Analysis of Radiation Damages of First Wall Materials for Fusion Reactor Using Monte Carlo Method

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1. Introduction

The purpose of ITER (International Thermonuclear Experimental Reactor) project is to verify technical and engineering problems for commercialization of fusion energy. Korea participates in this project and developing TBM (Test Blanket Module) Materials which must endure the high radiation filed and it is one of the crucial problems for the fusion technology. [1]

Several member states of ITER project are developing TBM for Tritium breeding part, DEMO. This is the core technology of fusion reactor.

The first wall is the interface between TBM and fusion plasma. Many researches regarding to radiation resistance of first wall is ongoing now internationally, because resistance to high radiation exposure of first wall determine the operation period of fusion reactor [2].

In this research radiation damage of TBM materials by high energy neutron and proton is evaluated by MCNPX and TRIM codes.

2. Code Simulation

In order to simulate radiation damage of first wall, Monte Carlo transport code MCNPX was used for neutron, and TRIM was used for charged particle.

Simulation geometry used in this work is set up to applicable for both MCNPX and TRIM. This geometry is given in the Fig. 1.

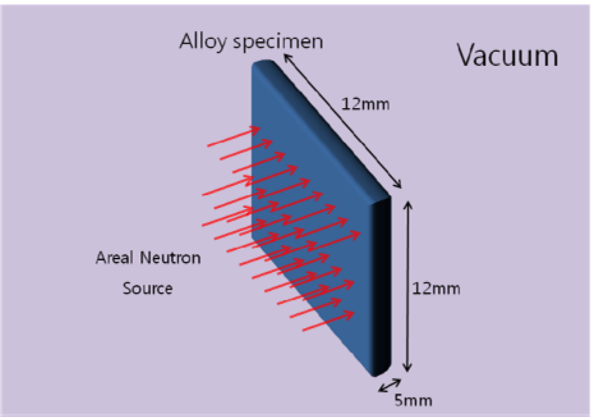

Fig.1. Simulation geometry for Calculation

Among the first wall materials Copper Alloy and Eurofer 97 are chosen for calculation. Chemical Compositions of Copper Alloy and Eurofer 97 are given in the Table Ⅰ. [1], [3]

Table Ⅰ. Material Composition

Materials	*Composition*
Copper Alloy	Cu 98.683 %, Cr 0.754 %, Zr 0.163 %, Cs 0.4 %
Eurofer 97	Fe 91 %, Cr 9 %

Geometry of investigated target consists of the slab shape with 12 x 12 x 0.5 mm. Target was divided into 50 layers, and each elementary cells have the thickness of 10μm. Therefore it is possible to simulate detailed spatial distribution of neutron fluence [1],[3].

Source models used in MCNPX and TRIM were areal neutron source and point proton source, respectively. The projectile energy of neutron and proton were 14.1 MeV and 95 keV (Fig. 2), respectively [4]. The sources are located at boundary surface of target.

Source model of MCNPX code was areal source and that of TRIM was point source, because areal source couldn't be set up at TRIM

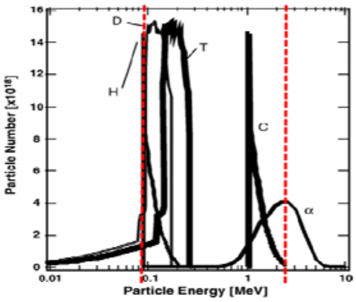

Fig.2. Spectra of particles and charged particles

3. Results and Discussion

3.1 MCNPX Simulation

The simulation used nuclear data based on the continuous-energy data libraries ENDF 60

In this study, "Nuclear Parameter" is adopted to evaluate PKA (Primary Knock-on Atom). The number of PKA can be calculated by following equation (1) [3]. The nuclear parameter is summation of cross-section about nuclear reaction of Copper Alloy and Eurofer 97. The nuclear parameters is given in the Table Ⅱ [1],[3].

