Design and Construction of Deuterium Target for Fast Neutron Production

P.Tayyebi* , F.Abbasi Davani

Department of Radiation Application, Shahid Beheshti University, Velenjak, Tehran, Iran

*pooneh.tayyebi@gmail.com

Abstract: In order to make deuterium targets (TiD), titanium layer with thickness 0.5 up to 2 μm and copper substrate have been used. Titanium coating on copper has been carried out by Ion coating method. Thicknesses of Targets have been measured by Rutherford Back Scattering (RBS) method and simulated by SIMNRA software. The targets, after thermal treatment, have been exposed to deuterium gas. For validation of deuterium diffusion in the targets they have been analyzed by ERD method. Then they have been bombarded with Deuterium ion (in the neutron generator) by different energies from 90 up to 140 keV and currents of 100 and 200 μA. Emitted neutrons from D-D reaction have been measured by BF_3 counter and neutron energy has been measured in zero angle respect to incident beam. A 2” ×2” liquid scintillator, NE 213, has been used. In this experiment neutron and gamma spectra have been discriminated by pulse shape discriminator (P.S.D) and zero cross timing. Colrow and FORIST codes have been used for unfolding and the neutron energy has been measured that is 2.5 MeV. It is concluded from bombardment results that the best thickness of target which is made, is 1 μm.

Keywords: Deuterium target, Neutron Generator, Ion coating , Neutron-Gamma discrimination, Colrow and FORIST, Neutron energy spectrum.

1- Introduction

Making suitable targets for neutron production, especially monoenergetic neutrons, have been always interested. These targets have been used for neutron production reaction studies and measurement of its energy [1], calibration of detectors [2], neutron therapy and etc. Different studies have been carried out on deuterium and tritium for making solid targets to produce monoenergetic neutron from D-D and D-T reactions in low energy (150 keV) accelerators. A lot of investigations have been carried out on solid target properties such as lifetime, thermal stability, neutron yield and energy. Vaporized zirconium and titanium layers on high thermal conductivity substrate (Cu, Mo, Ag, Al, W) have been used as deuterium and tritium absorbing metals. Ratio of absorbed hydrogen atoms to metal atoms is almost 1.5 and these targets are stable up to 200°C. The density of titanium is smaller than zirconium; the range of charged particles in titanium targets is more than that in zirconium targets. So that, titanium targets have more neutron yield than zirconium targets in low energy accelerators and titanium is usually used to make target [3]. Choosing an optimum thickness of target is an important point to access suitable lifetime and maximum neutron yield [4, 5].

