Study on Neutron Generation by Using Modified Prototype D-D Neutron Generator

In Jung Kim, Suk-Kwon Kim, Chang Su Park, Nam-Suk Jung, Hwa-Dong Jung, Kyoung-Jae Chung, Yong-Seok Hwang and H.D. Choi
Seoul National University, Shinlim-Dong, Gwanak-Gu, Seoul 151-742, Korea, vandegra@plaza.snu.ac.kr

1. Introduction

The effects of Ti target thickness and deuteron beam energy on neutron generation in the modified prototype D-D neutron generator [1] were studied. Three kinds of Ti targets with the thickness of 10 μm, 40 μm and 1 mm were used. Deuteron beam energy was varied from 45 keV to 65 keV. The effects of target thickness and deuteron beam energy were evaluated for every set of experimental run and the results were discussed.

2. Experiment

Ti targets of three kinds of thicknesses 10 μm, 40 μm, 1 mm were prepared. The targets with thickness of 10 or 40 μm were made by using a magnetron sputtering coating system. Ti layers were deposited on Cu substrates (3 mm thick) in vacuum. Ti target with the thickness of 1 mm was fabricated by machining a lump of Ti metal.

A Si detector was used to measure the protons generated from D(d,p)T reaction [1]. It was placed at 112 mm away from the center of target, 118° off the beam direction, and the detection area was defined by an aperture of 1.3 mmΦ. From the generation rate of protons, neutron yield is derived based on the ratio of the two competing reaction rates.

The ion source [2] was operated at 1.0 kW RF power, and the deuteron beam was extracted at 20 kV from the ion source. Deuteron beam was accelerated to 45 ~ 65 keV by applying negative bias to the target. Deuteron beam current was about 3 mA at the target position.

Proton spectra of Si detector were accumulated and retrieved every minute. Proton peaks were observed at about 2 MeV, and the FWHM (Full Width at Half Maximum) of the peaks were less than 200 keV. One of the measured proton spectra is shown in figure 1.

3. Results

Beam cross sectional marks were left on the targets by beam irradiation. The beam marks were regarded as the main region of neutron generation. The detection efficiency of the Si detector was determined from the detection geometry and the size of beam mark. The detection efficiency of the Si detector was 7.9×10^{-6}.

Neutron yield was determined from the generation rate of protons, which are approximately equal in the present device. The result of an experimental run performed with a 40 μm thick Ti target is shown in figure 2. The variation of neutron yield vs. deuteron beam energy was investigated in the experiments. In the beginning of beam irradiation, deuteron beam energy was fixed at 46 keV and it took some while before neutron yield got saturated. After neutron yield was saturated, deuteron beam energy was raised up to 65 keV in several steps. Response of neutron yield to the change in beam energy was prompt. Neutron yield was increased up to 1.5×10^{7} n/s at deuteron beam energy of 65 keV.

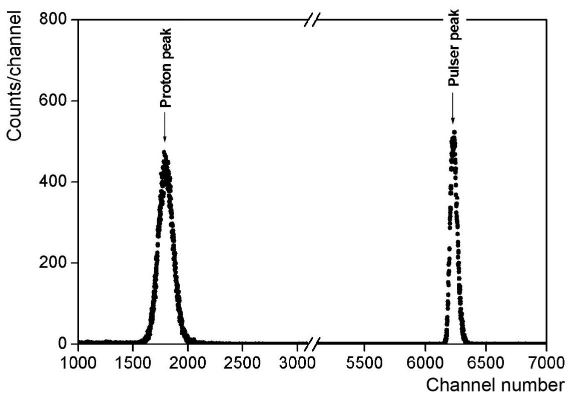

Fig. 1. Proton spectrum of Si detector from D(d,p)T reaction. Proton peak energy is 1.80 MeV and FWHM of the peak is 155 keV. This spectrum was accumulated for 10 minutes.

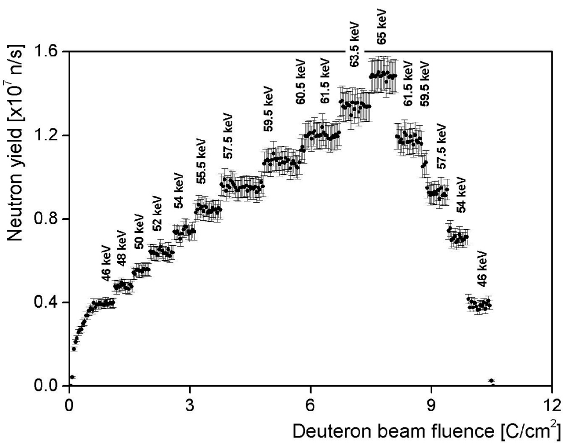

Fig. 2. A result of neutron generation run by using a 40 μm thick Ti on Cu target. Deuteron beam current was 2.7 mA during the run.

