DESCRIPTION FOR THE GENERAL PUBLIC

The core of a nuclear reactor experiences extreme environments of high temperature, high stress, chemical reactivity and intense radiation flux. In particular, the structural materials for Generation IV concept fission reactors will be subjected to exceptional fluxes of high-energy neutrons and extreme operating temperature. One of the main consequences of the interaction of high energy particles with materials is the formation of lattice defects resulting from the energy transfer to the atoms. The defects can take many forms: an atom can be kicked out from its initial lattice site, leaving an empty site (a vacancy) behind and creating an atom at an interstitial site in front, or they can for instance be defect clusters (aggregation of small defects), dislocation loops or three-dimensional defects. What is important, energetic ions can be used to understand the effects of neutron irradiation in reactor components avoiding of high residual radioactivity and the decline of neutron sources for materials irradiation. As opposed to extremely costly, lengthy, and complicated neutron irradiation, ion irradiation has been widely adopted due to its low costs, short irradiation times, and controllable irradiation conditions.

Demanding environment of future nuclear power systems will require improved irradiation resistance and high temperature mechanical performance from the applied component materials. Thus, the traditional structural materials, such as stainless steels, cannot sustain the extreme reactor conditions and can lead to the eventual failure of structural components. Due to this reason, the development of new materials with superior mechanical properties (especially at high temperatures), and radiation resistance is a great concern. This forms the primary motivation of the proposed work, where the evolution of functional properties of newly developed fcc $NiFe_x$ single crystal alloys will be studied under the extreme conditions (high temperature and ion irradiation). **Thus, the project results are crucial in adding to the studies of novel structural materials and helping their qualification and selection for advanced nuclear reactor concepts (Gen. IV) or related applications.**

The current research work applies to novel fcc $NiFe_x$ single crystal alloys for nuclear applications which were developed at NCBJ. The proposed project is one of the first efforts to study $NiFe_x$ single crystal alloys worldwide and thus, advances this new research field, establishing us to be the pioneers in this field. The proposed research will be the first of its kind to reveal the microstructural evolution and mechanical properties of the alloys subjected to irradiation and their response at high temperature. In addition, the current study utilizes the state of art experimental techniques such as ion-irradiation and Rutherford backscattering spectrometry (RBS/C ion channeling) which is used for qualitative evaluation of radiation damage. In addition, the RBS/C spectra will be fitted using a Monte Carlo (MC) simulation, which will allow to determine the number of defects and their distribution within the single crystals. The RBS/C technique will help to identify the level of radiation damage for the considered compositions in various fluences. Subsequently, additional investigations using the Transmission Electron Microscopy (TEM) will be performed to verify radiation defects' types and their concentration in the function of ion fluences and to capture potential defects migration mechanisms. Gathering the results from abovementioned experiments will provide a comprehensive insight into the structural changes of the studied materials. Finally, the nanoindentation technique will record mechanical changes such as hardness as a function of irradiation fluence. What is more, in order to better understand performance of $NiFe_x$ single crystal alloys, all the materials will be tested at high temperature up to 600ºC using nanoindentation technique, which allow to understand mechanical changes such as hardness. Materials will be tested in a virgin state as well as after ion irradiation (irradiated to the highest fluence of $4x10^{15}$ ions/cm^2). Thus, **the project results are crucial in adding to the studies on novel structural materials and helping their qualification and selection for advanced nuclear reactor concepts (Gen. IV) or related applications.**

The obtained results will enable to **comprehensively understand the effects of irradiation on the microstructure and the mechanical properties** of fcc $NiFe_x$ single crystal and the **correlation between these aspects**. As a part of this, some major research questions arise: 1) What are the types of defects created during irradiation?; 2) What are the sizes, density, and distribution of the defects in fcc $NiFe_x$ single crystals?; 3) How does the defect evolution/migration occur with varying irradiation fluences and concentration of Fe; 4) How do various defect microstructures impact the mechanical properties?; 5) What is the impact of varying Fe concentration and irradiation fluences on mechanical properties of Ni and $NiFe_x$ single crystals?; 6) What is the mechanical response of pristine and irradiated $NiFe_x$ single crystals at elevated temperatures?