CORRELATION OF DT AND DD FUSION NEUTRON DAMAGE IN SILICON SURFACE BARRIER DETECTOR

Toshiyuki Iida, Yasuhiro Sueyoshi, Sunarno and Akito Takahashi
Department of Nuclear Engineering, Faculty of Engineering,
Osaka University, Yamadaoka, Suita, Osaka, Japan

Abstract

In order to examine the correlation of DT and DD fusion neutron damage in Si, a silicon surface barrier detector (Si-SBD) was irradiation with neutrons from a deuteron accelerator. The leakage current increased proportionally with neutron fluence, which determined the neutron damage constant for the Si-SBD. The correlation factor of the DT and DD neutron damage in the Si-SBD was determined from the ratio of the DT and DD neutron damage constants and was found to be 2.3. We also calculated the rate of DT and DD neutron displacement damage for Si by using the TRIM-90 computer program and actual data on neutron reactions in the Si-SBD. The correlation factor of DT and DD neutron damage from the calculation agreed with that from the Si-SBD irradiation experiment.

1. Introduction

Data on fusion neutron irradiation effects are essential to the study of problems concerning the development and selection of detectors, sensors and related components for fusion diagnostic systems. In order to examine fusion neutron damage in silicon devices, a silicon surface barrier detector (Si-SBD) was irradiated with neutrons from a deuteron accelerator,OKTAVIAN[1]. The increase in leakage current of the Si-SBD, leading to the degradation of energy resolution, was measured *in-situ* during neutron irradiation. The purpose of this paper is to give accurate values of DT and DD neutron damage constants for the Si-SBD and to discuss the correlation of DT and DD neutron damage. At first this paper shows results of the neutron irradiation experiments and then discusses the correlation factor of DT and DD neutron damage in the Si-SBD.

2. Experiment

The Si-SBD sample for irradiation was made of an about 3 kΩcm n-type silicon wafer whose size was 12 mm in diameter and 100 μm thick. The electrodes of the front and rear surfaces of the detector were produced by vacuum evaporation of gold and aluminum, respectively. The Si-SBD sample was covered with 50 μm gold foils for the protection against the entrance of light and energetic charged particles due to neutron reactions from the outside. Figure 1 shows a schematic drawing of the experimental arrangement and the electronic circuit used for the *in-situ* measurement of the degradation of the Si-SBD. A reverse bias of 20 V was applied to the detector during irradiation. The leakage current was measured with an electrometer together with neutron fluence. We also measured spectra of electric charge induced in the Si-SBD by neutron reactions to discuss the correlation of DT and DD neutron damage. The temperature of the Si-SBD sample was kept constant (at 295 K) with a Peltier-effect device. Neutron fluence was obtained from the measurement of charged particles associated with neutrons, i.e. alpha particle for DT neutron and proton for DD neutron. A charged particle detector was set in the beam tube of the deuteron accelerator as shown in Fig.2.

