Prototype Manufacturing of Small Tritium Target inside JAEA

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Since 2006 we have conducted R&D for manufacturing a tritium target for the Fusion Neutronics Source (FNS) facility inside JAEA for ourselves. The small tritium target is produced by adsorbing tritium in a thin titanium layer deposited on a cup-shaped copper-alloy substrate. The titanium layer of 24 mm in diameter and ~ 5 μm in thickness is deposited on the bottom of the substrate. We carried out many tests of adsorbing deuterium to the titanium layer instead of tritium. As a result, we found out that the control of humidity is one of critical issues to keep high tritium concentration in the target. We succeeded in producing small tritium targets at the Tritium Processing Laboratory (TPL) in JAEA. The small tritium target manufacturing procedure was established.

Keywords: tritium target, titanium, humidity, outgassing, FNS, TPL

1. Introduction

The Fusion Neutronics Source (FNS) facility in Japan Atomic Energy Agency (JAEA) is an accelerator-based DT neutron source for fusion neutronics research. FNS has two beam lines and uses two types of tritiated titanium targets. One is a small target of 30 mm in diameter with about 370 GBq tritium at the 1st target room and the other is a large one of 310 mm in diameter with about 30 TBq tritium at the 2nd target room. We have imported the tritium targets so far, but the target purchase cost increased, while our budget decreased gradually. In 2006 we started R&D for manufacturing a tritium target for stable supply for FNS inside JAEA for ourselves. The progress of the small tritium target manufacture R&D is described in this paper.

2. Target manufacture flow

The small tritium target is produced by adsorbing tritium in a thin titanium layer evaporated on a cup-shaped copper-alloy substrate. The manufacture flow is as following;

1) Fabrication of a target substrate,
2) Titanium vapor deposition,
3) Activation of titanium layer if necessary,
4) Tritium adsorption.

3. Target substrate and titanium vapor deposition condition

The small target substrate of a cup-shaped copper-alloy is 30 mm in diameter and 20 mm in height as shown in Fig. 1. The titanium layer of ~ 24 mm in diameter and ~ 5 μm in thickness is deposited on the bottom of the substrate. The thickness of the titanium was decided as double range of a 350-keV deuteron beam in titanium. Figure 2 shows the picture of the small target for FNS.

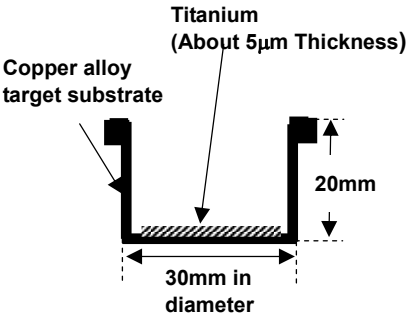

Fig. 1 Vertical cross section of small target.

Fig. 2 Picture of small target.

The tritium adsorption is influenced by titanium grain size, which changes depending on a titanium vapor deposition condition. In low temperature, a lot of small grains form the microstructure porosity. On the other hand, in high temperature, the grain grows and the microstructure vacancies decrease [1,2]. The suitable substrate temperature and deposition speed in vapor deposition are essential to adsorb a lot of tritium [3].

The preprocessing of the target substrate before the titanium vapor deposition and the titanium vapor deposition condition are as follows,

Substrate cleaning : supersonic wave cleaning with methylene-chloride

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Outgassing of substrate :
500 degrees C, 60 minutes
Vapor deposition temperature of substrate :
350 degrees C
Argon sputters cleaning : -2 kV, 10 minutes
Titanium thickness : 2.3 mg/cm^2
Vapor deposition area : 4.5 cm^2
Vapor deposition speed : 7.8 nm/s

4. Target substrate handling

Since titanium metal is very active to oxygen, oxidation film of a few nm in thickness is formed on a titanium-deposited surface in the atmosphere. At first it was thought that this oxidation film gradually thickened by contact with atmospheric oxygen and this oxidation film disturbed tritium adsorption. Therefore glow discharge cleaning of -2 kV with argon gas was carried out for one hour to remove the oxidation film on the titanium surface.

The adsorption chamber described in Sec. 5 heats the target substrate with a heater during tritium adsorption. The main gas released from the target substrate, heater and inside of an adsorption chamber during the heating was water vapor. Thus we considered that it was also important to handle the titanium-deposited substrate and adsorption chamber in low humidity environment. We performed deuterium adsorption test in environment humidity of under 3%, which was the lowest humidity level easily realized at FNS. The titanium-deposited substrate was stored in a storage vacuum chamber to avoid atmospheric humidity.

