Bridging the length scales on mechanical property evaluation

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ABSTRACT:

Small scale mechanical testing has gained significant attention in the nuclear materials community in recent years. The clear benefits of utilizing small length scales in nuclear materials research range from reduction in radioactive materials volume and hence enhancement of safety, obtaining mechanical property's from ion beam irradiated materials, increased number of statistics based on a limited amount of sample material available to probing of specific regions of interest on a component or microstructure. In addition these techniques allow to enhance the understanding of deformation mechanisms on irradiated materials and allow to be used for modeling benchmarks. In recent years significant progress was made in developing the appropriate techniques and new insight into irradiated material deformation mechanisms has been obtained. However, gaining reliable bulk properties from these tests still remains a challenge due to scaling artifacts. In the past significant attention has been given to size effects on simple model materials, but translating this knowledge to engineering alloys relevant to the nuclear materials community has not been accomplished yet.

This work features a combined experimental and modeling approach driven by data and science addressing these issues with a specific focus on high fidelity in the obtained data. We will conduct multi scale tensile test experiments from 1um to 1mm on representative F/M, austenitic and nanostructured alloys relevant to the nuclear community. A multitude of previously developed techniques are going to be used to span three orders of magnitude in length scale. Special attention will be given to multi-laboratory blind testing to enhance the confidence the community has in these methods. The experimental efforts are accompanied with development of continuum models based on input from finite element and dislocation dynamics approaches to derive scaling master curves on the selected materials. Both strengths and strain are of interest and will be studied here. We will generate master curves for both since they are the most relevant input data needed for materials assessment. Further, we aim to obtain a fundamental understanding of the plasticity interactions with specific strength-determining features such as precipitates and grain boundaries. All experimental efforts are strongly tied into modeling work.

This work contains the core PI's and Co-PI's but also engages unfunded industrial and international and collaborators. It is the intention of this program to serve as the basis for a community-wide effort on this topic and active outreach engaging the entire interested nuclear materials community will be pursued.