2- Target Construction

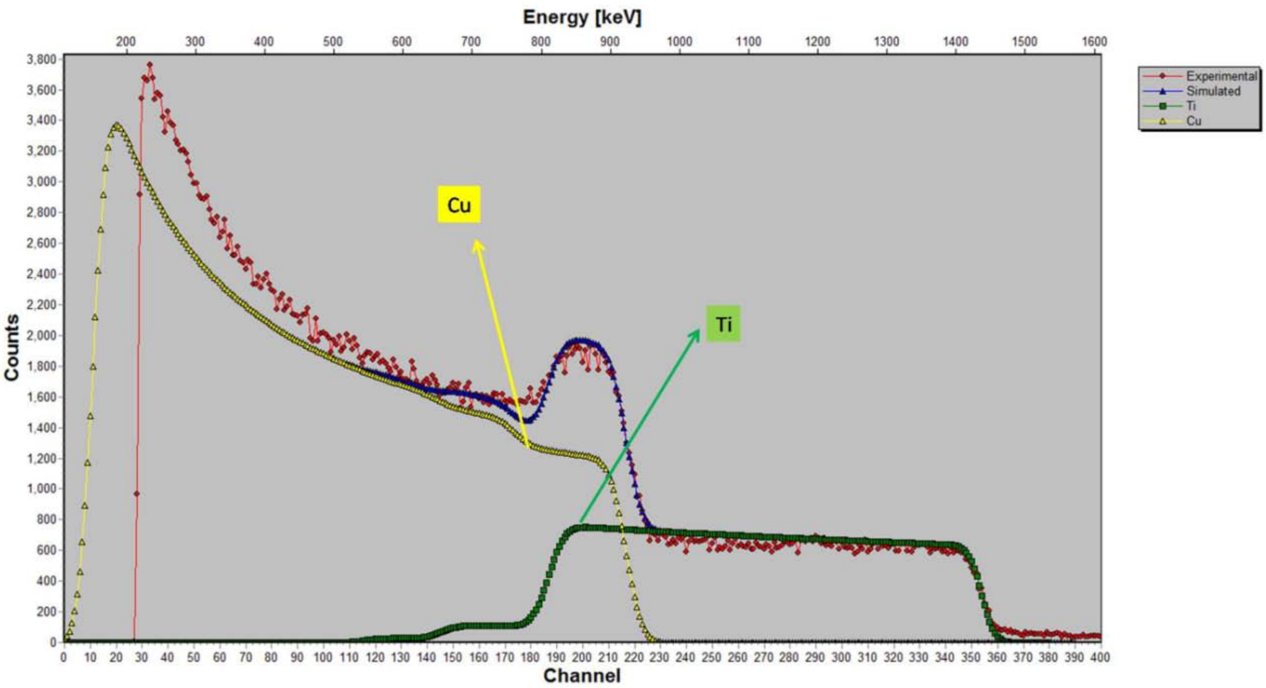
Copper has been used as substrate, because of its high thermal conductivity. Its dimension is 31.5 and 1 mm in diameter and thickness, respectively. Its diameter is the same as of target holder diameter in the most neutron generators. The thickness has been selected, anyhow, to keep drift tube vacuum on one side and environment pressure on the other side. Titanium has been deposited on copper substrate by ion coating. The thickness of the layer is in the range of 0.5 up to 1 μm. The thickness of layer has been measured by using RBS method and then simulated with SIMNRA[1] software. Fig. (1) shows the experimental and simulated spectra for 1st

Table (1). Thicknesses of targets have been measured by RBS.

Thickness (±0.001 μm)	Target no.
1.143	1
0.668	2
0.545	3

The activation operation, including thermal treatment (400, 500, 600 °C for an hour and 5.3×10^{-5} mbar), have been carried out for each target. After that, they have been exposed to deuterium gas (3 bar, purity more than 90%) for 3 days.

[1] Simulation of Nuclear Reaction Analysis

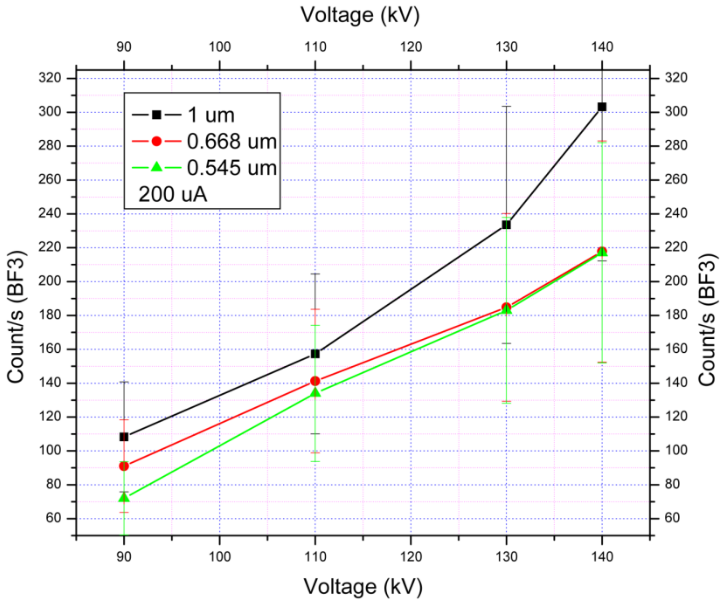


Fig(1). RBS Spectra of 1st target for measuring the thickness of titanium layer.

