



The 4th Indian Sakura Science Club Alumni Meeting

# Non-melting additive manufacturing (AM) pioneered by the knowledge of mechanics

力学の知識が開拓する溶融させないアディティブマニュファクチャリング

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**Date:** Saturday, 17th September 2022

**Time:** 11:00 -13:00 (IST), 14:30-16:30 (JST)

**Venue:** JST India Liaison Office and Zoom Webinar

## Yuji Ichikawa

- Associate professor, Tohoku University
- PRESTO Researcher, Japan Science and Technology Agency (JST)

# 材料力学

## Strength of Materials

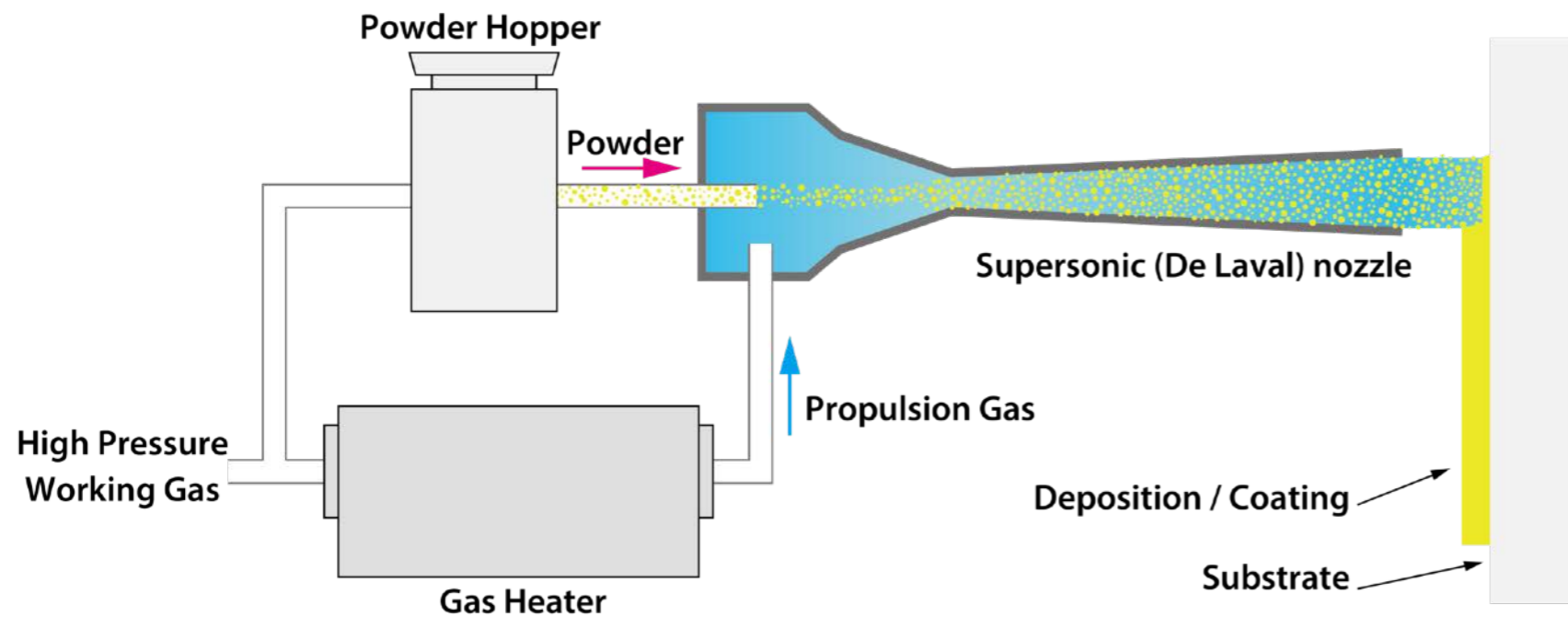
The study of deformation, failure, and fracture characteristics of materials.

