Seminar

Institute for Plasma Research

Title : Study of Transmutation, Gas Production and Displacement Damage in Iron, Tungsten and Chromium for D-T Neutron Irradiation

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Venue : Board Room, New building, IPR

Abstract :

The D-T neutrons can induce transmutation, gas production and displacement damage in fusion reactor materials e.g. iron, tungsten and chromium. These nuclear responses have adverse effects on the microstructural and engineering properties of reactor materials. In the present thesis, these three nuclear responses have been studied using the appropriate nuclear models and advance radiation damage mechanisms. To calculate the transmutation and gas production, nuclear cross-section data of all the open reaction channels are required. These cross-section data either can be taken from evaluated data libraries such as ENDF and TENDL or can be calculated with the nuclear reaction code TALYS-1.8. In the present thesis, appropriate nuclear models are selected and validated with the experimental data. The nuclear cross-section data is calculated with TALYS-1.8 code using the appropriate nuclear models and parameters. The discrepancies among the nuclear data from evaluated nuclear and experimental data libraries have been calculated and discussed. Helium and hydrogen production cross-section data are calculated and based on that, gas production per atom (GPA) in iron, chromium and tungsten is predicted for typical D-T neutron spectrum. The production of important transmutated isotopes has been studied for all the stable isotopes of iron, tungsten and chromium using the ACTYS code. The time evolution of transmutated isotopes are important in inventory build-up and radioactive waste management and are reported. To predict the displacement damage, energy spectra of primary knock-on atoms (PKA) and quantification of Frenkel pairs due to energetic PKA are two essential input parameters. In this thesis, the energy spectra of PKA from all the stable isotopes of iron, tungsten and chromium is evaluated with the TALYS-1.8 code. Molecular dynamics simulations of damage cascade of self recoil of up to 200 keV damage energies in iron, chromium and tungsten are carried out using the LAMMPS code. The time evolution of displacement defects has also studied and discussed. The MD simulation of self recoil for chromium element is carried out for the first time. The results obtained from the MD simulations have been used to calibrate the constant parameters of the arc-dpa method. The displacement damage cross-section has been calculated with the NRT and arc-dpa methods using the calculated nuclear data and damage matrices. The values of displacement per atom (dpa) in iron, chromium and tungsten are predicted for D-T neutron spectra of typical fusion reactor.

To validate the nuclear models for predicting the recoil spectra, the energy spectra of outgoing particles are required. The measured energy spectra of charged particles are degraded due to loss of energy and particles within the target foil itself. Thus, the measured energy spectra of outgoing charged particles need to be corrected to have the true energy spectrum. A Monte-Carlo method based on the transport of charged particles is developed and validated with GEANT-4.1. This method includes multiple scattering and the concept of a true flight path in its approach. The above-mentioned method has been compared with the existing methods available in the literature.