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Irradiation Chamber Design for the Study of Proton Beam Induced Radiation Damage

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1. Introduction

Structural materials used in the fusion reactor, ADS, fast reactor, etc. experience high dose irradiation during operation, for example, ~100 dpa/year in ADS, ~40 dpa/year in fast reactor, and ~30 dpa/year in the ITER's DEMO. [1] Because high dose irradiation induced damage make some troubles in these nuclear materials, investigations of radiation damage is very important for the development of the nuclear reactors and fusion reactors. The degradation of mechanical properties of materials induced by radiation damage depends on the irradiation temperature and dose. [2]

Irradiation of heavy ions including proton has been used for these kinds of radiation damage test of nuclear materials because of high DPA value induced by. For the studies of radiation damage dependent on the temperature and dose, irradiation chamber has to be designed available to control the temperature during proton beam irradiation. In this paper,

2. Methods and Results

The DPA value can be calculated by using many simulation codes, SRIM[3], PHITS[4], MARS15[5], FLUKA[6], and MCNPX[7]. Some DPA value calculations using SRIM and PHITS code were conducted by Yosuke Iwamoto, et al. as shown in Fig.1. [8].

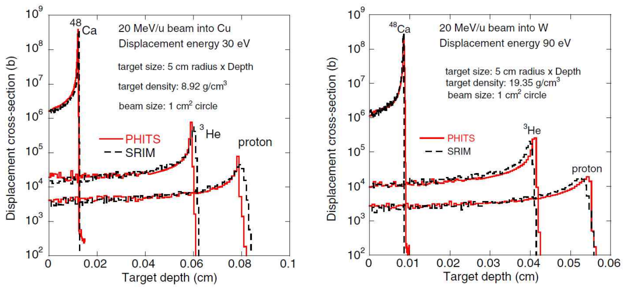
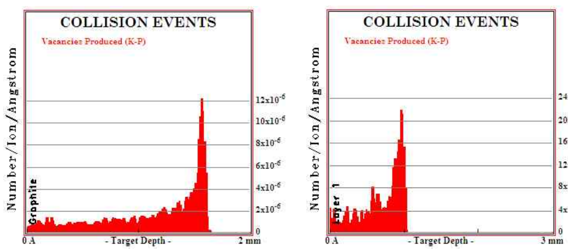


Fig. 1. The depth dependence of the displacement cross section is shown for a 5 cm radius and 0.1 cm thick copper and tungsten target irradiated by 20 MeV/u proton, ^{3}He and ^{48}Ca beams.

In Fig. 1, we can recognize that to obtain DPA value greater than one, protons more than 1E+21/cm^2 have to be irradiated to the copper and tungsten targets. In addition, to investigate radiation damage dependence on temperature and dose, high-power proton accelerator as well as an irradiation chamber system, that has temperature-control function.

2.1 SRIM Code Simulation

After proton beam extracted through the 500-μm thick AlBeMat beam window, 20-MeV proton beam energy reduced to 17.7 MeV. The SRIM calculation results for the representative structural materials, SUS, graphite, and copper, are shown in Fig. 2.



(a) (b)

Fig. 2. The depth dependence of the displacement cross section is shown for a 0.3 cm thick (a) graphite and (b) zirconium irradiated by 17.7 MeV proton beam.

2.2 Design of Irradiation Chamber

For high dose irradiation, high current proton irradiation conditions were considered. The heat loads to the targets with 17.7-MeV and 10-μA/cm^2 proton beam is about 177W/cm^2. To eliminate the heat caused by proton beam irradiation, cooling unit with feedback control system is necessary. To design the irradiation chamber, the specimen design for small tensile test has to be considered as shown in Fig. 3.

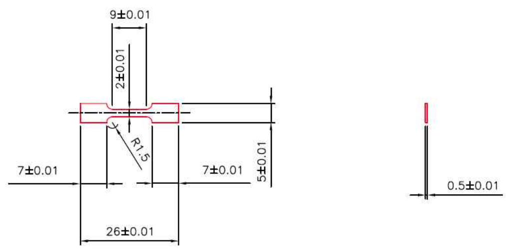


Fig. 3. Small Tensile Specimen Design.

The cooling unit is composed of thermo-element, plate-fin type heat sink, cooling fan, and heat pipe as shown in Fig. 4.

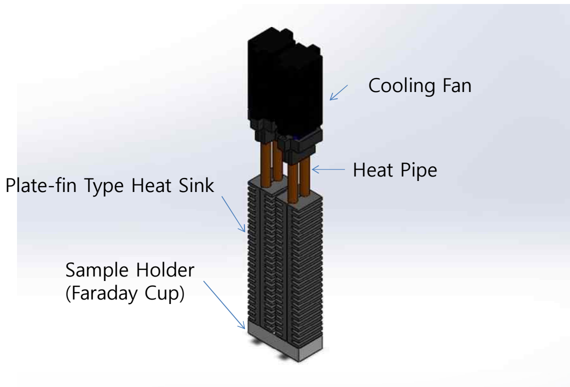


Fig. 4. Cooling unit design composed of thermo-element, heat pipe, cooling fan, and plate-fin type heat sink.

3. Conclusions

Irradiation chamber design is essential for the radiation damage test of structural materials, such as graphite, iron, zirconium, copper, etc. by using high dose proton beam irradiation. The main component, cooling unit, is composed of sample holder, faraday cup, thermo-element, heat pipe, plate-fin type heat sink, and cooling fan. The property test of proto-type and design optimization will be conducted using available proton beam irradiation facilities, MC-50 cyclotron and 100-MeV proton accelerator, KOMAC.

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