**Can we apply material deformation to material processes?**

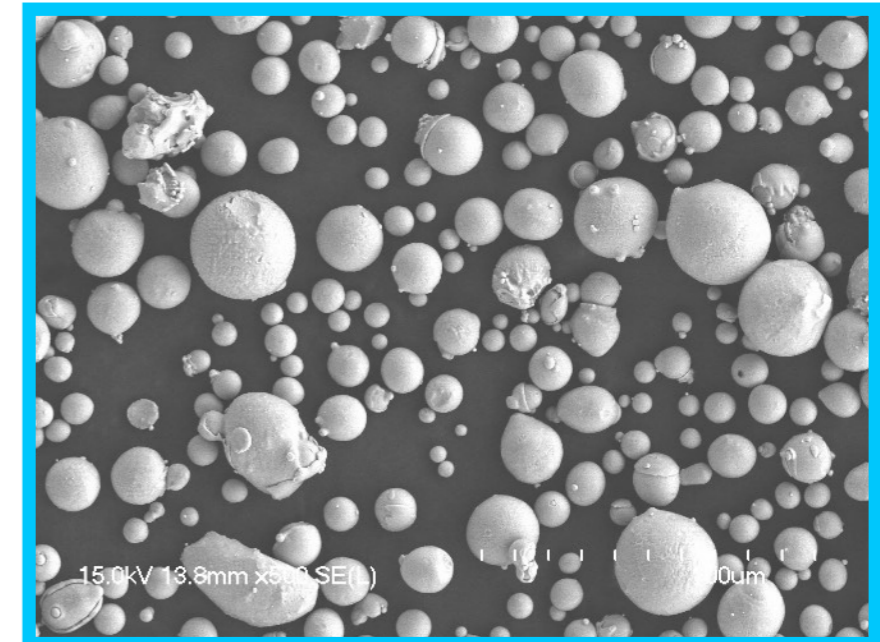
# Solid phase particle deposition process

