Development of high performance ODS alloys

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Program: Fuel Cycle

ABSTRACT:

This project aims to capitalize on insights developed from recent high-dose self-ion irradiation experiments in order to develop and test the next generation of optimized ODS alloys needed to meet the nuclear community's need for high strength, radiation-tolerant cladding and core components, especially with enhanced resistance to void swelling. Two of these insights are that ferrite grains swell earlier than tempered martensite grains, and oxide dispersions currently produced only in ferrite grains require a high level of uniformity and stability to be successful. An additional insight is that ODS particle stability is dependent on as-yet unidentified compositional combinations of dispersoid and alloy matrix, such that dispersoids are stable in MA957 to doses greater than 200 dpa but dissolve in MA956 at doses less than 200 dpa. These findings focus attention on candidate next-generation alloys which address these concerns. Collaboration with two Japanese groups provides this project with two sets of first-round candidate alloys that have already undergone extensive development and testing for unirradiated properties, but have not yet been evaluated for their irradiation performance. The first set of candidate alloys are dual phase (ferrite + martensite) ODS alloys with oxide particles uniformly distributed in both ferrite and martensite phases. The second set of candidate alloys are ODS alloys containing non-standard dispersoid compositions with controllable oxide particle sizes, phases and interfaces.

The project will employ coordinated experiments to study swelling, radiation hardening and changes in mechanical properties not only of these ODS alloys, but also further-optimized ODS candidates resulting from these first-round studies. The project will identify key factors influencing radiation tolerance of new ODS alloys for further property optimization. In addition to void swelling, post-irradiation testing will focus on atomic scale characterization of oxide particle stability, elemental segregation at oxide-matrix interface, and overall phase stability of alloys under extreme radiation conditions. Mechanical characterization efforts will include various micron-level mechanical tests, including pillar compression experiments and indentation experiments. To gain atomic scale understanding, the project will integrate these experiments with modeling capabilities, including molecular dynamics and dislocation dynamics simulations to understand the roles of yttria and other dispersoids as well as their various dispersion modes on both microstructural changes and mechanical property changes.