Neutron transmutation doping of n-type spherical silicon solar cell at high-temperature engineering test reactor

*Hai Quan Ho¹, Yuki Honda¹, Shimpei Hamamoto¹, Toshiaki Ishii¹, Etsuo Ishitsuka¹
¹Oarai Research and Development Center, Japan Atomic Energy Agency

Abstract

This study proposed a new method of neutron transmutation doping silicon (NTD-Si) for producing the n-type spherical solar cell at the high temperature engineering test reactor (HTTR), in which the Si-particles are irradiated directly instead of the cylinder Si-ingot as in the conventional NTD-Si. By using a ‘screw’, an identical resistivity could be achieved for the Si-particles without a complicated procedure as in the NTD with Si-ingot.

Keywords: HTTR, MVP, NTD-Si, n-type silicon, spherical solar cell, high conversion efficiency

1. Introduction

The p-type spherical silicon solar cell [1] (as shown in Fig.1) is a candidate for future solar energy with low fabrication cost, however, its conversion efficiency is only about 10%. The conversion efficiency of a silicon solar cell can be increased by using n-type silicon semiconductor as a substrate. However, it is difficult to apply a Czochralski method for growing a highly uniform n-type silicon semiconductor. Thus, this study proposed a new method of neutron transmutation doping silicon (NTD-Si) for producing the n-type spherical solar cell.

2. Method

A proposed scheme for NTD Si-particles is shown in Fig.2. The Si-particles moves circularly around the screw and from the top to bottom of NTD-hole by gravity. After being irradiated, the doped Si-particles are collected into the storage container by a suction tube for radiation removal. The neutronic calculations were performed with MVP-2.0 code and JENDL-4.0 library to estimate the resistivity of doped Si-particles. The configuration of the HTTR for NTD-Si was also optimized by changing the number of NTD-hole at replaceable reflectors from 3 to 12 and NTD-hole’s diameter from 10cm to 25cm. The optimization of NTD-holes was carried out while keeping the decrease of $\Delta k/k$ less than 0.5 %Δk/k. The irradiation time was estimated to obtain 10 Ω cm of resistivity, which is suitable for fabrication of the solar cell.

3. Results and conclusions

The optimum results with various number of NTD holes are illustrated in Table 1. In the case of 3 NTD-holes, 20 cm is optimum diameter which can produce approximately 39.6 ton/y of doped Si-particles. The irradiation time and reactivity insertion, in this case, are 42.4h and ~0.5%Δk/k, respectively. The case of 6 NTD-holes with 10 cm diameter could produce 22.5 ton/y of doped Si-particles, while about 33.6 ton/y could be irradiated in the case of 9 NTD-holes with 10 cm. Besides, it is not feasible to use all of the 12 replaceable reflectors because the negative reactivity insertion is larger than 0.5%Δk/k. In conclusion, this study proposed the new NTD method for irradiating n-type spherical silicon solar cell at the HTTR, which is expected to achieve the low cost and high conversion efficiency in comparison with conventional silicon solar cell.

References