In order to examine the glow discharge cleaning effect, we manufactured two small deuterium targets in the same method as shown in Sec. 5. One had the glow discharge cleaning of the titanium surface with argon gas to remove an oxidation film of the titanium surface, while the other did not. The titanium-deposited target substrates of the deuterium targets were kept in a storage vacuum chamber during one month in FNS before adsorbing deuterium gas. We measured DD neutron generation rates of the manufactured deuterium targets by bombarding deuteron beam at FNS in order to estimate how much deuterium was adsorbed. Figure 3 shows DD neutron generation rates to that of a deuterium target in which deuterons was fully implanted. The DD neutron generation rates of the manufactured deuterium targets with and without the glow discharge cleaning are around 80 % of that of a deuterium target in which deuterons was fully implanted, which is probably due to the oxidation film, and the difference between them is small. It was found out that the glow discharge cleaning was not necessary. We also examined the humidity effect. The DD neutron generation rate of a deuterium target manufactured in normal atmospheric humidity was less than 1 % of that of a deuterium target in which deuterons was fully implanted. Finally it was concluded that humidity disturbed tritium adsorption much more than the oxidation film.

The tritium gas (T_2) is adsorbed to the titanium surface and is dissociated. Dissociated tritium atoms (T) diffuse from the grain boundary to inside of titanium. It is considered that water molecule blocks up the adsorption of the tritium gas to the titanium surface.

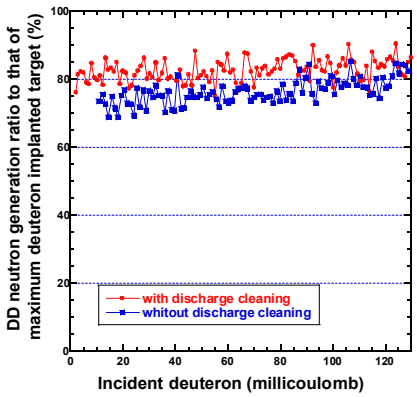

Fig. 3 DD neutron generation rates of manufactured deuterium targets normalized to that of a deuterium target in which deuterons was fully implanted.

5. Tritium adsorption procedure

It is essential keep the target substrate in tritium gas around 400 degrees C for a while in order to adsorb tritium to the titanium layer deposited on the target substrate. We developed a tritium adsorption chamber, which can keep a vacuum and have a heater for temperature control of the target substrate.

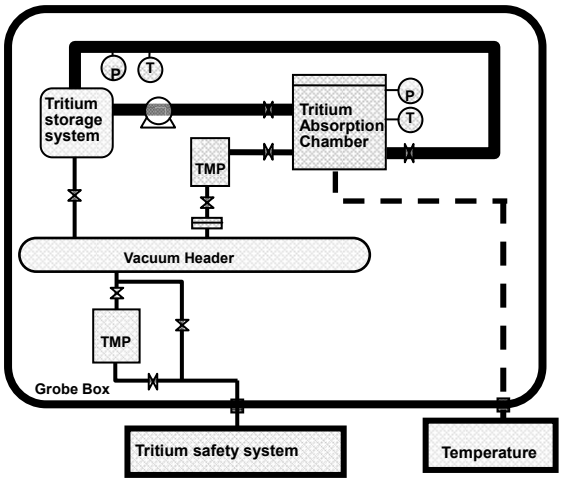

Fig. 4 Tritium adsorption system.

Figure 4 shows the outline of the tritium adsorption system. The tritium adsorption system consists of a tritium adsorption chamber, tritium storage line, circulation line, vacuum line and pressure, temperature monitors. The target adsorption chamber volume is 2.7

liter and the heating power is 450 watts. It can handle three small targets at a time. The metal gasket is used in all connection flanges to keep good seal performance. The tritium adsorption system is installed in the glove box of the Tritium Processing Laboratory (TPL), which can handle a large amount of tritium in Japan.

We manufactured two small tritium targets at the same time. For one of the two target substrates the glow discharge cleaning of the titanium surface with argon gas was performed to remove an oxidation film on the titanium surface. The titanium target substrates kept in the argon gas to avoid humidity were set to the adsorption chamber in the glove box of the TPL. The humidity in the glove box of TPL was kept to 1 ppm by circulating through nitrogen. The tritium leak test of the access flange was done to verify seal performance after the target substrate set up. The target substrate was heated up to the 430 degrees C in a vacuum, and then tritium gas of 6.5 kPa was infused to the adsorption chamber and was kept for one hour [4].