## Cold spray (CS)

The high-speed impact on a substrate without melting the material particles



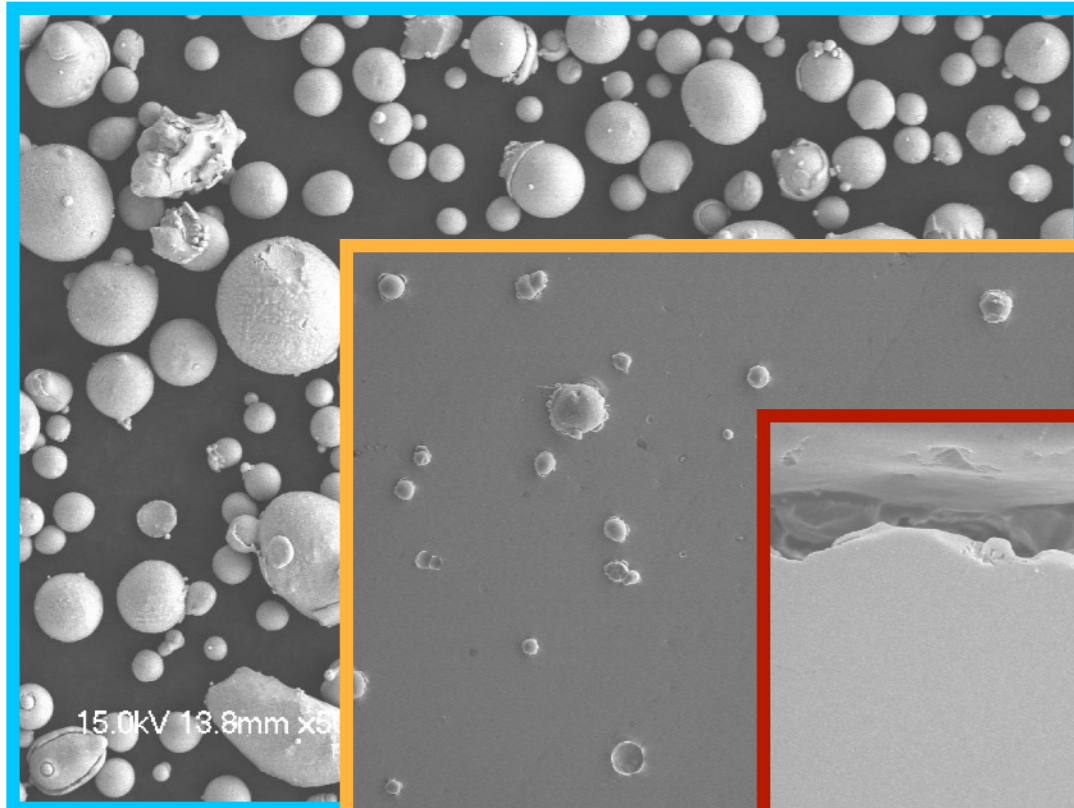
**Cold Spray (CS) Method**



