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Introduction

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Plasticity and Fracture at the Nanoscales – Advances in *In Situ* Experimentation Techniques Enabling Novel and Extreme Materials/Nanocomposite Design

This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.

Introduction

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Plasticity and fracture of materials at the nanoscales can deviate significantly from the same phenomena in bulk properties, which may have important implications if the materials are to be used effectively in real world engineering systems. Nanoscale materials and composites have been known to have important effects related to size, but today many other emerging materials – due to or enabled by novel manufacturing routes (additive manufacturing, or bottom-up approaches such as atomic or layer-by-layer deposition methodologies) – combined with 3D multi-hierarchical microarchitecturing have been reported to approach extreme limits of materials properties.

This is the first Focus Issue of *Journal of Materials Research* on *Plasticity and Fracture at the Nanoscales – Advances in In Situ Experimentation Techniques Enabling Novel and Extreme*

Materials/Nanocomposite Design, published in May 2019. In this Focus Issue, we have captured a portion of the broad spectrum of research representing some of the most important recent advances in the *in situ* experimentation of plasticity and fracture, especially those that enable the innovative development and extreme design of materials and nanocomposites with enhanced mechanical properties reaching or approaching the extreme limits of materials properties. All fundamental studies on mechanical properties of nanoscale/extreme materials and nanocomposites including *ex situ* and *in situ* SEM/TEM, synchrotron X-ray experiments, as well as modeling and simulations on relevant length scales have been included and discussed. Nanomaterials/nanocomposites of interest include metals, ceramics, polymers, amorphous materials and their derivatives containing carbon-based materials.

This *JMR* Focus Issue provides readers up-to-date information on the impact of these recent experimentation capabilities – the ability to observe directly how plasticity and fracture events interact with microstructures at the nanoscale – and how it could affect and enable novel and extreme materials and nanocomposite design. More importantly perhaps is how these recent advances in *in situ* techniques have indeed led to the unraveling of novel fracture toughening mechanism, and thus further discovery/design of new materials with such novel mechanisms.

We hope the readers will find this volume to be a significant collection of papers representing the rapid advancement in the field of in situ experimentation techniques. Finally, we are very grateful to both the authors and reviewers of the many high-quality manuscripts submitted to this *JMR* Focus Issue on *Plasticity and Fracture at the Nanoscales – Advances in In Situ Experimentation Techniques Enabling*

Novel and Extreme Materials/Nanocomposite Design.

ON THE COVER:

The cover of this Focus Issue shows a tale of two fabrication paths of the same Cu/Nb nanolayers – an important insight that is only possible with an in situ experimentation technique. Cu/Nb fabricated by PVD (Physical Vapor Deposition) exhibits a catastrophic fracture (a) rather unexpectedly (Cu/Nb nanolayers have been hitherto reported to be deformable to large strains), while substantial notch widening (accommodated by interfacial sliding, as shown in b) was observed via *in situ* experiments for the Cu/Nb samples fabricated by ARB (Accumulated Rolling Bonding) method. Such insights could only be obtained and further investigated with cutting-edge *in situ* small-scale mechanical testing inside an SEM (Scanning Electron Microscopy). The crack only starts to propagate at later stages and tears through the beam with large shear instabilities (c). Such *in situ* observation could result in the unraveling of potentially novel mechanisms for ductile fracture (and thus enhanced fracture toughness) involving interfacial sliding at the nanoscales.