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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Abstract :

D-T neutrons can induce transmutation, gas production and displacement damage in fusion reactor materials such as 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 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. Nuclear cross-section data is calculated with TALYS-1.8 code using the selected 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 are calculated and based on that, gas production per atom (GPA) in iron, chromium and tungsten is predicted for typical D-T neutron spectrum. Production of important transmutated isotopes have been calculated in all the stable isotopes of iron, tungsten and chromium using the ACTYS code. These 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, energy spectra of PKA from all the stable isotopes of iron, tungsten and chromium is evaluated with TALYS-1.8 code. Molecular dynamics simulations of damage cascade of self PKA of up to 200 keV damage energies in iron, chromium and tungsten are carried out using the LAMMPS code. Time evolution of displacement defects have also studied and discussed. MD simulation of self PKA in chromium element is carried out for the first time. The results obtained from MD simulations have been used to calibrate the constant parameters of the arc-dpa method. Displacement damage cross section has been calculated with the NRT and arc-dpa methods using the calculated nuclear data and damage matrices. 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 PKA spectra, energy spectra of outgoing particles are required. Measured energy spectra of charged particles are degraded due to loss of energy and particles within the target foil itself. Thus, 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 concept of true flight path in its approach. Above mentioned method has been compared with the existing methods available in literature.