Quality Management for Neutron Transmutation Doping of Silicon Ingot in HANARO

Ki-Doo KANG *, Ji-Uk KIM, Hwa-Kyung YUN, Chul-Hong LIM, Young-Chil KIM, Myong-Seop KIM and Sang-Jun PARK
Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong, Daejeon, 305-353, Korea, *ex-dooki@kaeri.re.kr

1. Introduction

Neutron transmutation doping(NTD) for producing an n-type silicon semiconductor is based on a conversion of the Si-30 isotope into a phosphorus atom by a neutron absorption reaction as follows,

$$Si^{30}(n,\gamma)Si^{31} \rightarrow P^{31} + \beta^- \ (T_{1/2} = 2.62\ h). \quad (1)$$

By using this doping method, silicon semiconductors with extremely uniform dopant distributions can be produced, and this is the dominant advantage of NTD compared with a conventional chemical doping.

Good uniformity of a dopant concentration is usually required for high power applications such as thyristor (SCR), IGBT, IGCT and GTO and for special sensors.

Achieving an accurate neutron fluence corresponding to a target resistivity as well as a uniform irradiation is the prime target of a neutron irradiation for NTD[1,2].

Generally, in order to reach an accurate neutron fluence, a real time neutron flux is monitored by a neutron detector such as a Self-powered Neutron Detector(SPND). And, after an irradiation, the total irradiation fluence is confirmed by measuring the absolute activity of a neutron activation sample that has been irradiated with a silicon ingot, and thus the SPND can be properly calibrated.

Excellent irradiation uniformity and a high accuracy for a target neutron dose have been achieved from the early works of NTD. However, to maintain this excellent quality, the neutron irradiation fluence should be continuously modified and controlled. So, in this work, an activity to maintain the irradiation quality is introduced.

2. Status of the NTD service

HANARO, a 30 MW research reactor, has two vertical holes in the heavy water reflector region for the NTD. The commercial NTD service for 5 and 6 in. silicon ingot has been going on at the NTD2 hole, additional 6 in. irradiation device at the NTD2 and a 6 and 8 in. irradiation facility using the NTD1 hole are under development.

Table 1 shows the weights and batches of silicon ingots which have been irradiated in the 46~49 th reactor periods of 2007.

Table 1. Status of the irradiated silicon ingots on 2007.

Si semiconductor companies	Weight (kg)	Batches	Type
A	4,316	198	N
B	2150	137	N , P
C	1018	41	P

Each batches of irradiation consists of 2 or 3 ingots, with total length of 60 cm.

3. Quality control of neutron irradiation

For the initial n-type silicon, the relationship between the irradiation neutron fluence and the resistivity is as follows[3],

$$\phi \cdot t = K\left(\frac{1}{\rho_f} - \frac{1}{\rho_i}\right), \quad (2)$$

After an irradiation, we compared the irradiated neutron fluence determined by zirconium in HANARO with the resistivity measurements data presented by Si semiconductor companies. The results are summarized in Figure 1 for "A" company. In the figure, the fitting value of K is deduced by using the final resistivity ρ_t confirmed by the company.

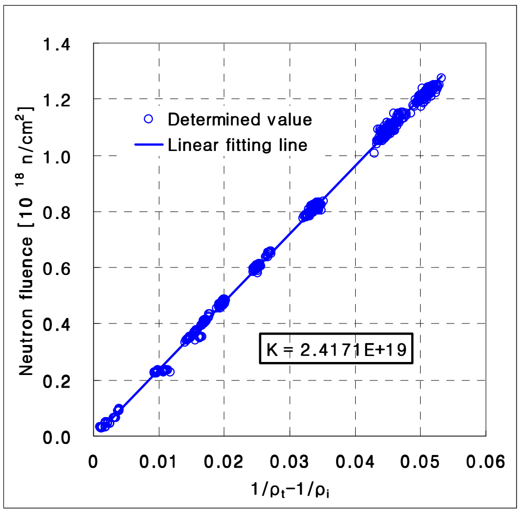

Figure 1. The relationship between the irradiated neutron fluence and resistivity for "A" company.