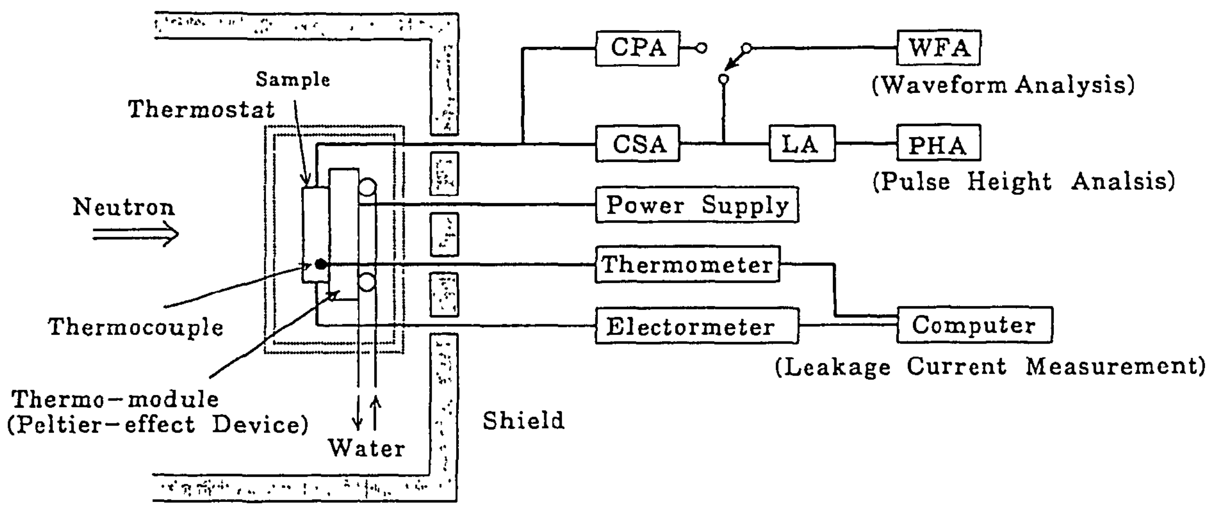

Fig.1 Schematic drawing of experimental arrangement and electonic circuit used for *in-situ* measurement of degradation of Si-SBD

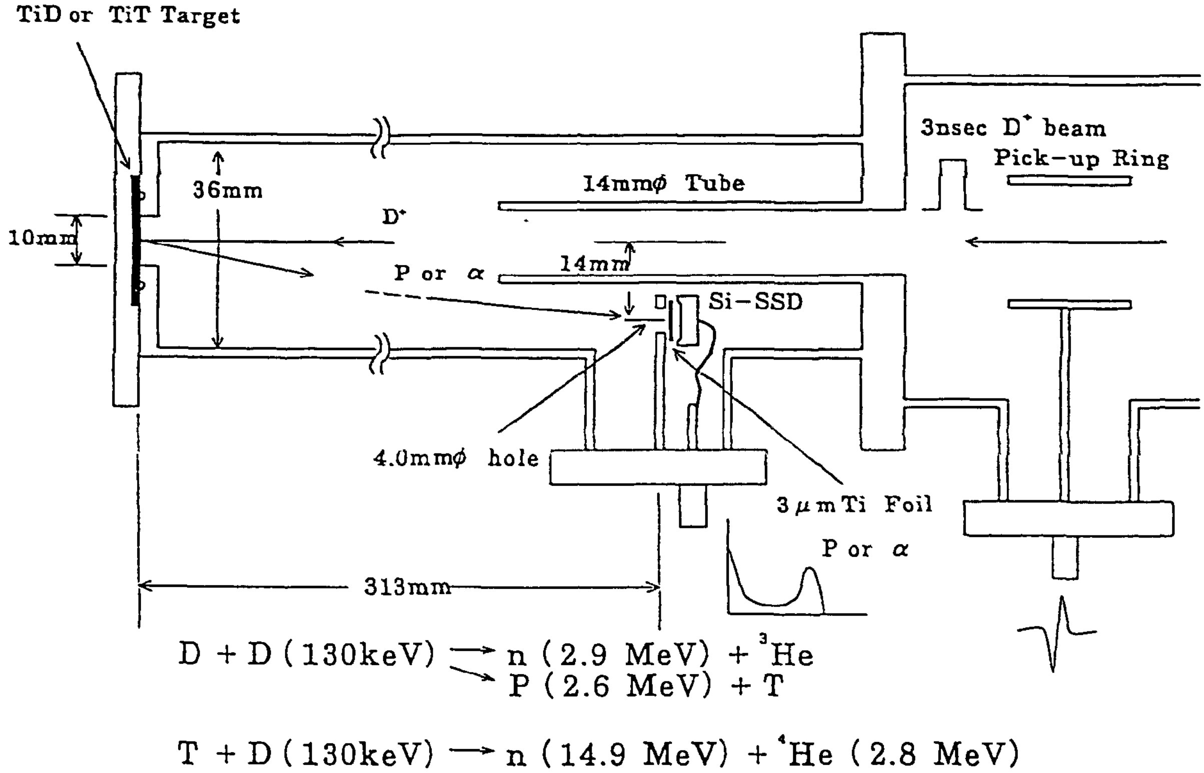

Fig.2 Neutron yield monitor

3. Results and discussion

The change in leakage current of the Si-SBD sample increased proportionally with neutron fluence, which is shown in Fig.3. The DT and DD neutron damage constants for the leakage current of the Si-SBD are given by the slope of the lines in Fig.3, and they are summarized in Table.1. The correlation factor of the DT and DD neutron damage in the Si-SBD was determined from the ratio of the damage constants in Table 1 and was found to be 2.3. This value is expected to be applicable to the fusion neutron damage estimation for other similar silicon devices.

