Developing Ultra-Small Scale Mechanical Testing Methods and Microstructural Investigation Procedures for Irradiated Materials

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ABSTRACT:

Materials propose the greatest challenge for nuclear reactor concepts, both those being proposed or those in service. Without materials that are available or qualified to be used in a nuclear environment it is impossible to realize future concepts with greater demands on the materials performance. For light water reactor applications and their lifetime extension the materials need to be reliable for at least 80 years. Advanced reactor concepts ask for extremely high dose, temperature and unusual environments that will require new materials and alloys. Both light water and advanced reactor concepts call for advanced materials understanding and research since both rely on high performance materials in this harsh environment. High temperatures, long deployments, high radiation doses and corrosion make a materials selection in these environments particularly difficult.

For new alloying ideas, it is highly desirable to only perform small experimental heats using smaller and smaller materials testing in order to avoid the costs of manufacturing large quantities. Accelerated materials testing, is important in order to achieve high doses quickly to enable new materials concepts under radiation and lead the way towards their qualification. Most accelerated materials testing approaches involve ion beam irradiation or high dose neutron irradiation. Ion beam accelerators only have a limited penetration depth into a material (allowing only µm of irradiated materials on a given sample). On the other hand, neutron irradiated materials are difficult to deal with due to activation concerns and there is often only a limited amount of material available. Regardless, both approaches call for the development of small-scale materials testing techniques and the need to link these techniques to bulk properties. Therefore, the development of novel small-scale mechanical testing in combination with microstructural investigation and modeling is of great interest to the nuclear materials community for both materials development as well as monitoring applications. Therefore in this work the combination of modeling and experiments on multiple length scales will be used to evaluate and improve existing small scale mechanical testing techniques in order to help make them relevant to macroscopic properties and useful nuclear engineers, inspectors and designers.

It is the declared goal of this project to develop new small-scale mechanical testing techniques (e.g. hot/cold hardness/compression, tension, bending, ductile to brittle transition temperature) to allow for the estimation or direct measurement of bulk properties. The outcome of our combined experiments and modeling will significantly enhance the statistics and information that can be obtained on small radioactive archived samples as well as new ion beam irradiated specimens.

This work will be conducted by close collaboration between experiments and modeling. In particular, we will focus on in situ experimental efforts that will allow us to understand mechanisms of materials deformation. Significant attention is given to nuclear engineering students with a focus in material science and material science students interested in nuclear engineering. This work will engage students in novel materials characterization techniques as well as require “out of the box” thinking to obtain the maximum amount of mechanical property information from irradiated materials. The fact that a lot of the experiments can be conducted in-situ enhances the visual “seeing is believing” output for the students and leads to a stronger engagement of the student community.