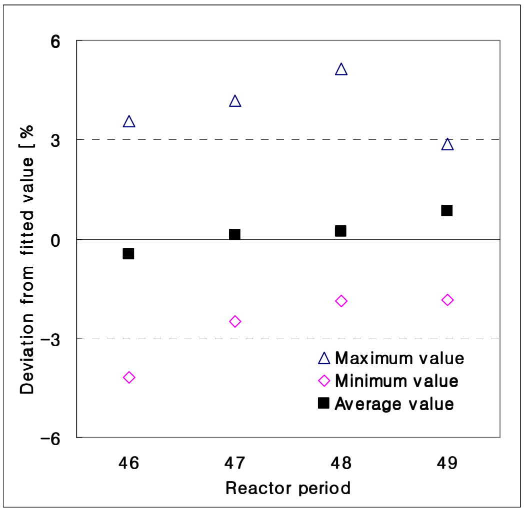

Figure 2. Deviation of irradiated fluence from fitted value for "A" company at each reactor period.

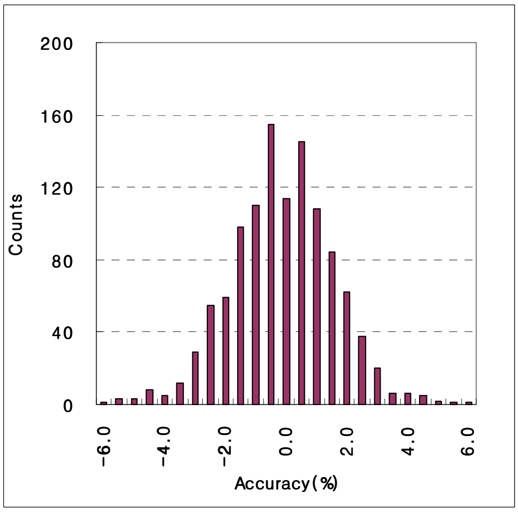

Figure 3. Accuracy of "A" company irradiation when K-value is 2.40×10^{19} n·Ω/cm.

Figure 3 shows the irradiation result when the K-value of 2.40×10^{19} n· Ω/cm was applied for this year. The K value was newly determined in 2006 on the basis of the accumulated measured results for the past 3 years[4].

Total number of data is 1130, and the distribution looks like a typical Gaussian function with a center at zero. However, the number of data below -0.5% is 12.6% larger then that of 0.5% or more. Therefore, if we apply the new K-value determined in Figure 1, an improvement in the irradiation result will be expected even though it is very small.

4. Conclusion

A uniform and accurate neutron irradiation is one of the critical factors in the NTD of Si ingots. In spite of a short experience on NTD at HANARO, we could achieve the best result from an early stage through a careful preliminary preparation. Recently, we updated a proportional constant for the Si ingots of a company and as a result we confirmed an improvement in the quality of the NTD Si ingots

REFERENCES

[1] B. J. Baliga, Modern Power Devices, John Wiley & Sons, New York, p.32, 1987.

[2] P. E. Schmidt and J. Vedde, High Resistivity NTD-Production and Applications, Electrochemical Society Proceedings, Vol.98-13, p.3, 1998.

[3] M. S. Kim, S. I. Wu, H. S. Kim, S. Y. Oh, S. Y. Hwang and B. J. Jun, Relationship between Resistivity and Irradiated Neutron Fluence in Silicon Neutron Transmutation Doping, Proceedings of the International Symposium on Research Reactor and Neutron Science(HANARO2005), April, 2005, Daejeon, Korea.

[4] K. D. Kang, J. W. Kim, H. K. Yun, C. H. Lim, Y. C. Kim, M. S. Kim and S. J. Park, Accuracy Adjustment for a Neutron Transmutation Doping of Si Ingot, Transactions of the Korea Nuclear Society Autumn, November, 2006, Kyeongju, Korea.