3- Targets Bombardment

Each of targets has been put at the end of neutron generator beam line. At first, generator current have been set in 200 μA then reduced to 100 μA, and its voltage has been changed from 90 up to 140 keV (90, 110, 130, and 140 keV). The number of emitted neutrons has been measured by BF_3 counter. Target was cooled by air passed through liquid nitrogen.

Figures (2) and (3) is related to 200 and 100 μA beam current, respectively show the count rate of BF_3 v.s incident deuteron energy for three targets. After bombardment, Elastic Recoil Detection (ERD) method has been used for Deuterium target stability analysis which is shown in fig.(4).



Fig(2). Count rate of BF_3 v.s voltage (200 μA)

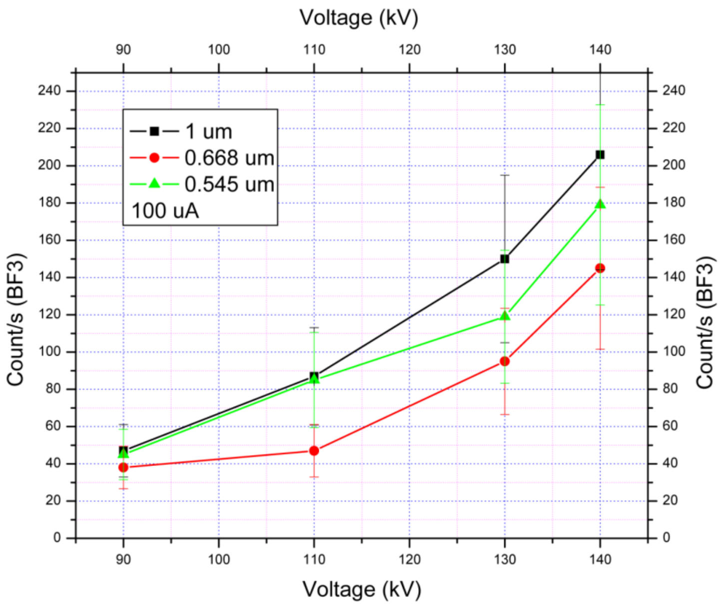


Fig (3). Count rate of BF_3 v.s voltage (100 μA)

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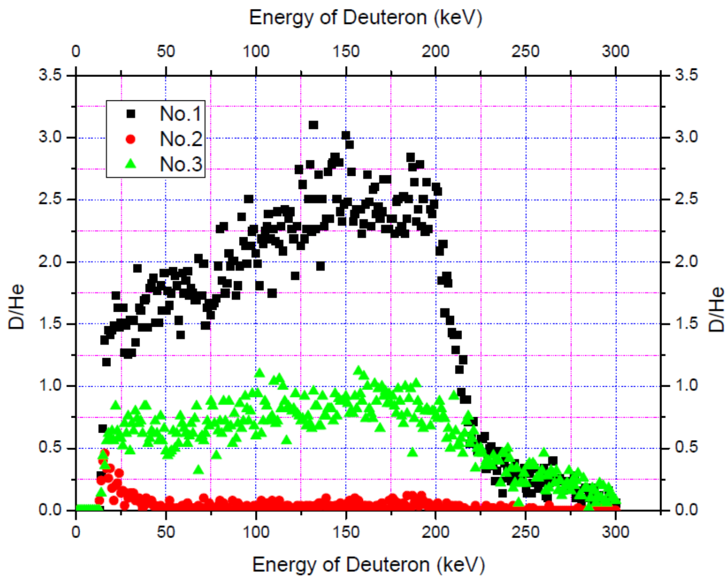

Fig (4). ERD analysis of deuterium target after bombardment in neutron generator.

4-Neutron and Gamma discrimination

A 2”×2” NE 213 scintillator has been set in front of the end of the beam tube in which the target was installed. The situation of the scintillator is represented in fig. (5).