The observed neutron generation vs. beam energy is shown in figure 3. The target thickness and the beam current of each experiment are noted on the figure. The increase of neutron yield in pace with the beam energy is mainly due to the rising $D(d,n)^3He$ reaction cross section. But the difference in neutron yield among the sets of conditions is due to both deuteron beam current and target thickness.

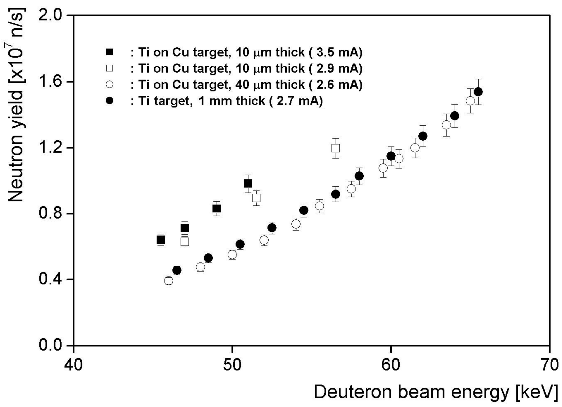

Fig. 3. Neutron yield vs. deuteron beam energy for various target thickness.

In order to investigate the effect of target thickness separately, D/Ti ratio was derived, which is the average content of deuterium in Ti target. D/Ti value was derived from neutron yield, deuteron beam energy and beam current by using the formula of neutron yield [3]. The result is shown in figure 4. D/Ti values of the targets were within from 0.10 to 0.15. The D/Ti value of the target with thickness of 10 μm was higher than that of others by about 30%. However, it was still less than the maximum value of D/Ti, about 2 [4], and the deviation was not considerable.

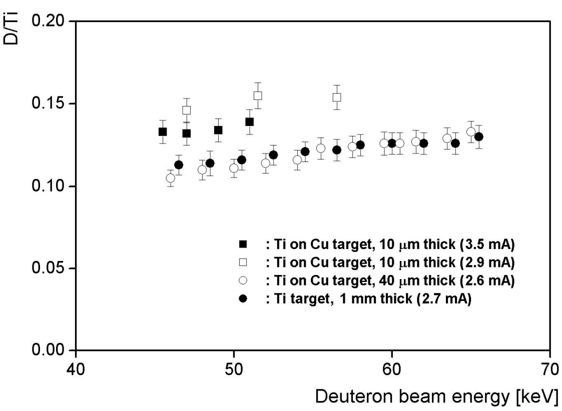

Fig. 4. D/Ti vs. beam energy for targets of various thicknesses.

4. Conclusion

The effects of deuteron beam energy and target thickness on neutron yield were investigated. Targets with the thickness of 10 μm, 40 μm, 1 mm were used, and deuteron beam energy was varied from 45 keV to 65 keV. In the beginning of beam irradiation, it took some while before neutron yield got saturated, but after this period neutron yield responded promptly to the variation of deuteron beam energy. The effect of deuteron beam energy on neutron yield was evident. Neutron yield was increased in pace with deuteron beam energy due to the increase of reaction cross section. However, the effect of target thickness was not evident, for D/Ti values of the targets were underlying the maximum value.

ACKNOWLEDGEMENTS

This research was performed under the program of Basic Atomic Energy Research Institute (BAERI) which is a part of the Nuclear R&D Programs funded by the Ministry of Science & Technology (MOST) of Korea.

REFERENCES

[1] I. J. Kim, S. K. Kim, C. S. Park, N. S. Jung, H. D. Jung, J. Y. Park, Y. S. Hwang, and H. D. Choi, Modification of Prototype D-D Neutron Generator, Transactions of the Korean Nuclear Society Autumn Meeting, Oct. 2005, Busan, Korea.
[2] H. D. Jung, M. J. Park, S. H. Kim, and Y. S. Hwang, Development of a Compact Helicon Ion Source for Neutron Generators, Review of Scientific Instruments, Vol. 75, pp. 1878-1880, 2004.
[3] I. J. Kim, and H. D. Choi, Calculation of Neutron Yield for a D-D Neutron Generator, Abstracts of Proceedings of the Korean Nuclear Society Autumn Meeting, Oct., 2003, Youngpyong, Korea.
[4] D. V. Schur, S. Yu. Zaginaichenko, V. M. Adejev, V. B. Voitovich, A. A. Lyashenko, and V. I. Trefilov, Phase Transformations in Titanium Hydrides, International Journal of Hydrogen Energy, Vol. 21, pp. 1121-1124, 1996.