laser Technology 100 (2018) 27–39.



Sources:

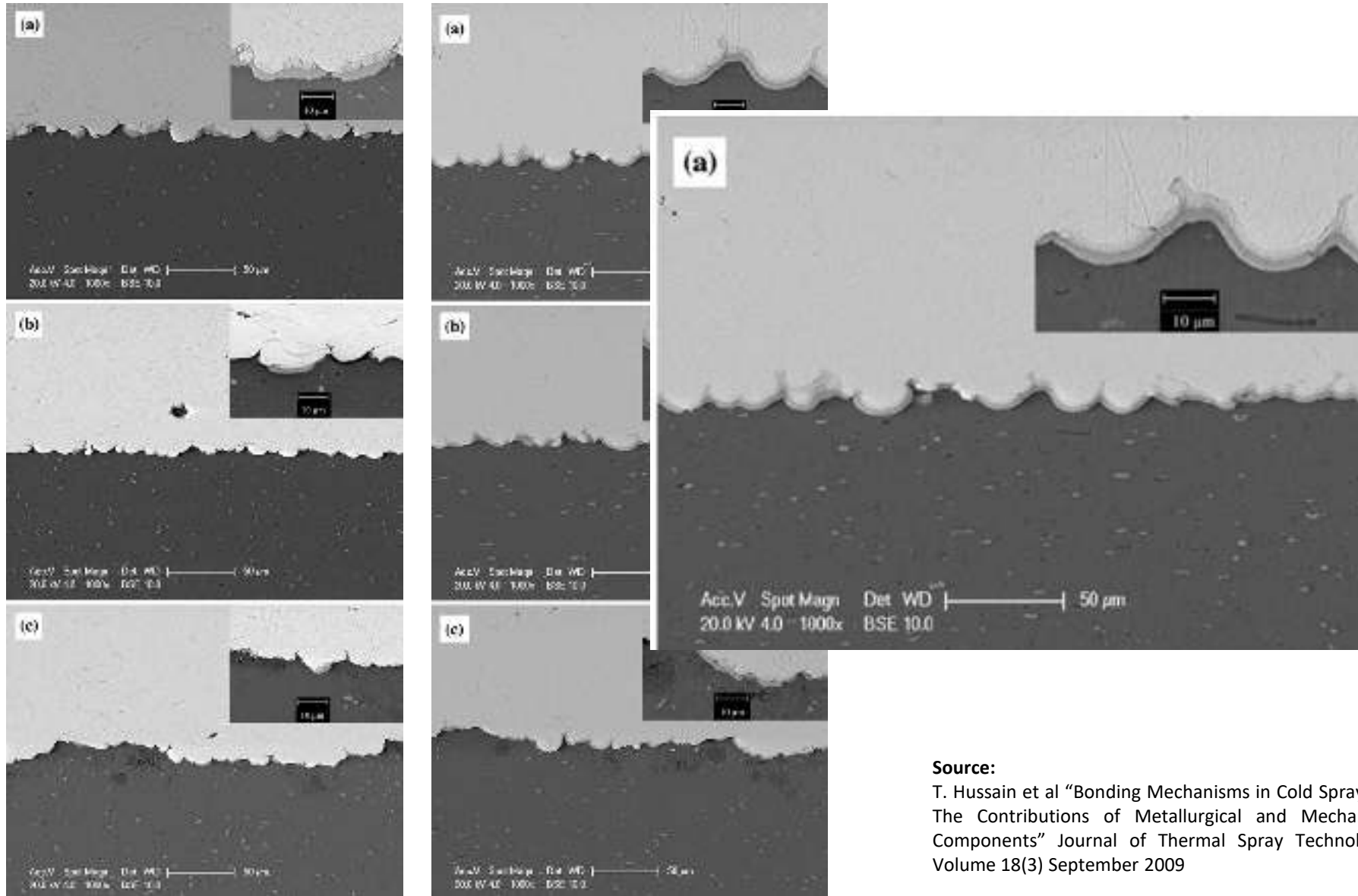
- A.Sova et al “Deposition of aluminum powder by cold spray micronozzle”, The International Journal of Advanced Manufacturing Technology (2018) 95:3745–3752
- A.Sova et al “Preliminary study on deposition of aluminium and copper powders by cold spray micronozzle using helium”, Surface & Coatings Technology 220 (2013) 98–101