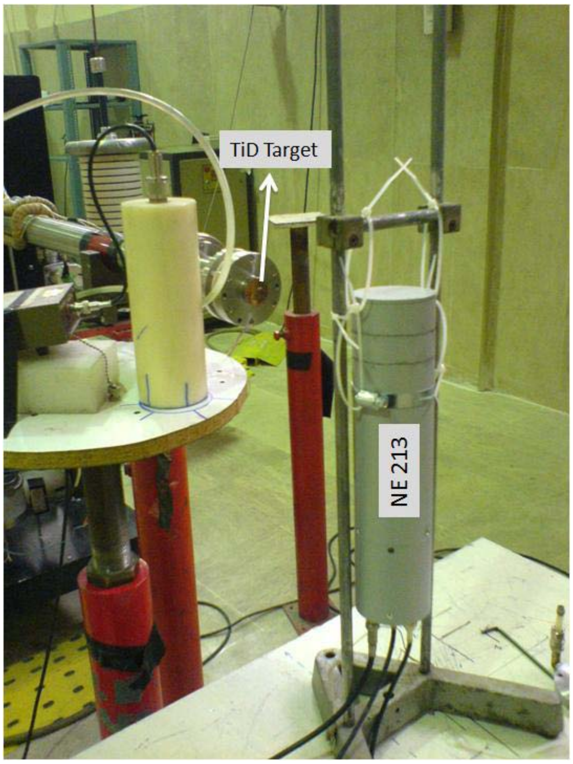

Fig. (5). the situation of the target and the scintillator. The scintillator has been set to the zero degree respect to the incident D beam.

For neutron and gamma discrimination, the zero cross timing, due to its proper discrimination quality in low energy, has been used. ^{252}Ca neutron source has been used for setting the electronic system and ^{22}Na gamma source has been used for the calibration of energy. Fig. (6) Shows the electronic setup for the discrimination.

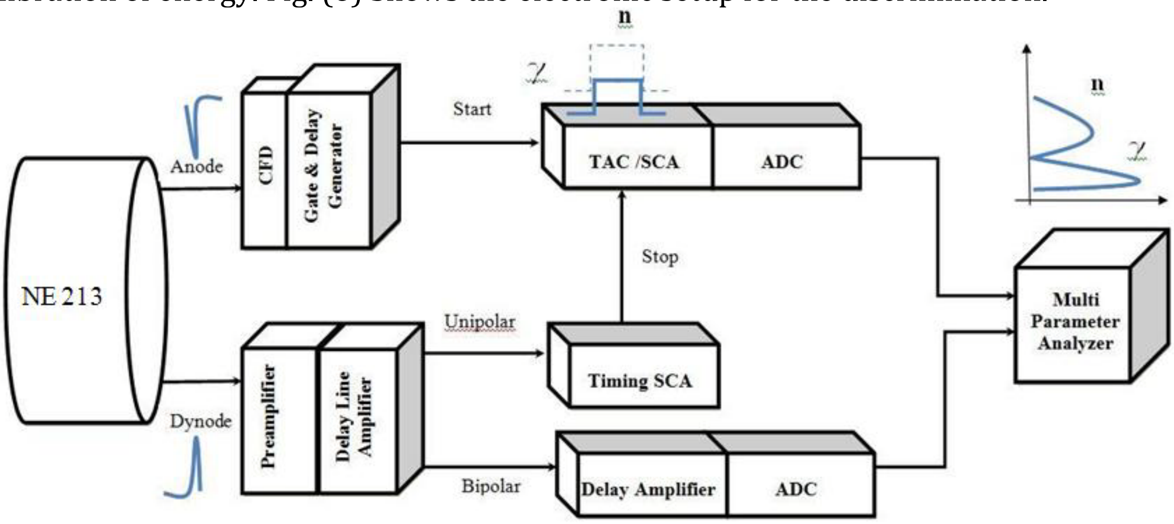

Fig. (6) Set up of the neutron-gamma discrimination.

