Physically Based Constitutive Modeling on the Ultra High-Rate Deformation of Metals in Additive Manufacturing

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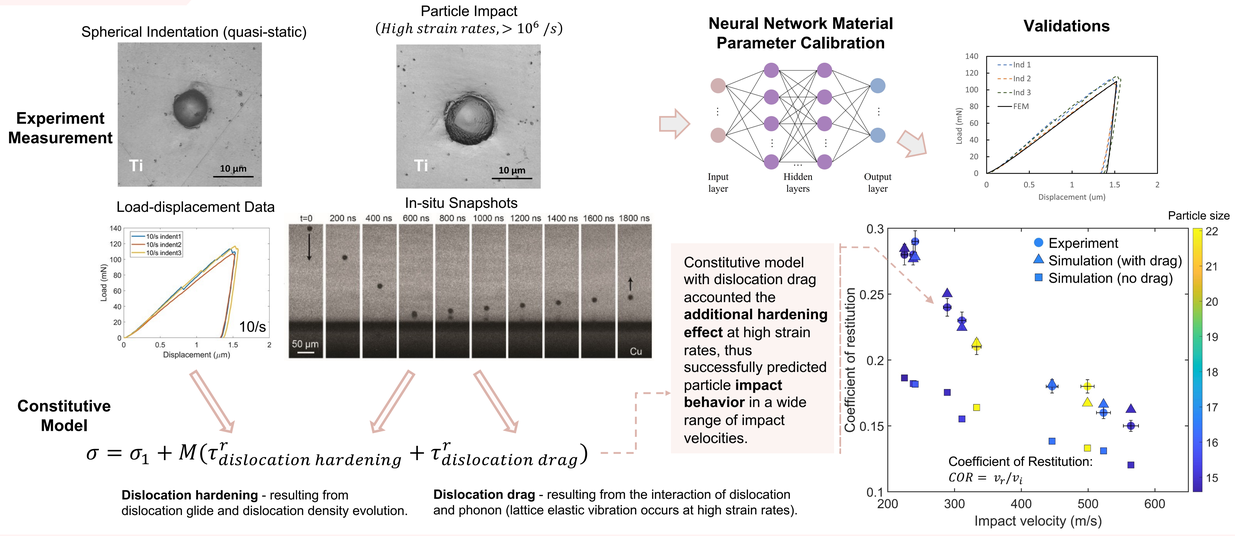
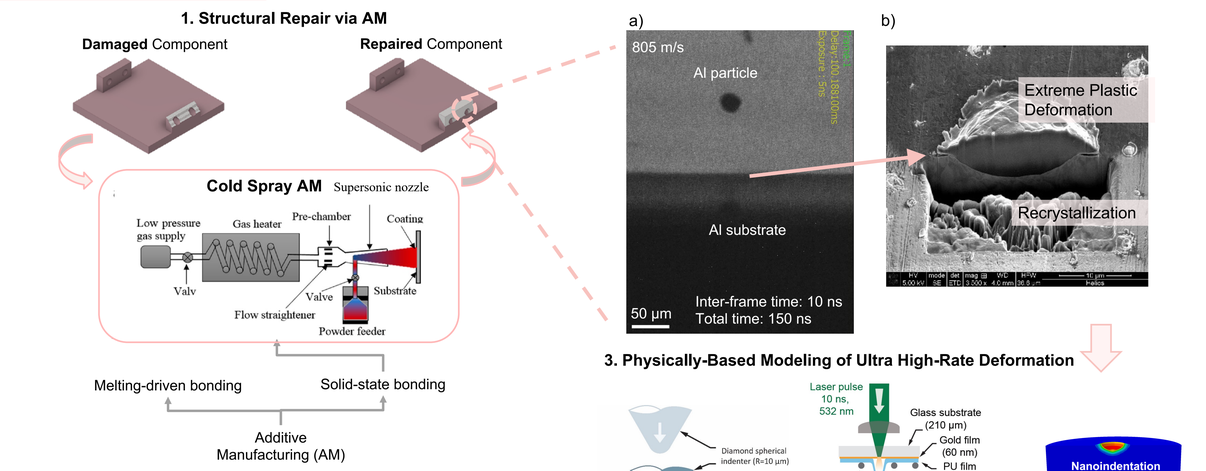
Highlights

- Focusing on the **unit process** of **cold spray additive manufacturing**, understanding the **material behavior** and **microstructure evolution** in the process of particle-substrate impact at ultra high velocity.
- Material's mechanical behavior in a wide range of strain rates is measured by nanoindentation and laser induced particle impact test (LIPIT).
- Dislocation-based constitutive model with deformation mechanisms activated at different strain rates.
- Predicted material behavior in ultra high-rate deformations, simulation providing estimation of resultant microstructure and plastic work.

Methods

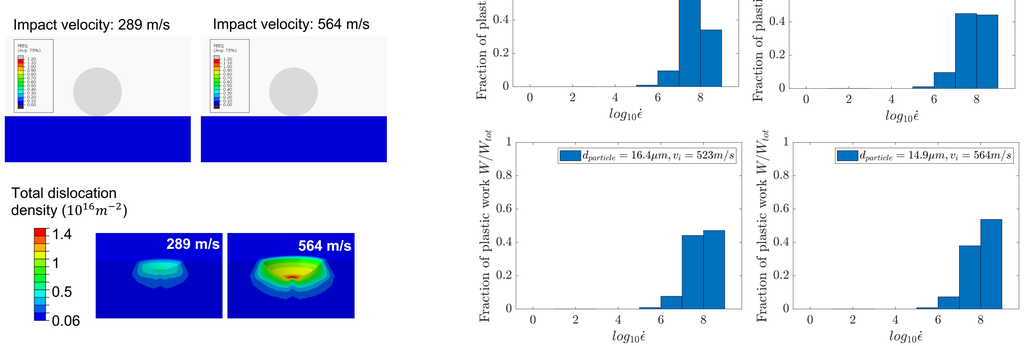


Introduction



1. Illustration of structural repair of metal components using cold spray additive manufacturing. **2. a)** The unit process of cold spray, ultra high-rate metal particle-substrate impact and subsequent bonding, reproduced by LIPIT, **b)** bonded interface characterization, microstructure change and extreme plastic deformation on both particle and substrate. **3.** Spherical impression-based approach for physically-based constitutive modeling of materials in ultra high-rate deformation.

Results and Discussion



Top Left: FEM aminates for two impact cases. **Bottom Left**: Higher impact velocity results in higher dislocation density at the south pole of the impact crater, evidencing a more sever dynamic recrystallization. **Right**: Plots of fraction of plastic work done at different strain rates. As impact velocity increases, plastic work moves to higher strain rates, indicating a more extreme plastic deformation happens at higher impact velocity.

$$\Delta W_{j,k} = \sigma_{j,k} \Delta \varepsilon_{p\,j,k} v_j$$

W : Plastic work done
σ : Stress
ε_p : Plastic strain
v : Elemental volume
j : jth volume element
k : kth time increment