We also calculated the amount of neutron displacement damage for the Si-SBD by using the Monte Calro program for transport of ion in material, TRIM-90[2] and actual data on neutron reactions in the detector sample. Figure 4 shows the spectra of charge produced by neutron reactions in the Si-SBD sample. The energy calibration was made with a standard ^{241}Am alpha source. Some high energy peaks in the spectrum for DT neutrons can be identified as those from Si(n, α)Mg reaction. The number of DT neutron reactions caused in the Si-SBD through the irradiation can be estimated on the basis of the counts of those peaks. Concerning the response due to Si(n, p)Al reaction, the depletion layer of the Si-SBD was 100 μm and too thin to analyze the energy of protons. Thus, nuclear data from ENDF/B-VI were used for the estimation of the number of neutron reactions related to proton emission in the detector. Similarly the number of (n, n) and (n, n') reactions caused in the Si-SBD was estimated on the basis of the actual counts of the (n, α) reaction and the ENDF/B-VI data. As for the DD neutron reaction, response due to the elastic scattering can be recognized in the spectrum, and the number of the reaction in the Si-SBD though the irradiation was calculated from counts in the spectrum.

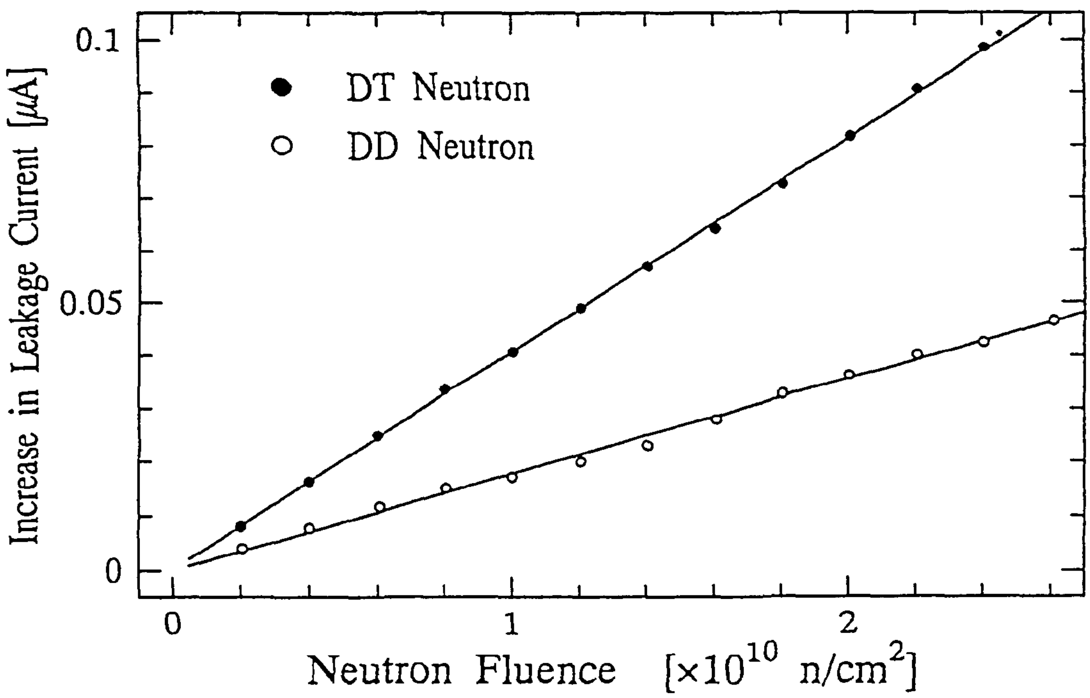

Fig. 3 Increase in leakage current vs. neutron fluence for Si-SBD

Table 1 Neutron damage constants for leakage current of Si-SBD

DT Neutron	DD Neutron
4.1×10^{-9} nA/(n/cm^2)	1.8×10^{-9} nA/(n/cm^2)

