Innovative Coating of Nanostructured Vanadium Carbide on the F/M Cladding Tube Inner Surf Mitigating the Fuel Cladding Chemical Interactions

PI: Yong Yang – University of Florida

Collaborators: Simon Phillopt – University of Florida

Program: FCR&D: Nanonuclear R&D

ABSTRACT:

The goal of the proposed project is to conduct applied and fundamental research towards the development of diffusion barrier coatings on the inner surface of ferritic/martensitic fuel cladding tubes. Advanced cladding steels such as T91, HT-9 and NF616 have been developed and extensively studied as advanced cladding materials due to their excellent irradiation and corrosion resistance. However, the fuel-cladding chemical interaction (FCCI), accelerated by the elevated temperature and high neutron exposure anticipated in fast reactors, can have severe detrimental effects on the cladding steels through the diffusion of Fe and Ni into fuel and lanthanides towards into the claddings. For this proposed study, the diffusion couple experiments will be focused on T91, NF616 and HT9 for clad, and both surrogate and uranium bearing fuel.

The proposed work is aimed at developing a low temperature coating process using organometallic precursor, vanadocene Cp2V (Cp=C_5H_5). An innovative coating setup will be built to deposit a uniform nanostructured vanadium carbide layer (less than 10μm in thickness and nano-sized grain structure) on the inner surface of long F/M cladding tube. Compared with mechanical lining and conventional CVD technologies, the proposed low temperature process can offer several advantages: 1) no significant residual stress or axial texture from cold-drawing, 2) no detrimental effects on the martensitic substrate, and 3) a strongly bonded thin and uniform vanadium carbide coating can be readily obtained.

The functionality of the coating as FCCI barrier will be examined experimentally using diffusion couple tests (cerium and uranium). The integrity of the vanadium carbide coating will be evaluated using ion irradiation for radiation stability and quench tests for cracking resistance. The diffusion coefficients of U and Ce in V, V_2C and F/M steels will be systematically mapped over a range of temperatures and annealing schedules. These results will provide benchmark against to which compare atomistic modeling. Even though vanadium carbide has been identified as one of most effective FCCI barrier element, the fundamental underlying mechanisms have not been fully understood. The proposed atomistic modeling will help understand these fundamentals processed.

The proposal brings together personnel, facilities, and capabilities across the experiments (65%) and atomistic modeling (35%). The anticipated research outcomes will significantly boost up a successful deployment of advanced cladding steels for transuranic bearing metal fuels. The findings will provide an insight for scientifically understanding of the FCCI in a coating cladding fuel system.