U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Title: **New Design Equations for Swelling and Irradiation Creep in Generation IV Reactors**

Our understanding of void swelling and irradiation creep has been challenged recently by new discoveries that necessitate the development of a more comprehensive modeling of microstructural evolution under irradiation, and a derivation of new constitutive equations for swelling and irradiation creep different from those in the past. The microstructural foundations of these new constitutive laws will provide design equations for swelling and irradiation creep which can be confidently extrapolated and applied to Generation IV reactor concepts. Some of these new discoveries include the commencement of void swelling at lower doses with lower dose rates; the occurrence of void swelling in LWRs and at temperatures lower than previously believed possible; the observations of high concentrations of hydrogen in LWR components which exhibit void swelling, implicating hydrogen in addition to helium as a nucleating agent for voids; and the finding that irradiation creep is first enhanced when void swelling commences, but then declines and nearly vanishes as a steady-state swelling rate is approached. These new discoveries are the result of having constructed and analyzed an extensive database from many different irradiation experiments. The proposed comprehensive modeling of void nucleation and evolution of the microstructure is now made possible with the dramatic advancements in scientific computing afforded by the ASCI (Advanced Strategic Computing Initiative).

We are proposing to develop the theoretical models and the computer simulation codes to predict the evolution of the microstructure in structural materials exposed to neutron irradiations and to the chemical and thermo-mechanical environments in Generation IV reactors as well as existing reactors. In addition, we propose to develop also compact, macroscopic constitutive equations for swelling and irradiation creep that can be used in reactor design and performance evaluation.

We are pursuing a dual approach in this project, consisting of two, coupled feedback loops of model development and model verification. One feedback loop encompasses the microstructural models and TEM data from irradiated samples. The other feedback loop deals with macroscopic constitutive laws for swelling and irradiation creep and their calibration with data from density measurements and creep strains. The two loops are connected by the derivation of the functional form of the constitutive laws from the microstructural models. The dual validation at the microscopic and the macroscopic level will greatly enhance the consistency and the validity of the predictions when the performance parameters of Generation IV reactors are outside the range for existing reactors.