In the present irradiation experiment, the displacement damage in the Si-SBD is caused mainly by recoil atoms. The amount of the displacement damage due to alpha particles and protons is negligible compared with that due to recoil atoms. The energy spectrum of Mg atoms from (n, α) reaction in the Si-SBD was calculated from the kinematics using the spectrum data in Fig.4. Since precise charge spectrum for (n, p), (n, n) and the other reactions was not outputted from the Si-SBD in the irradiation experiment, the energy spectra of Al and Si energetic atoms from DT neutron reactions were given by calculation with the nuclear data under the isotropic treatment. And the amount of displacement damage for Si due to Mg, Al, and Si energetic atoms was calculated using the TRIM computer program. According to this calculation, the correlation factor of DT and DD neutron damage in the Si-SBD is determined from the ratio of the amount of displacements by DT neutrons to that by DD neutrons and is shown in Table 2. The correlation factor from the calculation approximately agreed with that from the measurement of leakage current of the Si-SBD. This means that the origin of the neutron induced leakage current of Si-SBD is closely related with the displacement damage and also the hardness of the Si-SBD to different energy neutrons can be estimated by the displacement damage calculation.

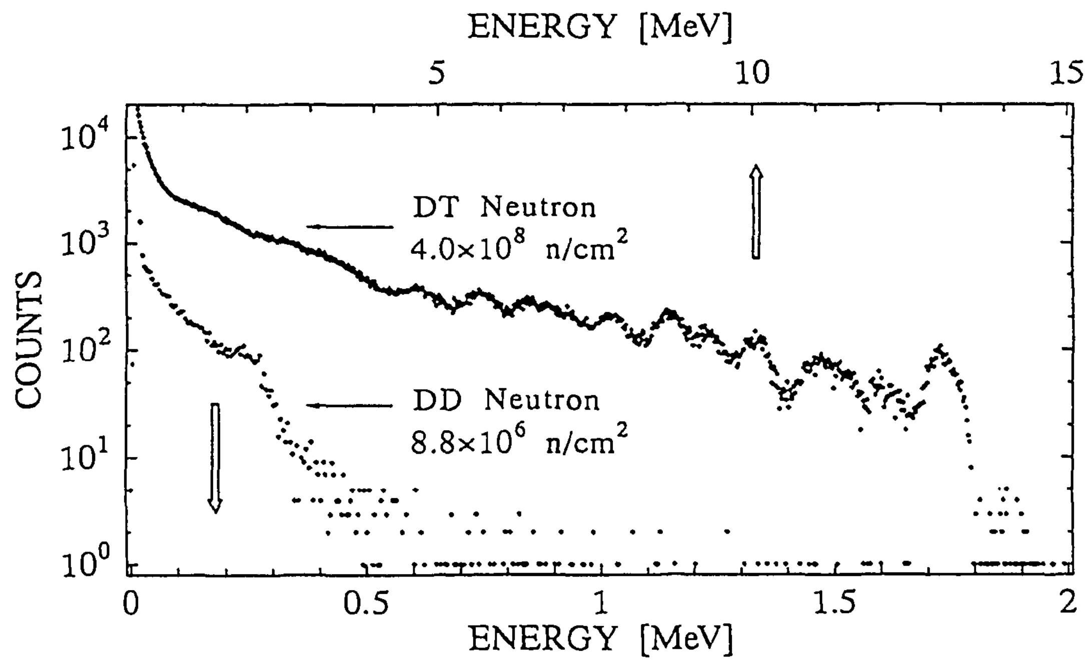

Fig.4 Response of Si-SBD to DT and DD fusion neutron

Table 2 Correlation factor of DT and DD fusion neutron damage for Si-SBD

Experiment (Leakage current)	Calculation (Displacement damage)
2.3	2.5

4. Summary

In order to examine the correlation of DT and DD fusion neutron damage in silicon devices, a Si-SBD was irradiated at room temperature with neutrons from the deuteron accelerator, OKTAVIAN. The degradation of the Si-SBD was measured *in-situ* during neutron irradiation. The leakage current increased proportionally with neutron fluence, which determined the neutron damage constant for the Si-SBD. The correlation factor of the DT and DD neutron damage in the Si-SBD was determined from the ratio of the DT and DD neutron damage constants and was found to be 2.3.

On the assumption of an isotropic neutron reaction, we also calculated the rate of the DT and DD neutron displacement damage for Si by using the TRIM-90 computer program and the actual data on neutron reactions in the detector. The correlation factor of the DT and DD neutron displacement damage from this calculation agreed with that from the Si-SBD irradiation experiment.

References

[1] The stopping and Range of Ions in Matler, J.F.Ziegler (Pergamon,1985).
[2] K.Sumita, A.Takahashi, T.Iida and J.Yamamoto, Nucl. Sci. Eng. 106 (1990) 249.