$$PKA = N \int_{E_d}^{E_{SN}} \Phi(E)\sigma_s(E)dE \quad (1)$$

Table Ⅱ. Nuclear Parameter

Materials	*Nuclear parameter*
Copper Alloy	1.1724E-01· Φ
Eurofer 97	1.028E-01· Φ

Using the nuclear parameter, Neutron fluence from the MCNPX result computed the number of PKA. It is simulated by MCNPX that average neutron fluence in the Copper Alloy is 0.7027 neutrons/(neutron source cm^2) and average Neutron fluence in the Eurofer 97 is 0.7023 neutrons/(neutron source cm^2). Error of Simulation is less than 1%

Based on the result from MCNPX, the number of PKA was computed. Average number of PKA in Copper Alloy is 0.08238 atoms/(neutron source cm^3). Distribution of number of PKA normalized per source neutron in the layers with thickness 10μm in Fig.3.

Average number of PKA in Eurofer 97 is 0.07220 atoms/(neutron source cm^3). Distribution of number of PKA normalized per source neutron in the layers with thickness 10μm in Fig.4.

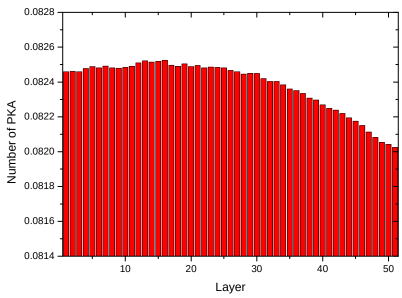

Fig.3. Number of PKA of Copper Alloy by MCNPX

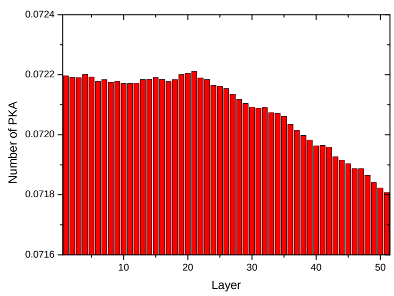

Fig.4. Number of PKA of Eurofer 97 by MCNPX

3.2 TRIM Simulation

The hydrogen ions (protons) have been implanted with the energy of 95keV into Copper Alloy and Eurofer 97.

Average number of PKA in the Copper Alloy is 0.0268 atoms/(Å Ion). Distribution of number of PKA normalized per ion angstrom in the layers in Fig.5.

Average number of PKA in the Eurofer 97 is 0.0268 atoms/(Å Ion). Distribution of number of PKA normalized per ion angstrom in the layers in Fig.6.

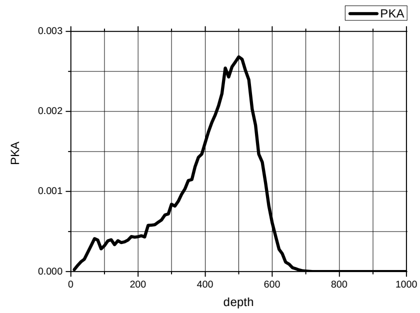

Fig.5. Number of PKA of Copper Alloy by TRIM

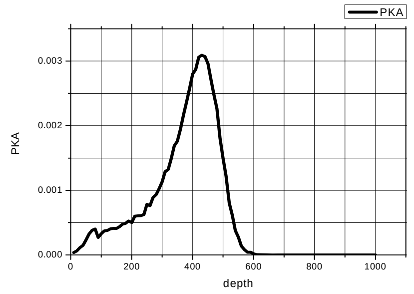

Fig.6. Number of PKA of Eurofer 97 by TRIM

4. Conclusions

Simulation of radiation damage of first wall by neutron and proton is carried out with MCNPX and TRIM codes.

The neutrons have been irradiated with the energy of 14.1 MeV into Copper Alloy and Eurofer 97. Simulation results show that Eurofer 97 have the more number of PKA produced by neutron in comparison to Copper Alloy.

The Ion (Proton) has been implanted at the energy of the 95 keV into Copper Alloy and Eurofer 97.The more PKA is produced in Eurofer 97 than Copper Alloy.

More intensive simulation study will be carried out and the mechanical and physical properties of first wall materials will be analyzed.

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