THE SMALLEST MACROSCALE TENSILE TEST – A MODEL TO DESCRIBE CONSTRAINED FLOW AT THE MICROSCALE

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This work addresses the strain response and plastic flow behavior of grain boundary or interface containing materials during small scale mechanical testing. We introduce a set of geometric criteria allowing us to constrain a sample to obtain macroscopic-like flow behavior on a microscale test, as shown in Figure 1. Furthermore, the featured parameter, the blocked volume ratio, provided a new description of plasticity of microscale tensile samples in a constrained volume due to external interfaces such as coating and grain boundaries. The proposed description was experimentally validated with different Ni-based materials and different constraints (grain boundary and coating interfaces). The developed theory would open new research avenues in establishing the connection between microscale response to bulk properties as follows:

- The proposed concept of blocked volume ratio presents a simple but yet effective way to predict a material flow behavior (necking vs. slip) at the microscale. The developed model is demonstrated for FCC single crystals; therefore, it is of high interest to extend the model to other crystal systems.

- Understanding and predicting what mode of plastic deformation past yielding opens the door to obtain macroscopic behavior on microscopic samples. It introduces the new opportunity for obtaining representative macroscopic properties of site-specific microstructural features of materials and potentially eliminate the costs, feasibility, and safety concerns associated with bulk-scale measurements in many applications such as thin films, nuclear power, and miniaturized devices.

- Further, the blocked volume concept can be utilized to encourage interfacial failure by suppressing “slip band formation mode” in nearby materials; therefore, it enables a direct examination of interfacial strength, such as grain boundaries, at the microscale. Important interfacial failure modes in alloys such as stress corrosion cracking, helium embrittlement, and hydrogen embrittlement can then be investigated using small scale testing.

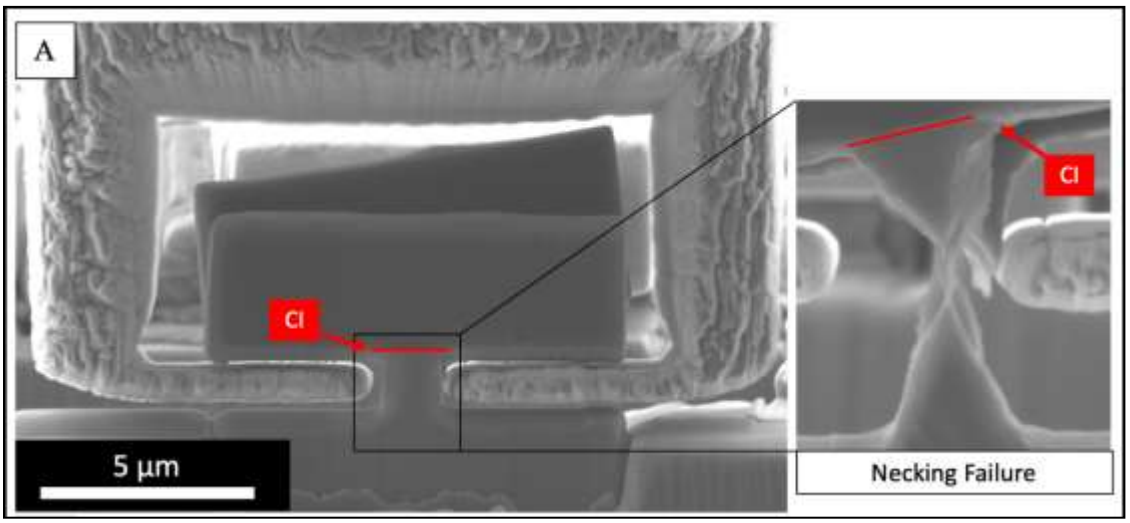

Figure 1. SEM image shows the macroscopic-like deformation of the microscale tensile sample containing a coating interface (CI)