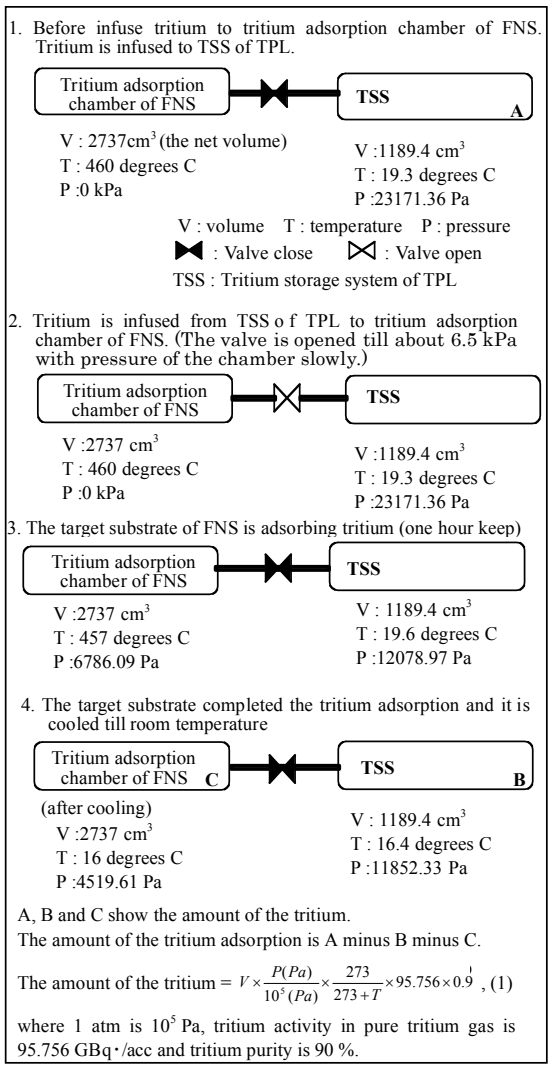

Fig. 5 Data for the amount estimation of the tritium adsorption.

After heating power off, the remaining tritium gas was recovered to the storage tank by circulating to the storage tank line. The amount of tritium adsorbed to titanium was estimated from pressure and temperature in the adsorption chamber and Tritium Storage System (TSS). Figure 5 shows the data for the amount estimation of the tritium adsorption. We calculated quantity of tritium adsorption with the formula (1) from subtracting B and C from A shown in Fig. 5. The amounts of the adsorbed tritium in the two targets were deduced to be both about 320 GBq, which were comparable with those of previously imported small targets.

6. DT neutron production characteristics

We measured DT neutron production performance of the manufactured targets with FNS. The initial DT neutron generation rate with the discharge cleaning was about 1.7×10^{11} n/s per 1 mA deuteron beam of FNS, while that without the discharge cleaning was 1.8×10^{11} n/s per 1 mA deuteron beam of FNS. The initial DT neutron generation rates of the target with and without the discharge cleaning were almost the same. Figure 6 shows the change of the DT neutron generation rates of these targets and previously imported targets with bombarding deuteron beam quantity. The reason of this attenuation is tritium release from the target due to heat of bombarding deuteron beam, not consumption due to DT reaction. The attenuation rates of the neutron generation rate of the manufactured targets are small, while those of the most imported targets are large. It is concluded that the neutron generation performance of the manufactured targets is quite good.

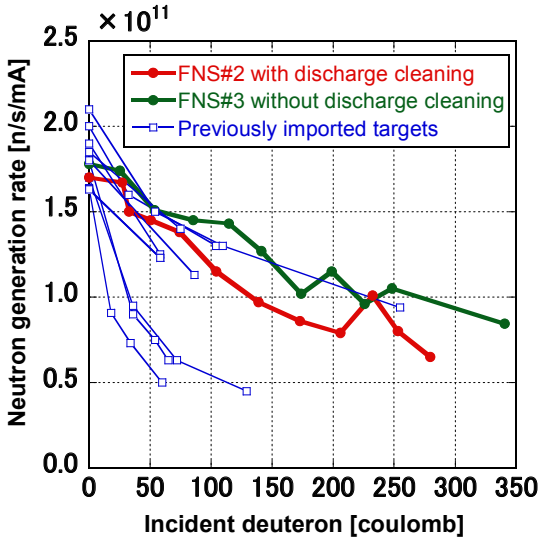

Fig. 6 Change of the DT neutron generation rates.

We replace the target when the neutron generation rate is less than 0.5×10^{11} n/s/mA. The neutron generation rate is determined by the tritium quantity in the target, which is released due to heat by bombarding

deuteron beam, depending on titanium deposit temperature and a storage period of the targets. The previously imported small targets were used from about 4 days to 12 days (7 hours/day) with an average DC beam current of about 1mA, but the manufactured targets were used for more than 12 days.

7. Summary

Since 2006 we have conducted R&D for manufacturing a tritium target for FNS inside JAEA. It was found out that it was humidity to avoid tritium adsorption on the target. We succeeded in the tritium adsorption of two target substrates at the same time at TPL. The initial DT neutron generation rates of the target with and without the discharge cleaning were almost the same. The DT neutron generation performance of the manufactured targets was quite good. The manufacture condition and procedure of the small target was established. Now we are developing a tritium adsorption chamber by using which eight small targets and one large target can adsorb tritium at the same time.

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