Radiation Resistant High Entropy Alloys for Fast Reactor Cladding Applications

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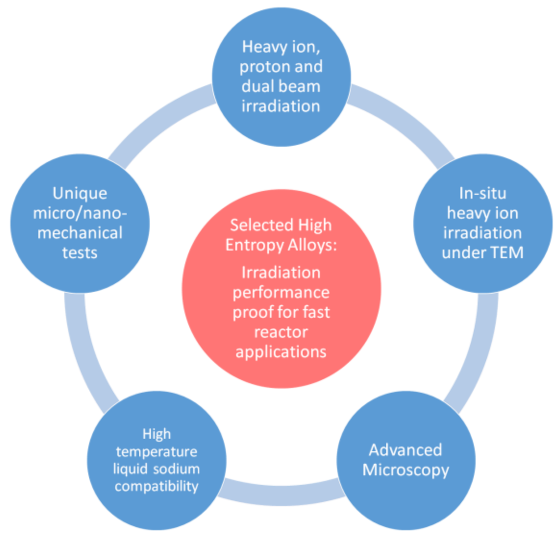
ABSTRACT:
In the proposed research, we will investigate the radiation damage performance of high entropy alloys (HEA) as promising "out of the box" class of metallic materials for sodium-cooled fast reactor (SFR) cladding and other in-core applications. The focus will be on radiation damage effects on the microstructure in this class of alloys at high temperatures and dpa (displacements per atom) levels, but this project will also include mechanical property measurements of irradiated layers (up to operational temperatures) and corrosion performance of the alloys in high temperature liquid sodium environment. To accomplish the proposed research in-depth and within the time-lines of the project, two types of HEAs, one based on 3d transition metals CrFeMnNi (face centered cubic structure) and the other based on light refractory metals NbTaTiVZr (body centered cubic structure) will be investigated. The alloys will be prepared by various processes, including arc melting, vacuum induction melting and field assisted sintering, which are available across the partnering institutions, and the processes yielding the most promising microstructures will be used for irradiation studies. Irradiations will be performed using protons, heavy ions, and dual beam (He + heavy ion) irradiations over a range of temperatures and dpa levels, intended to induce a wide range of irradiation damage mechanisms in the alloys. Precise mesoscale and nano-structural and nano-compositional characterizations and mechanical properties assessments will be performed. These irradiation-induced changes will be evaluated by using a range of state-of-the-art complementary characterization techniques. Nano-hardness and micro-mechanical tests of the irradiated regions will also be performed to assess any changes of alloys' mechanical properties due to irradiation damage and their relationships to micro-, nano-structural changes. Finally, high temperature (700°C) liquid sodium compatibility tests of the unirradiated and irradiated HEAs will be performed and microchemical changes in the near-surface regions of the alloys will be characterized after exposure for evaluation of corrosion resistance and mechanisms. The study is expected to demonstrate the feasibility of HEA as a class of materials for fast reactor cladding applications and benchmark the overall performance of these alloys against the presently used ferritic-martensitic and austenitic steels. The research will be performed in close collaboration between the proposing university, two U.S. national laboratories and an international university with extensive expertise in irradiation effects in conventional alloys as well as in HEAs.



Logical path to investigate the irradiation performance of the selected high entropy alloys