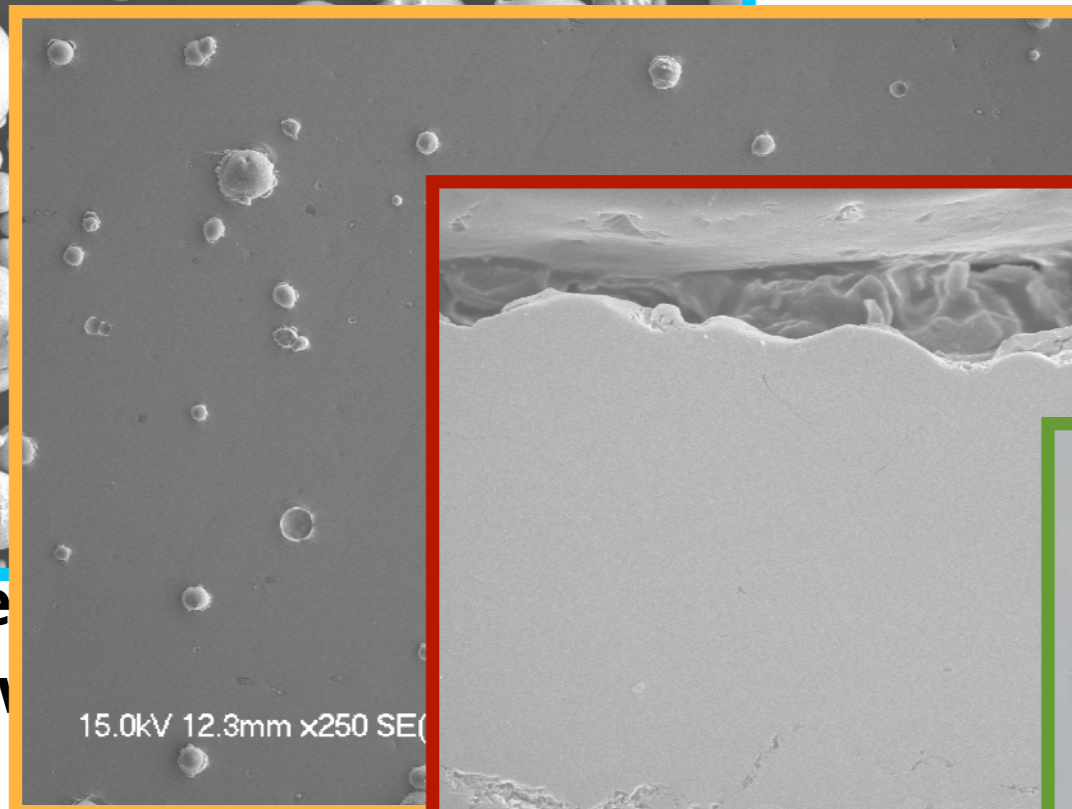
**Feedstock powder**

# Solid phase particle deposition process

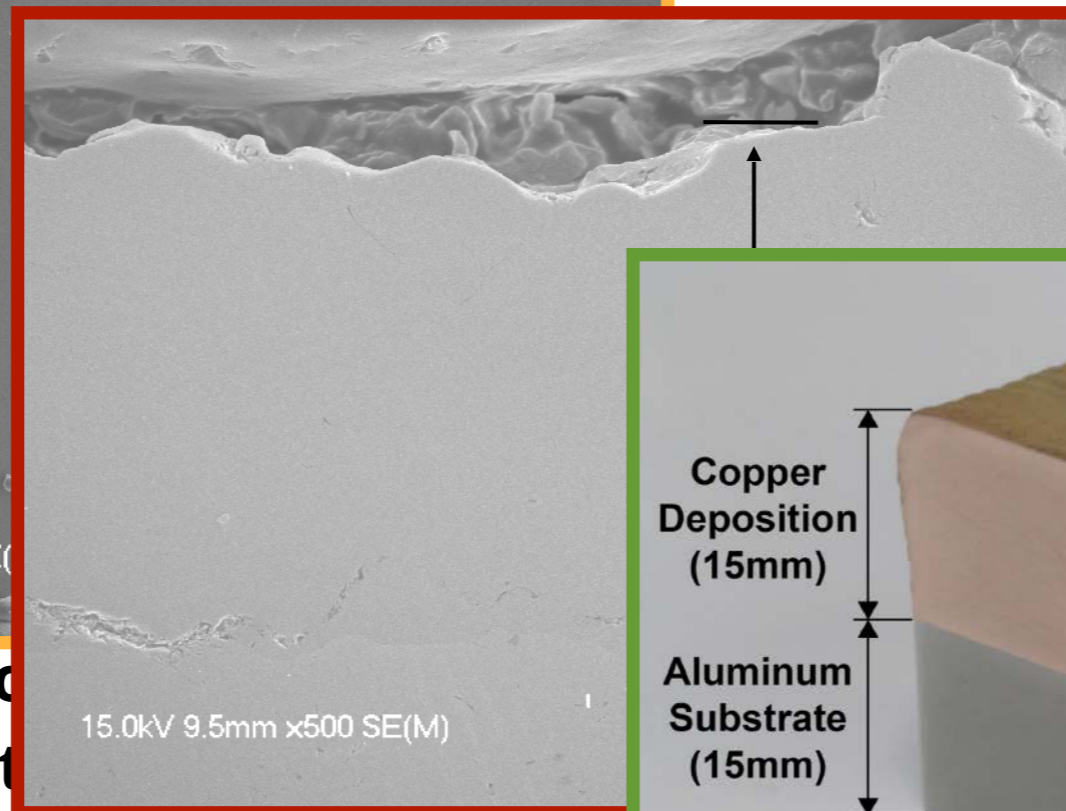
## Cold spray (CS)



