Title: Heavy Ion Irradiation of FCC and BCC High Entropy Alloys for Advanced Nuclear Reactor Applications

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In-core materials for advanced reactor designs are expected to demonstrate corrosion and radiation damage resistance superior to currently-licensed stainless steels and ferritic-martensitic steels. Specifically, for the sodium-cooled fast reactor, cladding material will be subjected to several hundreds of displacements per atom (dpa) over the operating lifetime. Candidate materials must resist void swelling, creep failure up to 650 °C, fracture at 320 °C or lower, and corrosion in liquid sodium. High-entropy alloys (HEA) present a novel alternative structural material to, for example, optimized austenitic steels such as D9, ferritic-martensitic steels such as HT9 or G92, and oxide dispersion-strengthened ferritic-martensitic steels. HEA consist of four or more primary alloying elements in single-phase solid solution, with no individual element exceeding 35 at% concentration. HEA are theorized to resist degradation by radiation because of a combination of two effects.

First, the heat wave propagation theory predicts that increased variation in atomic mass reduces the phonon mean-free path post-thermal spike, lengthening the time for cascade cooldown and facilitating athermal recombination of point defects. Second, the complex chemical landscape implies a narrower gap in diffusion rate between vacancies and interstitials, which may increase diffusion induced recombination and slow point defect diffusion at sinks. Low dpa heavy-ion irradiation experiments were performed to illuminate these hypothetical radiation damage mechanisms, while high dpa studies were performed to simulate long-term microstructural and microchemical radiation effects. The CrFeMnNi (FCC) and NbTaTiV (BCC) HEA families, whose phase evolutions have been modeled by CALPHAD, were compared to less compositionally complex reference materials.

To quantify surviving point defects via cascade overlap quantification, *in situ* cryogenic irradiations were conducted at 50K in the IVEM-Tandem facility at Argonne National Laboratory, comparing the damage cascade evolution in CrFeMnNi NbTaTiV systems to less compositionally complex reference materials. Irradiation experiments at 50, 100, and 200 dpa were also performed on the FCC (at 300 and 500 °C) and BCC (at 500 and 700 °C) HEA as well as less compositionally complex reference materials. Irradiation effects have been analyzed by TEM as well as APT and nano-indentation to shed light on the irradiation resistance of these multiple HEA systems.