...Tamping seems to be able to explain everything we do not understand

Source: Ying-Kang Wei et al “Optimization of In-Situ Shot-Peening-Assisted Cold Spraying Parameters for Full Corrosion Protection of Mg Alloy by Fully Dense Al-Based Alloy Coating”, J Therm Spray Tech (2017) 26:173–183

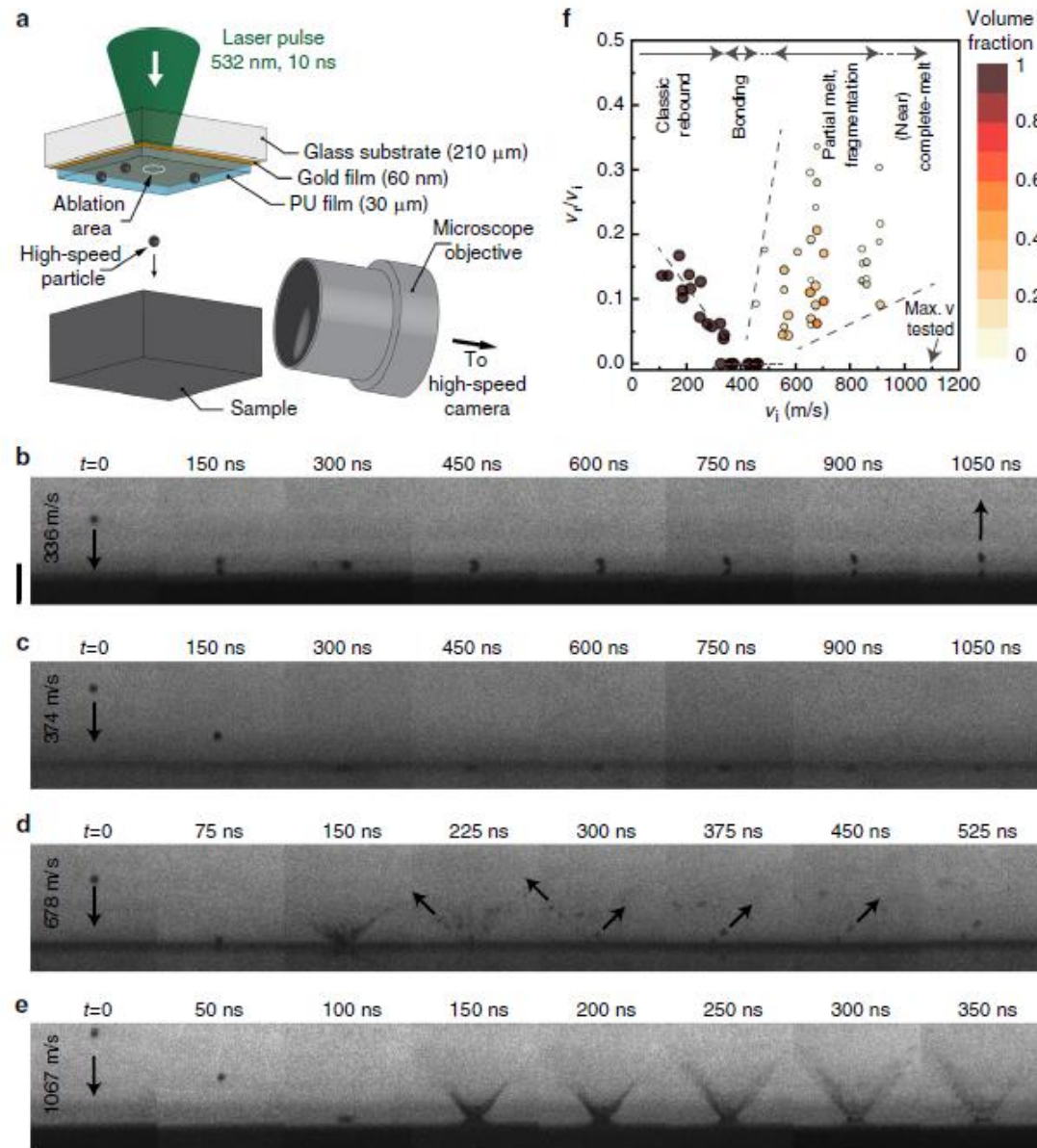
Excitement N. 8: Intermetallics in Cold Spray do exist



Source:

T. Hussain et al "Bonding Mechanisms in Cold Spraying: The Contributions of Metallurgical and Mechanical Components" Journal of Thermal Spray Technology, Volume 18(3) September 2009

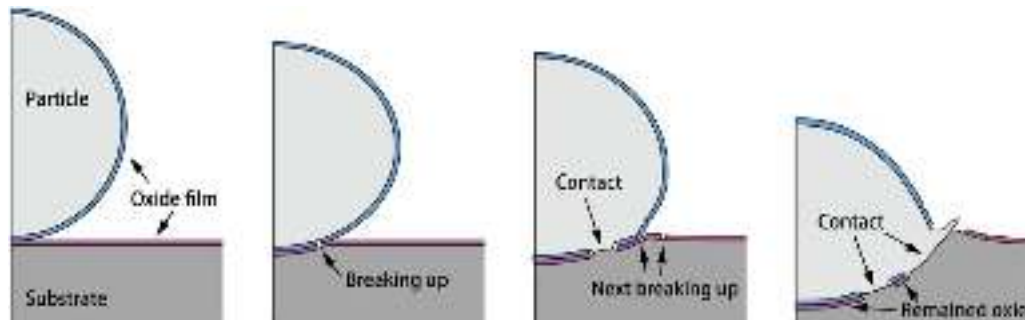
Excitement N. 9: High speed videos of particle impacts



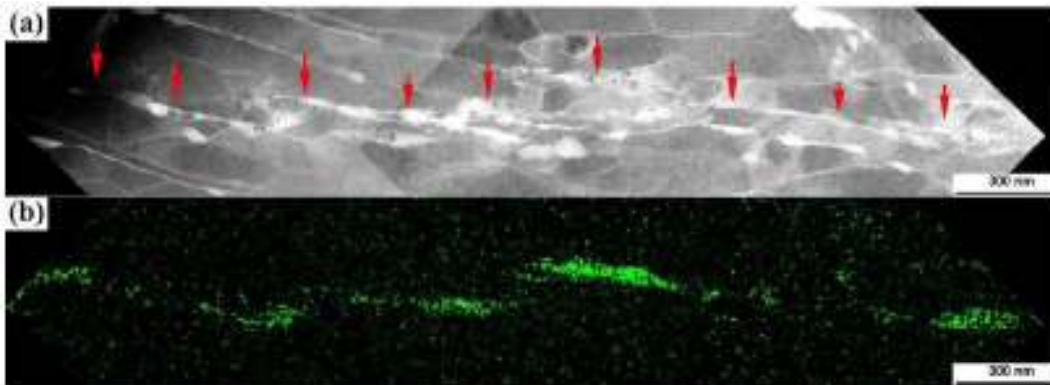
Source:

Mostafa Hassani-Gangaraj et al "Melt-driven erosion in microparticle impact", NATURE COMMUNICATIONS, 2018