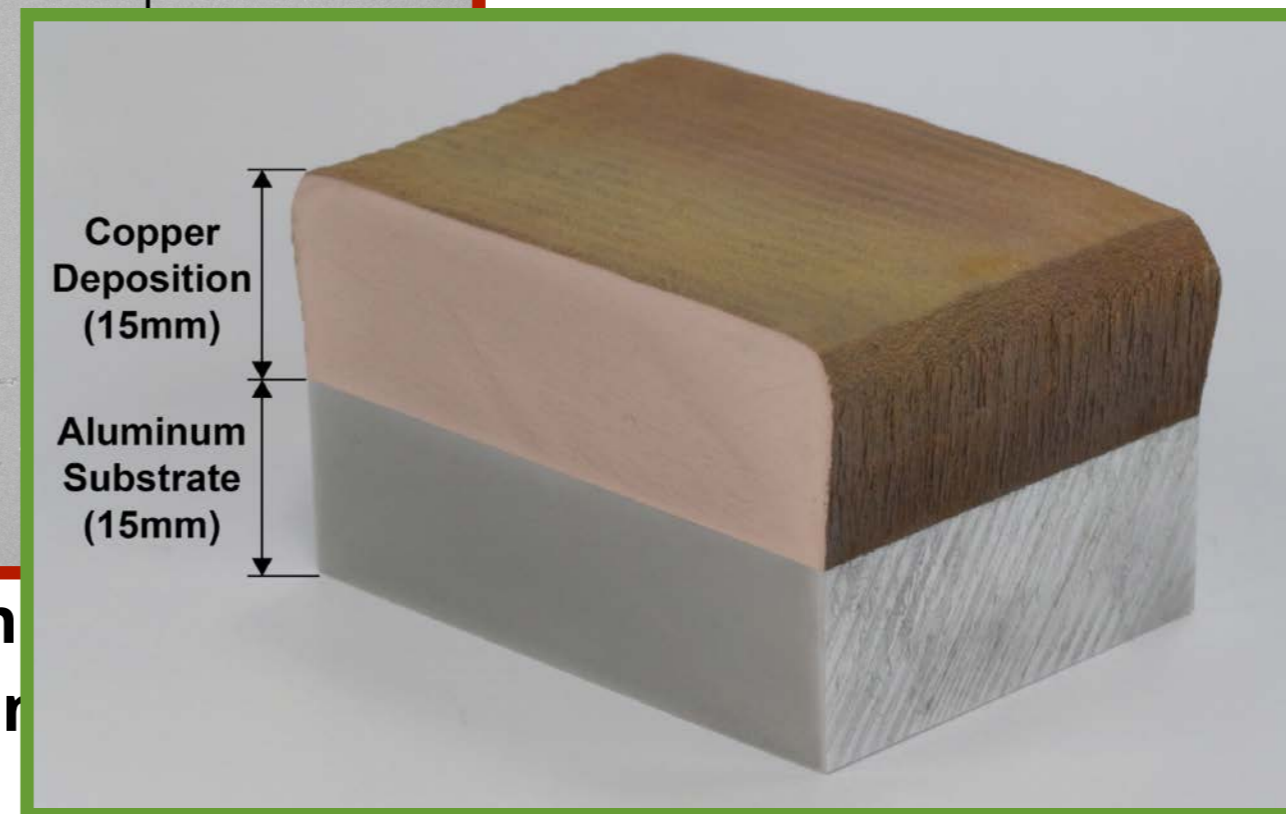
Feed  
(few



Impact of  
(t



Stack and make th  
(cross-section



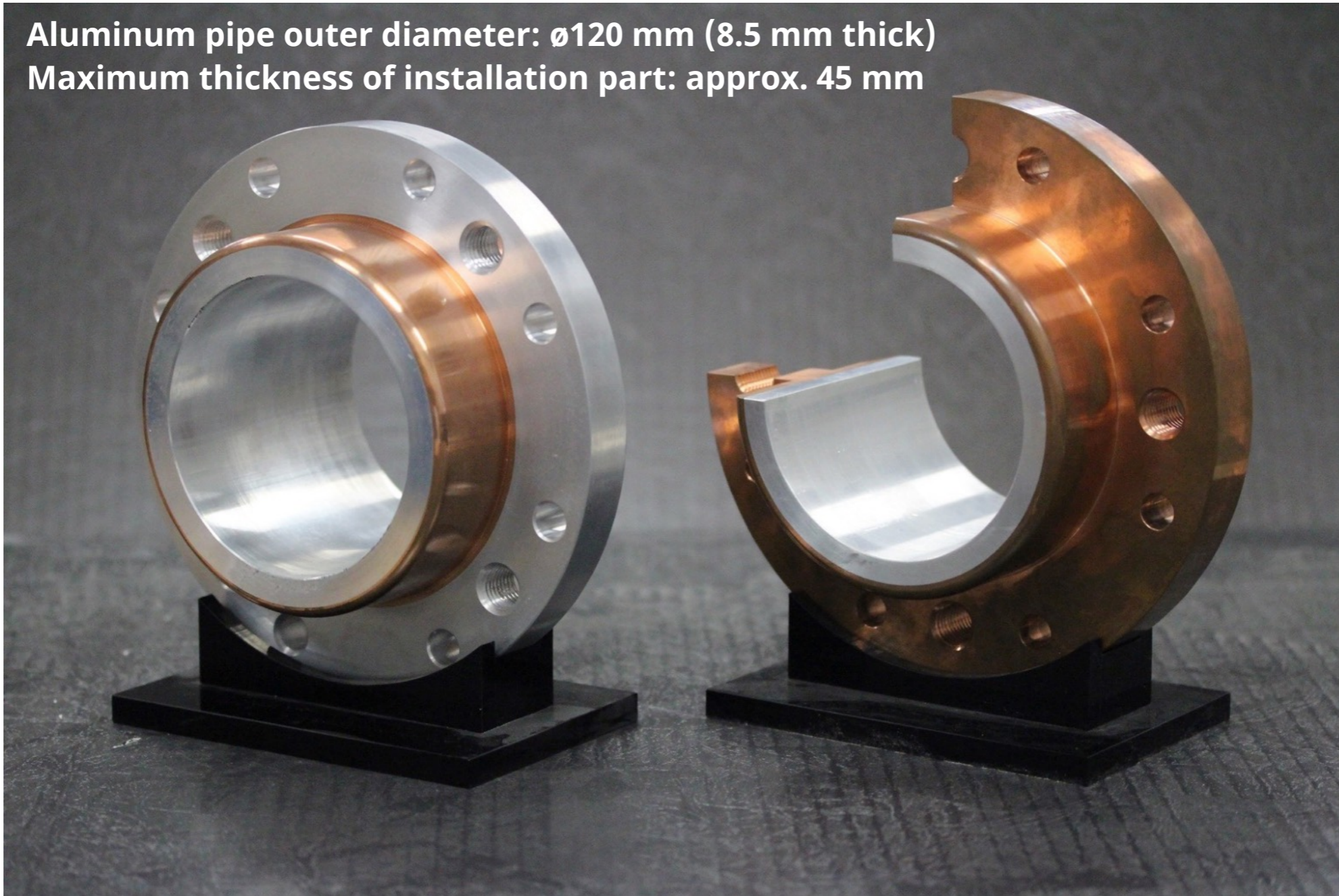
**Thick deposition**



# Solid phase particle