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A Study on the Thermal Neutron Filter for the Irradiation of Electronic Materials at HANARO

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1. Introduction

Neutron irradiation method may be used as a way to produce the high-quality electronic materials because it is possible to make homogeneously interacted material with the neutrons. The representative example is a technique of making the semiconductor with the transmutation using the pure Si. This NTD (Neutron Transmutation Doping) Si is used as a high-quality semiconductor because it has a uniform resistance. Likewise, the electronic materials are being investigated to improve the performance of material using the neutron irradiation method[1].

The mechanism for reaction between the electronic materials and the neutrons depends on the energy of the neutron. Capturing reaction by thermal neutrons causes the transmutation and a lot of defects are made by fast neutrons. The study for the effect by such neutron energy is necessary to understand the performance improvement of the irradiated electronic materials. In addition, it is necessary to minimize the activation by thermal neutron to easily handle the irradiated materials.

Therefore, in this paper, the basic study of the development of the thermal neutron filter is presented for the irradiation of electronic materials.

2. Irradiation hole for the electronic materials

There are 32 vertical irradiation holes and 7 horizontal irradiation holes in HANARO as shown in Fig. 1. Among them, the horizontal irradiation holes are used for the micro and nano-scale analysis for materials. Therefore, the most of irradiation tests for electronic materials have been conducted using the vertical irradiation holes. Although the vertical irradiation holes such as CT, IRs, ORs in the core have been used for the irradiation performance test of nuclear materials with high neutron flux, it is difficult to handle the irradiation time. In addition, NAA (Neutron Activation Analysis) holes are not appropriate because the experimental conditions are strict due to the installation of PTS (Pneumatic Transfer System). Therefore, IP irradiation holes mainly used for RI (Radioactive Isotope) production can be used for the irradiation of electronic materials.

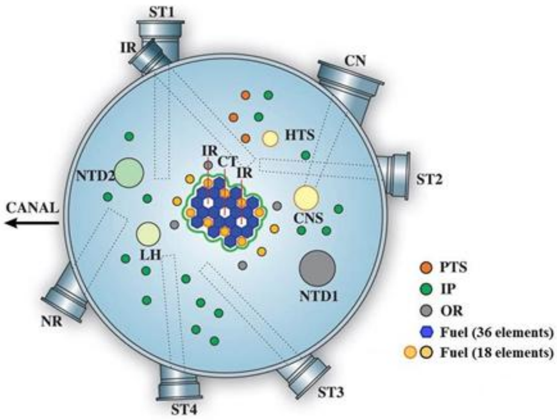

Fig. 1. The schematic diagram of irradiation holes in HANARO

3. Design of the irradiation device

The rig for RI production has been used for RI production at the IP irradiation holes. Since the integrity of the irradiation device is important, the rig for RI production verified in HANARO is used as the irradiation device for the electronic materials. Four irradiation capsule assemblies are inserted in a rig. Fig. 2 shows the drawing of capsule assembly composed of inner and outer capsule. The outer capsule containing the inner capsule can be handled by handling tools using the upper structure. The inner capsule sealed by mechanical compression contains the irradiated specimens.

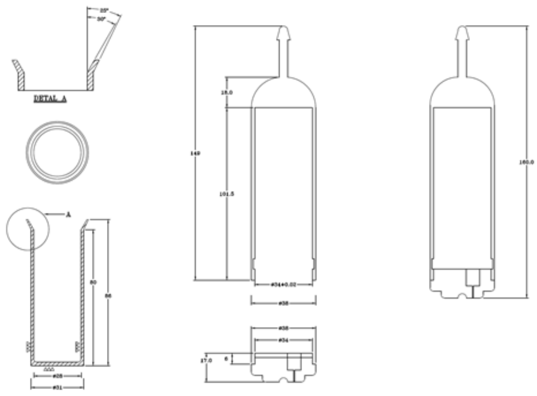

Fig. 2. The drawing of the inner and outer capsule

The irradiated specimens surrounded by the thermal neutron filter will be inserted in the inner capsule. The specimen container was designed by the reference to the test carried out. Conventional specimens were 10 mm by 10 mm sheets and 10 mm diameter disks. Therefore, the specimen container as the thermal neutron filter was designed to accommodate the specimen sufficiently.

