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Design of Neutron Screen for 8″ NTD Irradiation in HANARO

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1. Introduction

The silicon Neutron Transmutation Doping (NTD) facility is one of the most important facilities of the HANARO. Two vertical irradiation holes, NTD1 and NTD2, are provided in the reflector region. We have been providing the commercial NTD service for 5″ silicon ingot in the NTD2 hole since the end of 2002, and we are developing an irradiation device for 6″ ingot in the NTD2 as well as a facility for 6″ and 8″ ingots in the NTD1. This paper presents the design of the neutron irradiation device for the 8″ silicon ingot in the NTD1 hole from the viewpoint of the nuclear design. It is the latest report on a series of NTD device designs for 6 inch and 8 inch ingots in NTD1 and NTD2 holes.

2. Methods and Results

A Si ingot for NTD is usually grown by floating zone method. It is in the shape of right cylinder of which length is normally 20 to 30cm and the diameters of ingots available in the market are 4″, 5″or 6″ and a production of 8″ is under development. A high quality NTD-Si shall have high uniformity of resistivity in radial and axial direction of which specification is given by each customer. The relative difference between the maximum and minimum resistivity in the axial or radial distribution shall be within a few %. While the radial uniformity is usually achieved by rotating the ingot during irradiation, three different methodologies are found for the axial uniformity. For the case of HANARO, neutron screen method is adopted. The primary role of the neutron screen, the wall part of the ingot container, is to make the axial neutron flux distribution in the Si ingot as flat as possible. Note that the resistivity is inverse-proportional to the total number of $Si^{30}(n,\gamma)$ Si^{31} reactions occurred, and the number of reactions is almost proportional to the thermal neutron fluence. Thus we are using either the thermal neutron flux or reaction rate distribution to represent the distribution of resistivity.

2.1 Neutron Screen Design

In this work, we used the MCNP code to simulate details of the neutron screen. As the diameter of the Si ingot increases from 6″ to 8″, the gap available between the inner surface of the NTD1 hole (diameter of 22 cm) and the outer surface of the ingot is reduced significantly. Thus the aluminum, which is the screen material for the current 6″ irradiation, is not suitable any more due to its small neutron capture cross section.

From preliminary analyses based on the thermal diffusion length of several kinds of structural materials, we chose the stainless steel as the material for the screen. Then we optimized the neutron screen design for the uniform irradiation in the Fig. 1 shows neutron screen shape and its MCNP model containing two Si ingots stacked vertically inside the NTD1 hole.

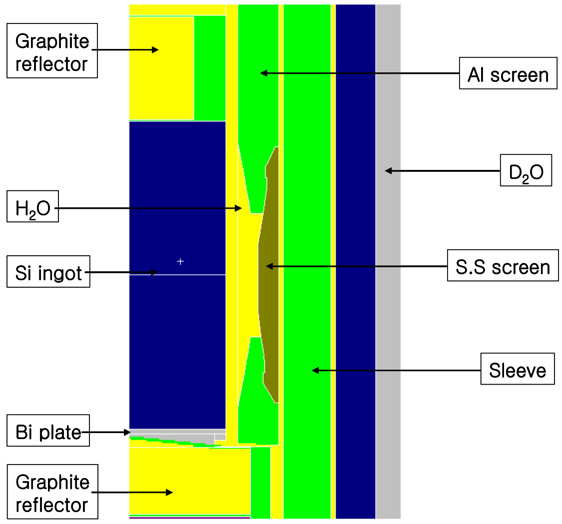

Fig. 1. MCNP model of Si ingots and neutron screen inside the NTD1 hole

For profiling the axial and radial reaction rate distribution, 60 cm long Si ingot was axially divided into 30 plates and radially divided into 5 rings. An MCNP run made use of total 50 million histories, with which the fractional standard deviation (fsd) was less than 0.5%.

2.2 Calculation Results

Fig. 2 shows the axial relative $Si^{30}(n,\gamma)$ Si^{31} reaction rate distribution. We achieved the axial uniformity of less than 2.5%, which is well within a usual requirement. The uniformity is defined as the difference between the maximum and minimum relative reaction rate.

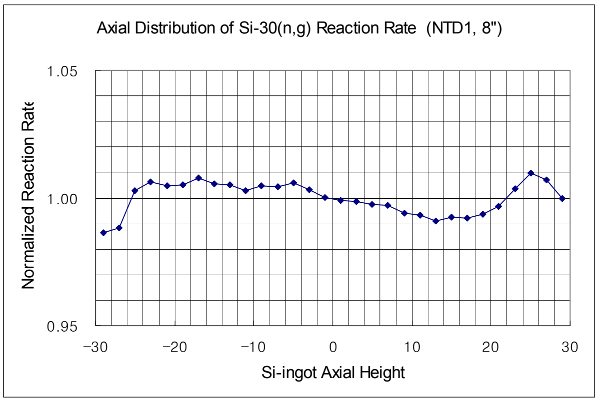

Fig. 2. Axial $Si^{30}(n,\gamma)Si^{31}$ reaction rate distribution

We also pay great attention to the radial uniformity in 8″ ingot because more attenuation of neutrons is expected in 8″ ingot than that in 6″ ingot. Fig. 3 shows the radial relative $Si^{30}(n,\gamma)$ Si^{31} reaction rate distribution. We achieved the radial uniformity of less than 3.0%, which is well within a usual customer's requirement of 5%, and moreover, it is comparable with the radial uniformity in 6″ ingot of about 2%.

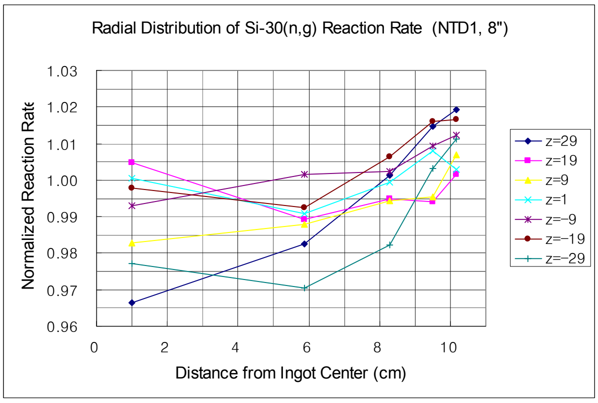

Fig. 3. Radial $Si^{30}(n,\gamma)Si^{31}$ reaction rate distribution

3. Conclusion

We designed the neutron screen for 8″ Si ingot irradiation in the NTD1 hole of HANARO, which is near optimum in achieving a flat axial and radial distribution of resistivity in the irradiated Si ingot. The fluctuations in the axial and radial distribution were estimated to be within ±1.2%, ±2.0%, respectively, from the average. Using this design, we expect a commercial 8″ NTD service will be very plausible while satisfying customers' requirement not only on the axial but also radial irradiation uniformity.

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