deposition process

## Cold spray (CS)

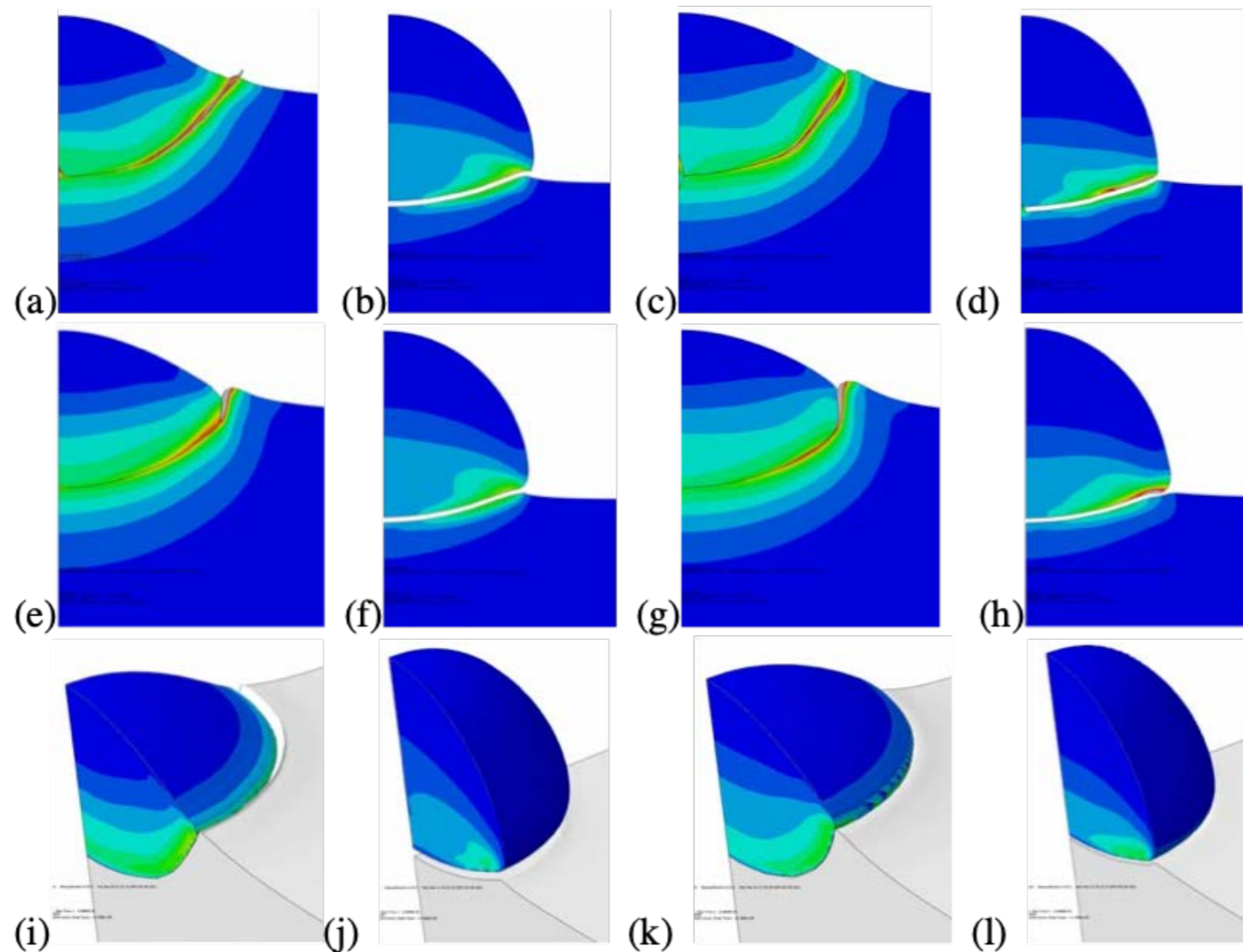
Aluminum pipe outer diameter:  $\varnothing 120$  mm (8.5 mm thick)  
Maximum thickness of installation part: approx. 45 mm