Excitement N. 10: CS coatings can have oxides

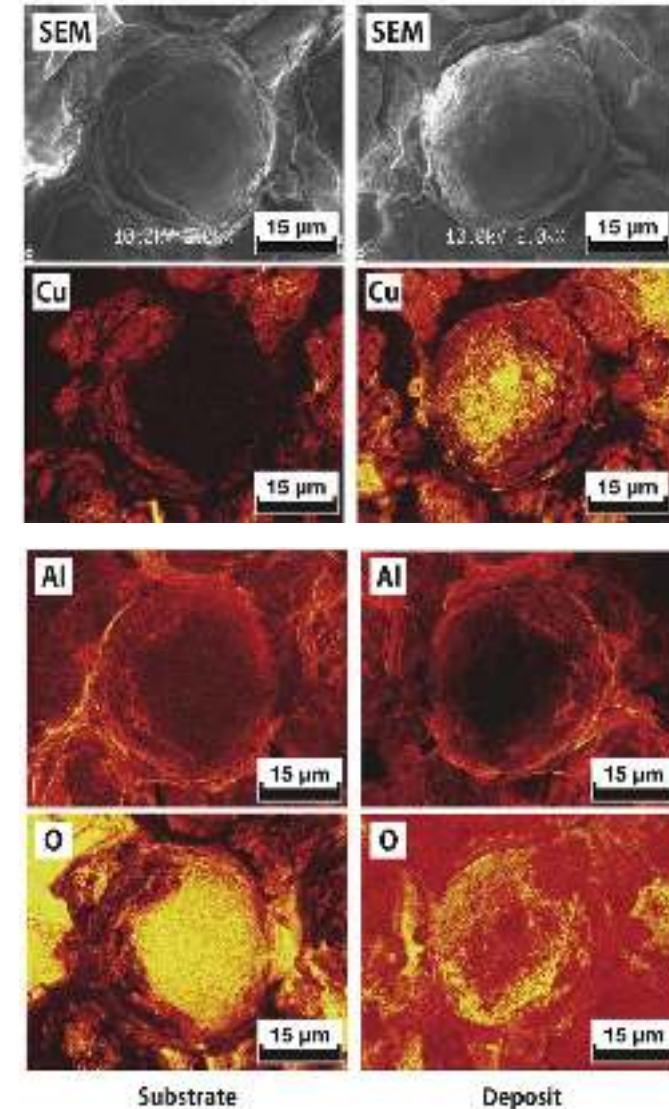


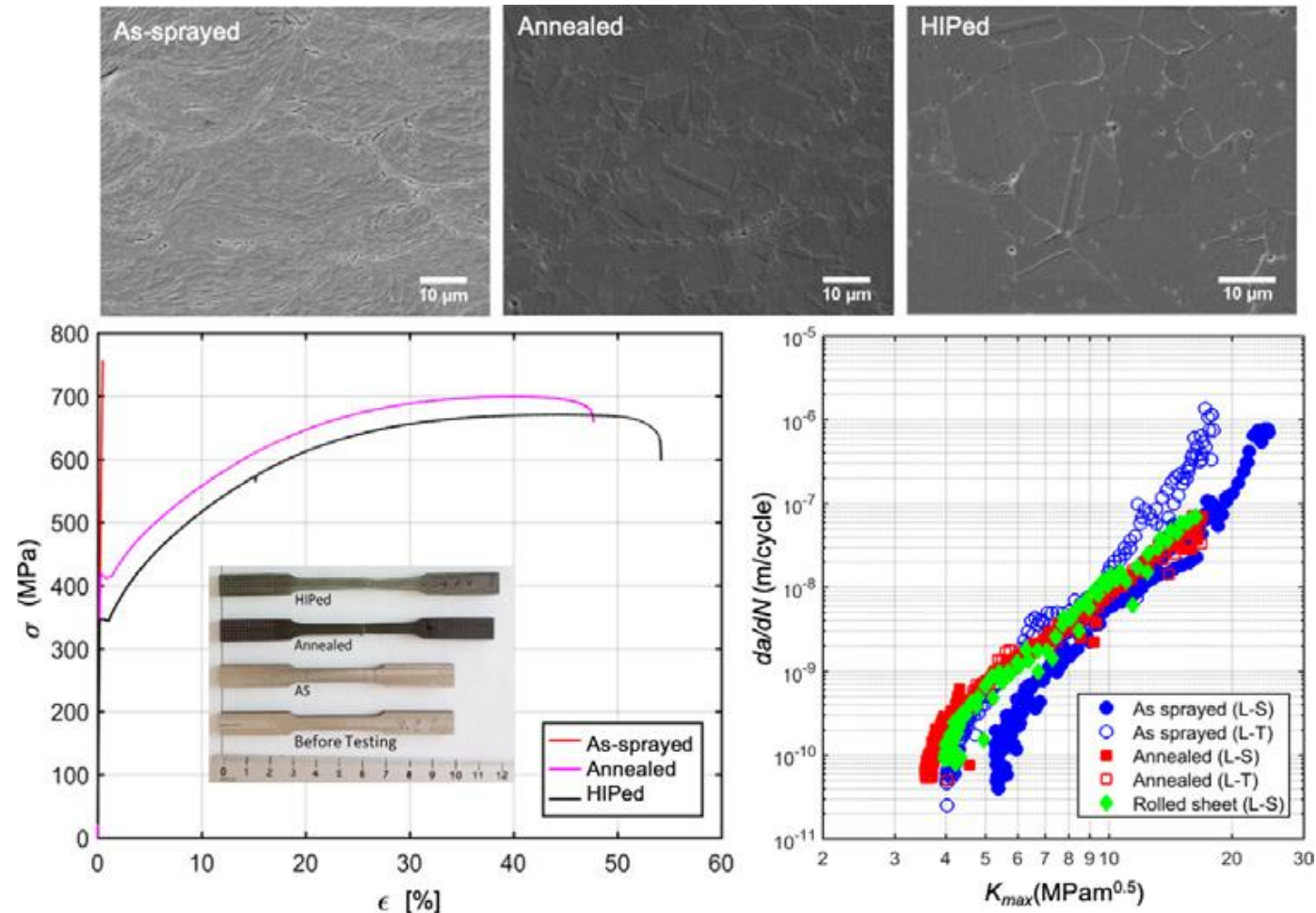
Al 7055



Sources:

- Ying-Kang Wei et al "The mechanism of Enhancement on inter-particle bonding in in-situ micro-forging assisted Cold Spray, ITSC 2019 proceedings
- Y. Ichikawa et al "Elucidation of cold-spray deposition mechanism by auger electron spectroscopic evaluation of bonding interface oxide film", Acta Materialia 164 (2019) 39-49

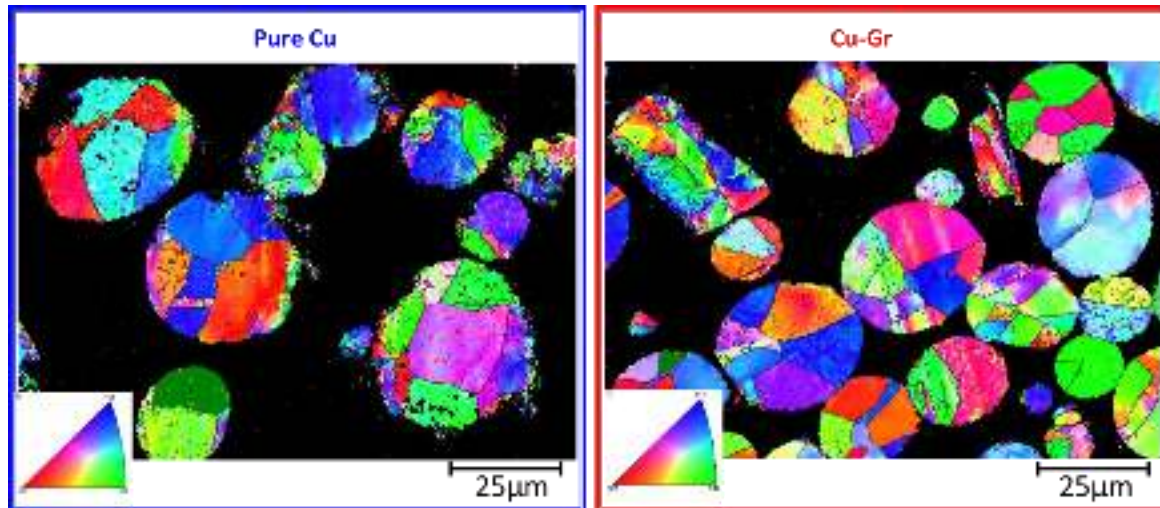
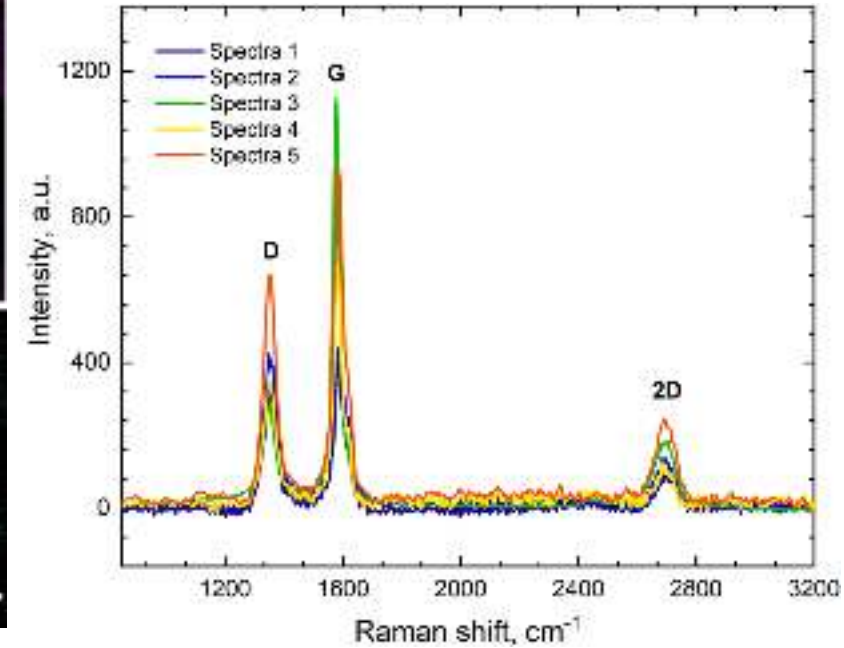
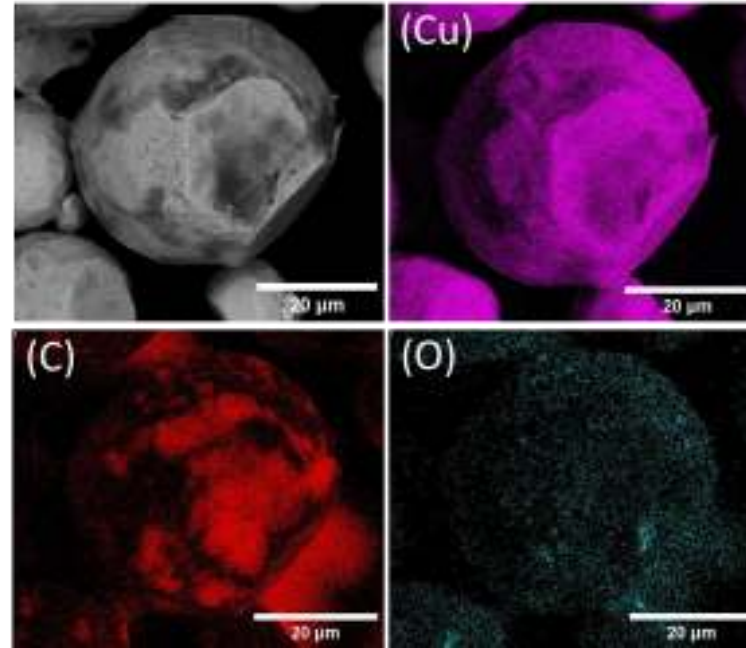
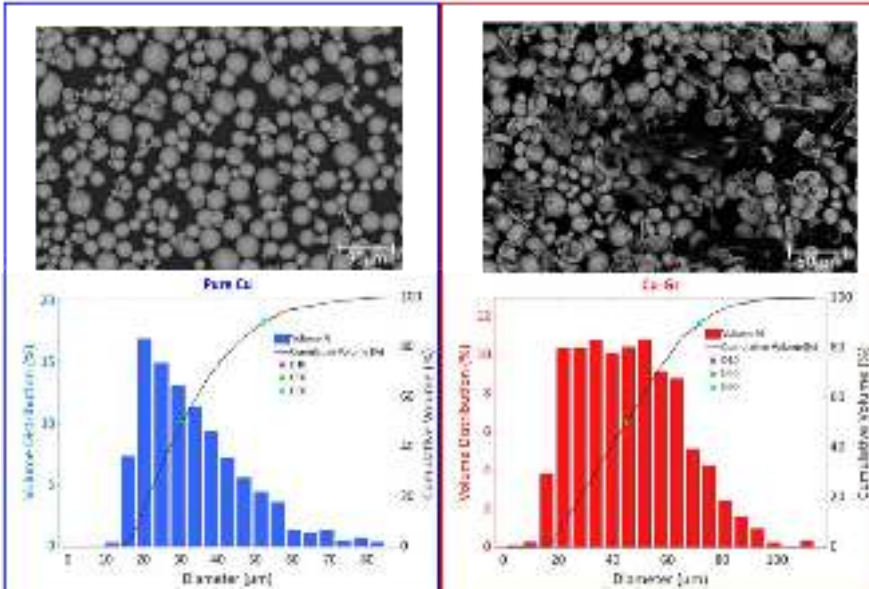




Source:

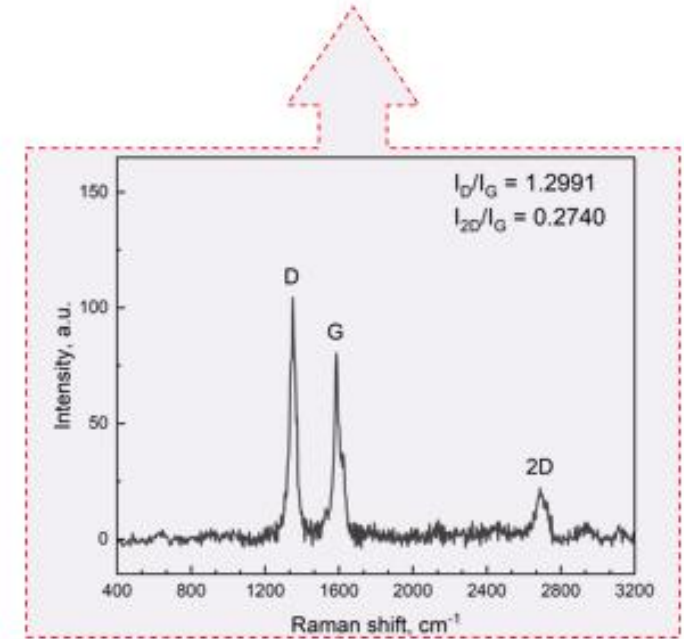
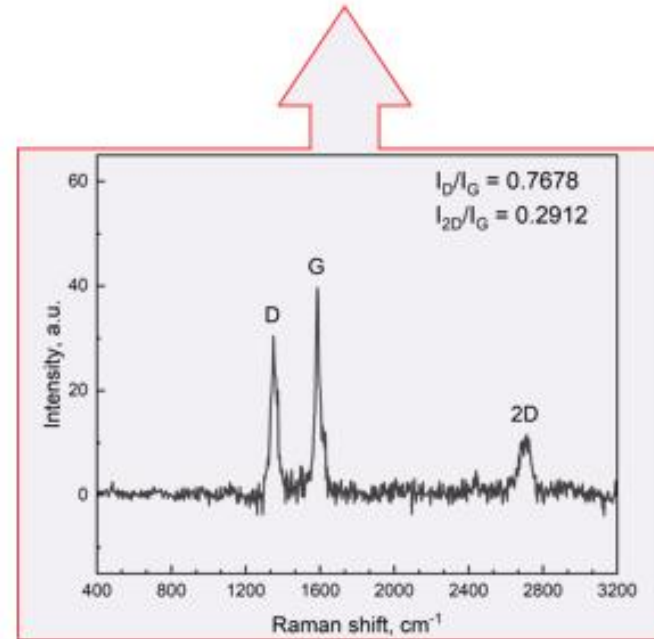
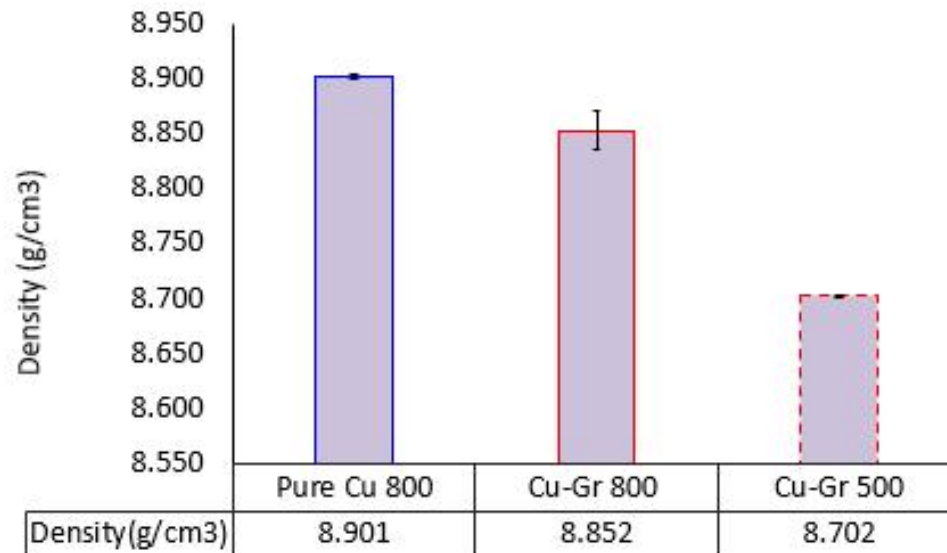
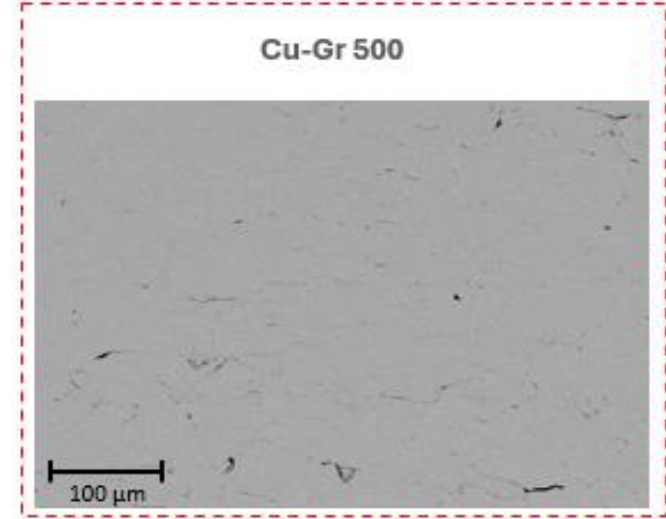
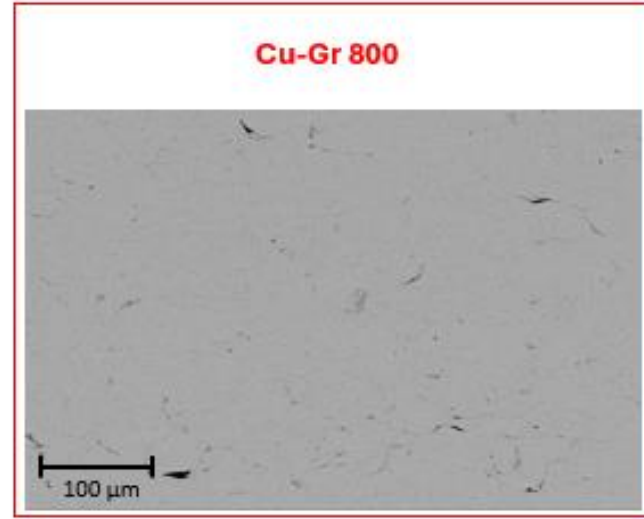
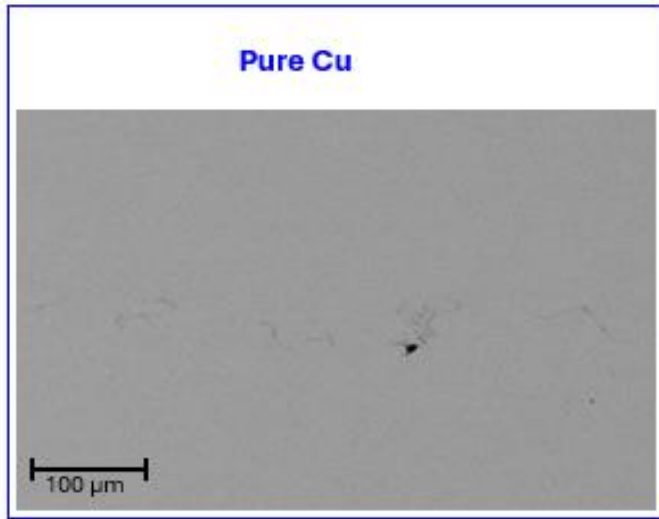
S. Bagherifard et al "Tailoring cold spray additive manufacturing of steel 316 L for static and cyclic load-bearing applications", Materials and Design 203 (2021) 109575

Excitement N. 12: 2D material composites with CS



Source:

F. Zarei et al "Microstructural evolution and mechanical properties of cold sprayed copper-graphene composites", ICEAF 2025, Greece



- ❑ There are many more “excitements”, I only have listed some
- ❑ CS has witnessed, in the past 30 years, key developments in process, equipment, materials and applications
- ❑ The IP landscaping is robust, patents cover many areas
- ❑ We did not witness a CS commercial “explosion” (i.e. such it has been for the computer), but applications are “gently” growing in number (as supposed to be)
- ❑ Overall, the CS journey has been exciting! I do expect the process to continue to grow; one key topic will be materials (powders) **for** CS

B. Jodoin, D. Guo, A. Hawkins, Z. Leclerc, D. MacDonald, A. Nastic, R. Nikbakht, R. Ortiz-Fernandez, S. Rahmati, M. Razavipour, P. Richer

Cold Spray Laboratory, University of Ottawa

M. Kazasidis, N. Fan, S. Yin

STAM, Trinity College Dublin



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin



Thank You for listening!