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Accelerated Irradiations for High Dose Microstructures in Fast Reactor Alloys

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ABSTRACT

Understanding microstructure development in materials irradiated to high dose is, in a sense, the holy grail of materials performance in reactor systems. Fast reactor ducts will likely see damage levels of 200 dpa, and for the Traveling Wave Reactor to become a reality, the clad and some structural materials must withstand ~600 dpa. A prime difficulty in studying high dose microstructures is that test reactors cannot reach this damage level in reasonable time frames or at manageable costs. Water-based test reactors (ATR, HFIR) can provide ~3-5 dpa/yr level. Fast reactors accumulate damage more quickly but are limited to ~20 dpa/yr. Because of the low dose rate and high cost, the existing library of neutron-irradiated samples at high dose is extremely limited, making a systematic study of microstructure evolution at high dose nearly impossible. However, information on material response at high dose is very much needed to guide the development and selection of advanced irradiation-resistant alloys. As such, only ion irradiation is capable of providing the required levels of damage in reasonable time frames with negligible cost compared to neutron irradiations. Yet ion irradiation suffers from two potential drawbacks; the volume of irradiated material, and the relatively unknown effect of high damage rate on the resulting microstructure. Micro-sample fabrication and testing, while not a replacement for bulk property determination, holds the promise for minimizing the drawback of limited irradiated volume for property determination [1]. The capability of high damage rates to produce microstructures relevant to reactor conditions remains the greatest challenge. *That is, can very high damage rates be used to explore the high dose microstructures that are relevant to fast reactor conditions?*

This project will determine the extent to which high dose rate, self-ion irradiation can be used as an accelerated irradiation damage tool to understand microstructure evolution at high doses and temperatures relevant to advanced fast reactors. Swelling and phase stability at very high doses (up to 500 dpa) in candidate reactor structural and duct materials (including both legacy (T91 and HT9) and advanced (ODS and NF616) ferritic-martensitic (F-M) steels) will be evaluated. Incubation doses for swelling and precipitation as well as swelling rate at high doses will be evaluated and results will be compared to those available from neutron irradiations. Experiments will be coupled with modeling to understand the effect of high dose rate on incubation dose and microstructure evolution at high doses. This project not only provides much-needed near-term information on microstructure response at high doses for candidate reactor materials, but also provides fundamental understanding of the prospect of using ion irradiations to emulate neutron irradiation microstructures.