Fig. (7) shows the discriminated spectra of neutron and gamma. Vertical and horizontal axis show energy and the time, respectively. FORIST and Colrow have been used for unfolding the neutron spectrum. Fig. (8) shows the neutron energy spectrum which is resulted from bombardment of the target with 0.5 mm thickness.

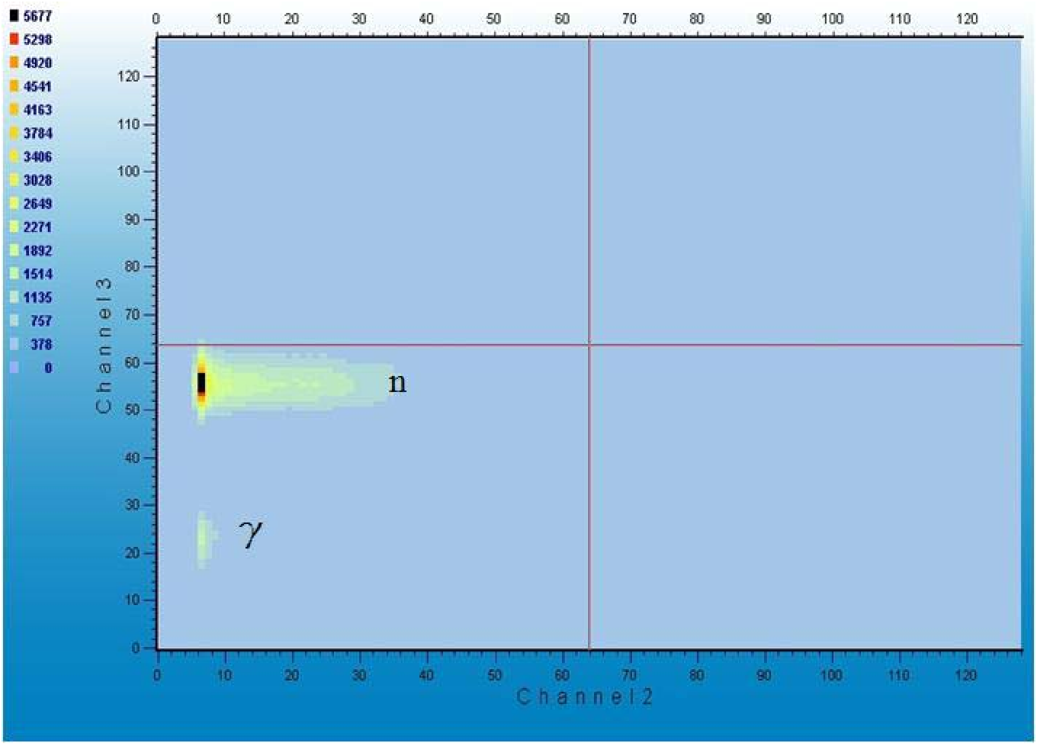

Fig.(7). Neutron gamma discriminated spectra from 0.5 mm target.