4. Analysis of thermal neutron filter

To select the material of the thermal neutron filter, the evaluation was conducted considering the candidate materials. The calculation for the performance of filter was conducted using MCNP. Fig. 3 shows the model of MCNP for this calculation. The container's height is 40 mm and inner diameter is 20 mm.

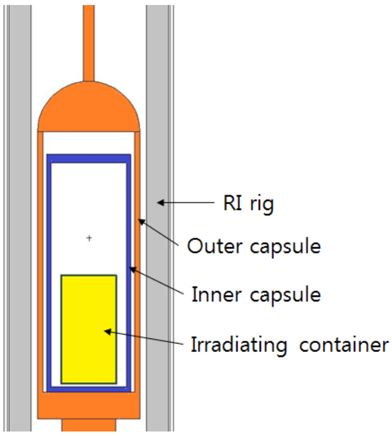

Fig. 3. The calculation model of MCNP

The candidate materials were selected on the basis of experience, applicability, and nuclear data. Table 1 shows the specification of candidate materials for the thermal neutron filter. Hf is used as a control absorber rod material in HANARO and to reduce the power for the fuel performance test. Cd is widely used as the shielding material. Dy and Ir were selected considering their absorption cross-section between Cd and Hf.

Table 1. The specification of candidate materials

Material	Absorption cross-section (σ_a)	Density (g/cc)	Atomic Number	Melting point(K)
Cadmium	2450	8.65	48	594.22
Dysprosium	930	8.56	66	1680
Hafnium	102	13.36	72	2506
Iridium	426	22.5	77	2719

Fig. 4 shows the average neutron spectrum if 1 mm-thick Al container is considered. The fast neutron flux was much lower than thermal neutron flux because IP irradiation hole is located in D_2O reflector area.

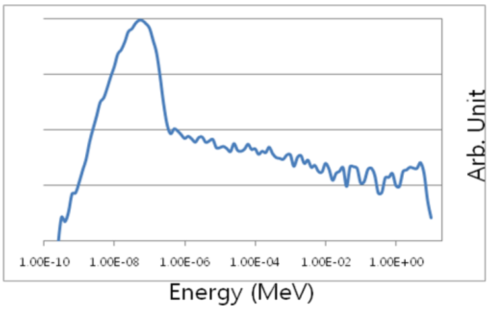

Fig. 4. The average neutron spectrum in Al container

Fig. 5 shows the calculated neutron flux in the container considering the candidate materials. The container thickness was changed for some materials. Although Hf filter showed the low efficiency as the thermal neutron filter in spite of the increase of thickness, Cd filter showed the good performance. Dy and Ir filters showed similar thermal shielding performance. As the result of this calculation, Cd is a good material among them as the thermal neutron filter. However, the application of Cd filter must be carefully considered because its melting point is absolutely low.

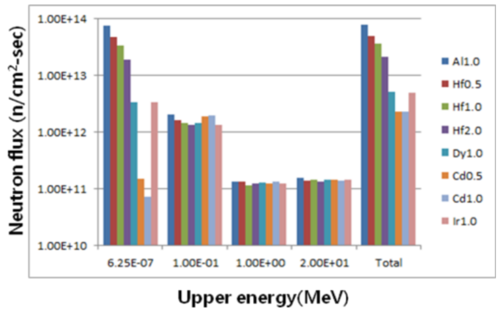

Fig. 5. The calculated neutron flux in the container

5. Conclusion and future work

The thermal neutron filter was investigated to be used for the irradiation of electronic materials at HANARO. IP irradiation hole was selected and the irradiation device was designed. The analysis was conducted considering four candidate materials. Among them, Cd filter showed the good performance. The Cd filter will be designed and manufactured and its performance will be measured by flux monitoring method.

ACKNOWLEDGEMENTS

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REFERENCES

[1] K.N. Choo, M.S. Cho, B.H. Jun, C,J, Kim, and S.J. Park, Neutron Irradiation of Electronic Materials at HANARO, Journal of Applied Mathematics and Physics, Vol. 2, p. 837, 2014.