Nuclear Energy University Program
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Low Temperature, Ultrafast Annealing of Nanoscale Defects in Nuclear Graphite

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ABSTRACT:

Nuclear graphite degrades over time by neutron radiation in the reactor, which negatively impacts reactor performance and safety. The damage mechanisms are well understood, but there is little or no knowledge on how to repair or mitigate the damage. Currently, thermal annealing is the only way in literature to anneal radiation damage, but it is not effective on graphite, at least not below 1000 degrees Celsius. Thermal annealing also takes many hours to be effective.

This project aims to develop a new knowledge to anneal radiation damage at less than 100 degrees Celsius temperature and less than a minute. Instead of temperature, this project considers a mechanical force that acts on defects when electrical current is passed through the material. Known as the electron wind force (EWF), the non-thermal stimulus is directional in nature, and it acts only on the defects. The challenge to harness its power is that it is always dwarfed by associated electrical (Joule) heating. A technical breakthrough is proposed where EWF is isolated from the heat and is exploited to anneal defects in graphite.

The two-year project comprises of two major tasks: (a) Model and implement the proposed annealing technique on neutron irradiated nuclear graphite and validate the outcome of microstructural characterization (b) Measure mechanical and thermal properties in both irradiated and annealed condition to establish the microstructure-property relationship. The research will involve neutron irradiated NBG-17 graphite undergoing X-ray diffraction, Transmission Electron Microscopy (TEM) and Raman spectroscopy. Young's modulus, hardness and creep properties will be measured, along with thermal diffusivity and specific heat. A detailed research and scope plan is developed to accomplish this through six sub-tasks. The deliverables of this project will the reports on the new knowledge developed in each of the sub-tasks and a final report. radiation and high temperature and (b) their influence on elastic modulus, strength, toughness and creep.

The project is led by the Pennsylvania State University, performing the novel low temperature and ultrafast annealing, in-situ TEM, X-ray, Raman spectroscopy, as well as properties measurement. Idaho National Laboratory is another collaborator, performing neutron irradiated specimen preparation and provided historical characterization data to cross-validate the findings from Pennsylvania State University. The overall outcome will open a new path towards repairing neutron radiation damage in nuclear graphite to enhance performance and safety while reducing wastage. In addition, the cutting edge technology will be transferred through workforce development to enable NE mission.