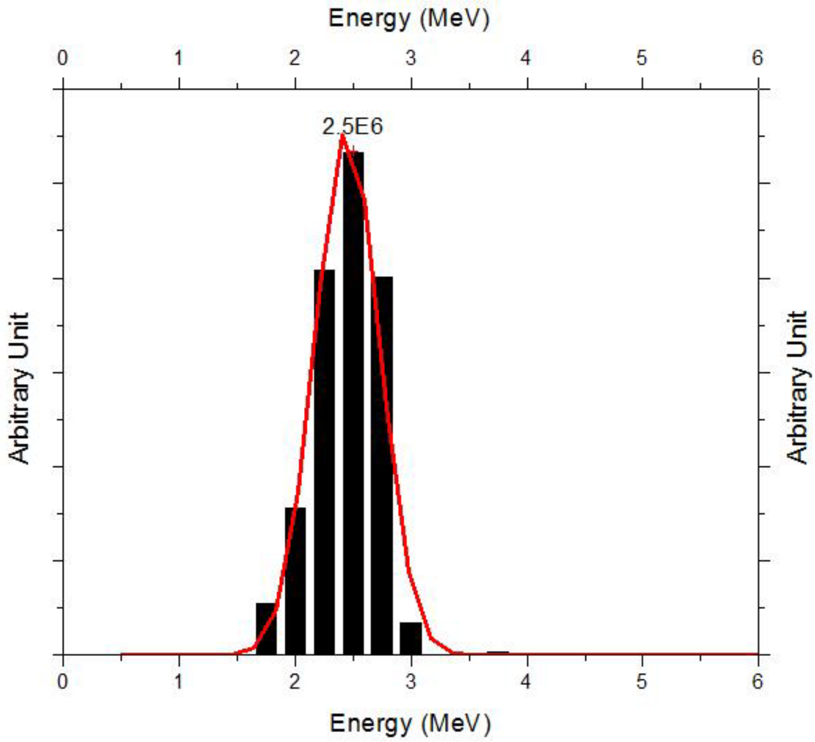

Fig.(8) .Final neutron energy spectra from bombardment of 0.5 mm target by d-D reaction.

5- Result and Discussion

Since the cross section of D-D reaction at E_D<1 MeV increases with the energy of the beam (FIG.9), it is expected that increasing in voltage leads to increase emitted neutrons, which is shown in figures (2) and (3) for each targets. It is also observed that increasing the thickness of the target leads to increase count rate of BF_3. In fact the target with the maximum thickness, in comparison to other targets, is able to absorb more deuterium, and hence, increasing the quantity of deuterium nucleus, leads to increase emitted neutron flux from the D-D reaction.

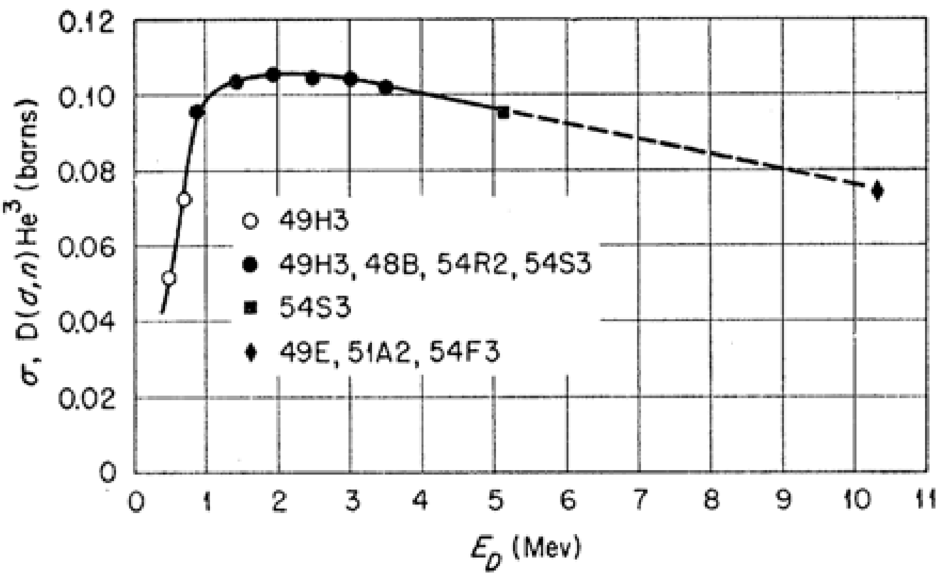

Fig (9). Cross section of D-D reaction according to incident deuterium energy [6].

In fig.(3), neutron yield of 2nd target with thickness of 0.668 μm is smaller than 3rd target (with thickness 0.545 μm). It is observed in fig. (4) that the 2nd target is severely depleted and quantities of deuterium gas in its surface layer were low, and only a small quantity of gas is presented in deeper layers. The reduction of gas in this target may be related to thermal degassing, and the neutron yield is decreased. It is also observed that the quantity of absorbed deuterium in 1st target (1.143 μm), even after bombardment, is more smaller than the others. Hence the best target that we can make is the target of 1 μm thickness.

References:

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