

Shear-Deformation-Induced Modification of Defect Structures and Hierarchical Microstructures in Miscible and Immiscible Alloys

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Shear-based deformation is used for several advanced materials' processing methods such as friction-stir-based processing, welding, or additive manufacturing[1-5]. In these processes, the mechanical-thermal coupling obscures a deep mechanistic understanding of the microstructural evolution of multi-phase metallic systems under extreme shear deformation, and the knowledge of how these microstructures influence mechanical properties is in its nascency (Figure 1). The challenge arises from the complexity and interdependent nature of many atomic-scale to macroscale phenomena that can occur when materials are subjected to shear deformation-based processing. Using multi-modal correlative microscopy techniques and computational simulations, the change in dislocation density and local misorientations, grain/phase boundary migration, dynamic recrystallization, and further deformation of recrystallized microstructures during the processing are characterized. In this work, we highlight the influence of shear deformation on the microstructural hierarchy and mechanical properties of binary alloys such as Al-Si, Cu-X (X = Nb, Cr or Ni). Our studies show that shear-deformation-induced grain refinement, multiscale fragmentation, and metastable solute saturated phases with distinctive defect structures lead to a significant increase in the flow stresses measured via micropillar compression[6]. These results highlight that shear deformation during solid-phase processing can achieve persistently metastable microstructures with enhanced mechanical properties alloys with varying solute miscibility. The experimental insights obtained here are crucial for developing atomic-scale to mesoscale predictive models for microstructural evolution of alloys under high strain shear deformation.

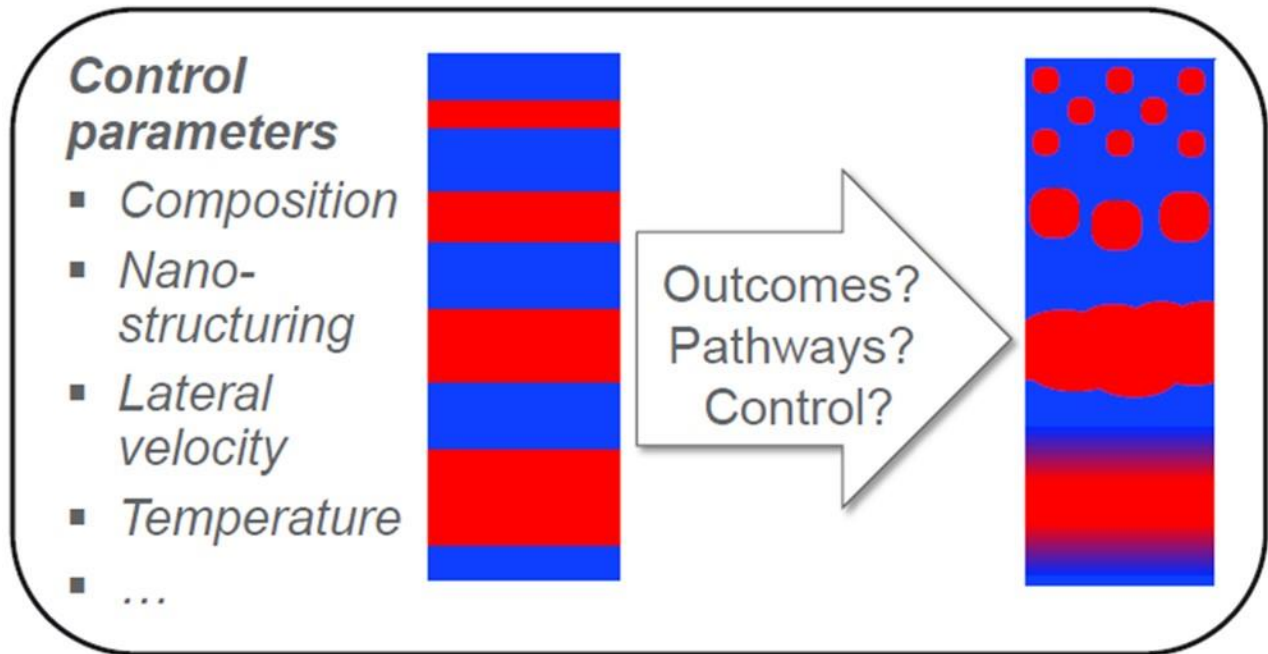


Figure 1. Figure 1. Schematic showing the present knowledge gap in the understanding the influence of processing parameters on the final material microstructure in solid phase processing

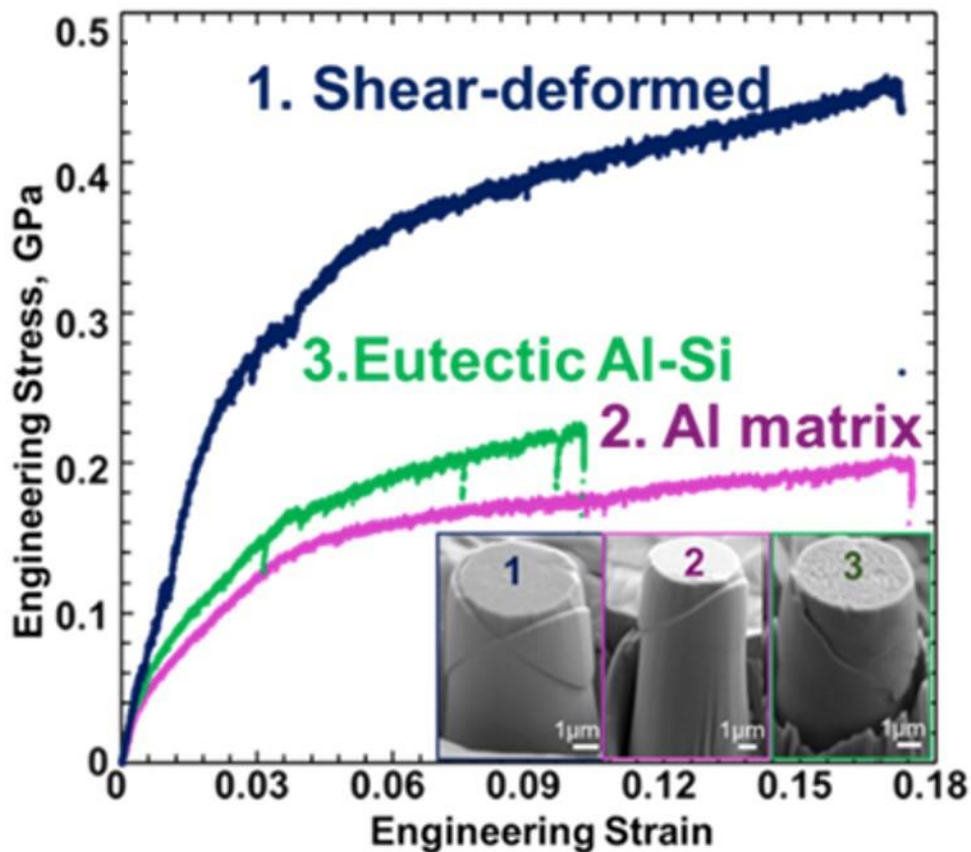


Figure 2. Figure 2: Nanomechanical testing if shear processed and as-cast microstructures show a 2-fold improvement in the mechanical properties after solid state shear processing of alloys (reproduced from published article[6]).

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