**Copper is installed over aluminum pipe.  
Aluminum is installed on top of it.**

**Copper over aluminum pipe  
(Partially cut)**

# Simulation of the cold spray particle deposition process



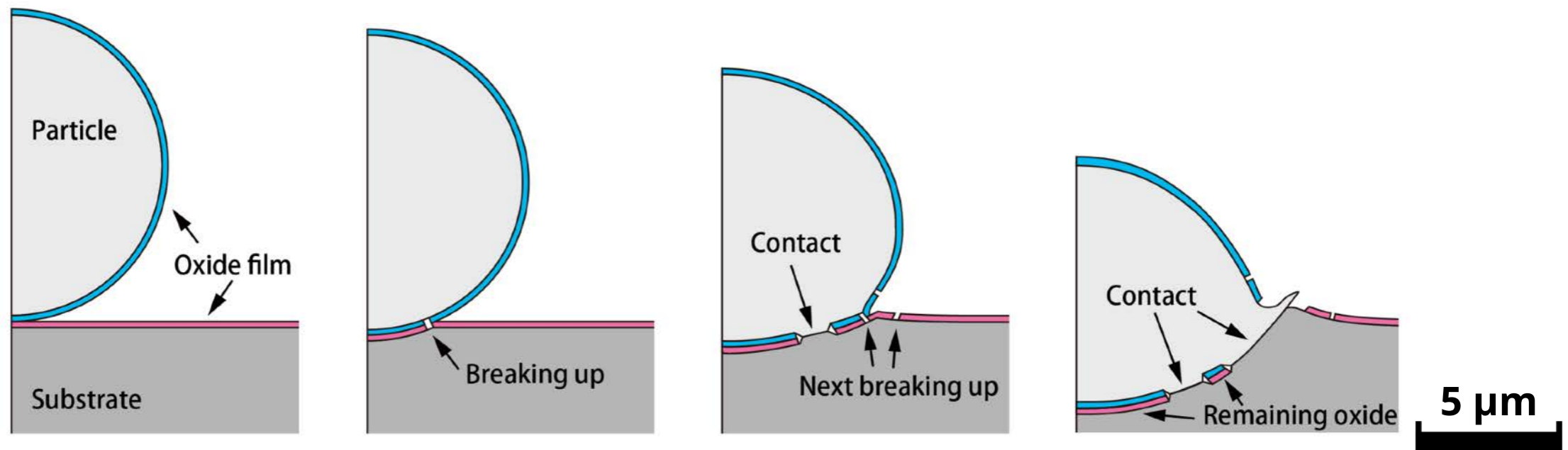
**FIGURE 2.** Contours of the equivalent plastic strain of Cu/Cu(a,e,i), Al/Al(b,f,j), Cu/Al(c,g,k), and Al/Cu(d,h,l) at 400m/s modeled by the Lagrangian method (a,b,c,d), ALE method(e,f,g,h) and CEL method(i,j,k,l).

## [Simulation of the cold spray particle deposition process](#)

J Xie, D Nélias, WL Berre, K Ogawa, Y Ichikawa, Journal of tribology 137 (4)



# Basic deposition mechanism of CS



*Y. Ichikawa et al. Acta Materialia, 164 (2019,) 39-49*

1. Deformation of particles due to external forces
2. Non-equilibrium surface formation due to it
3. Stabilization by a new chemical reaction (joining with a partner)

**Dynamic nanomechanochemistry reactions that occur at the nanoscale and in an extremely short time**

# Summary

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- **Our team considers this phenomenon to be a nano-scale chemical reaction induced by mechanics, and we are trying to understand the phenomenon using a mechanical engineering-based approach.**
- **Future Challenges, Our Dreams:**
  - We want to be able to handle a wider variety of materials more freely.
    - Polymer: YES, we can! Dr. Kesavan Ravi, IIT (ISM) Dhanbad
    - Ceramics
- **Your cooperation is indispensable to making this dream a reality!**
- **We look forward to a Future Collaboration with you!**
- **We would be pleased if this fascinating field of research could be a key to promoting India-Japan exchanges.**



# Acknowledgements

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- **The subsequent budgets support this research. We want to express our gratitude to all the people involved.**
  - JST PRESTO: JPMJPR2091
  - JSPS KAKENHI: 16KK0140, 15H05501
- **If you have any questions, please get in touch with me via e-mail**
  - Yuji Ichikawa, Ph.D. ([ichikawa@tohoku.ac.jp](mailto:ichikawa@tohoku.ac.jp))
- **About CS deposition mechanism (review paper, Open access)**
  - Y Ichikawa, K Shinoda: Current status and challenges for unified understanding of bonding mechanism in solid particle deposition process, Materials Transactions, 2021.
  - <https://doi.org/10.2320/matertrans.T-M2021813>

