Development of Titanium Drive-in Solid Target for a Compact Fast Neutron Generator

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Introduction

- A compact fast neutron generator is developed with a neutron energy of 2.5 MeV in KAERI
- A Titanium drive-in solid target was fabricated with the OFHC-copper material including the water cooling structure to overcome the heatload by the injection of deuterium ion beams with an energy of 100 keV/100 mA
- Design parameters of fast neutron generator

Main Parameter	Required Value	Remarks
Neutron Yield [n/s]	~ 10 ⁹	Continuous Operation
(D+-Beam) Energy/Current [keV/mA]	100 / 100	based on D+-Beam
Target Cooling Capacity [kW]	> 10	based on ~10 ⁹ n/s
Neutron Energy [MeV]	2.5 MeV	Single Energy
Neutron Output Stability [%]	< 10	based on ~10 ⁹ n/s

Evaluation for thermo-hydro-dynamic properties of headload performance on solid target

- For estimation of heatload properties on water-cooled solid-target with an injected deuterium beam power of 10 kW by using the commercial codes (CATIA P3 V5R20, ICEM) CFD, CFX 17.0):
 - CATIA P3 V5R20 : Geometry Design
 - ICEM CFD : Element Mesh Generation
 - CFX 17.0 : Thermo-hydro-dynamic Analysis
- To find the maximum temperature (73°C) of target surface for deuterium ion beam irradiation of 10.7 kW
- To find a maximum temperature (73°C) of target surface and a maximum temperature (52°C) of cooling water for the case of maximum water flow rates with 2.4 m/s (42.6 kPa)

• Design parameters of Titanium drive-in solid target

Main Parameter	Design Value			
Accelerated Particle	D+			
Target Shape	Cone			
Deuterium Loading Material	Titanium (Ti)			
Main Structure Material	OFHC			
Beam Entrance Diameter [mm]	100			
Target Depth [mm]	85.5			
Titanium Layer Thickness [µm]	~ 10			

Compact Fast Neutron Generator

Test Facility of Compact Fast Neutron Generator

 For extraction of hydrogen ion beams(a maximum beam power of 100 keV/100 mA) on the surface of titanium drive-in solid target without neutron shielding structures • For generation of high density hydrogen(and/or deuterium) plasma in ECR plasma generator with a frequency of 2.45 GHz



and 3.8 m/s (0.9 kPa) at the inlet and outlet positions of solid-target

Temperature Contour at Absorbed Power 10.693 [kW]

Limited temp. [°C]	Target Max. temp. [°C]	Coolant Max. temp. [°C]											
200	73.022	52.108											
Temperature Target section view 72.916 64.097		Temperature Target Volume 73.022 64.338		- Absc	orbed Power: 10.693 [k	W]							
55.277		55.655		Target Coolant (Water)									
46.458		46.971		Target Model	Target Max. temp. [°C]	Max. temp. [°C]	Max. Velocity of flow [m/s]	Inlet		Outlet			
37.639		38.288						Velocity [m/s]	Pressure [kPa]	Velocity [m/s]	Pressure [kPa]		
c1 20.000		20,920		Target_v1.2	73.022	52.108	7.118	2.420	42.689	3.891	0.944		
		[C]			Section view	Target Inner Surface	Target Volume	Target Volume Target Coolant (Water)					
Temperature Target Coolant Volume	(a)	Temperature Target Inner Surface		항복	(Temperature)	(Temperature)	(Temperature)	Temperature		Velocity of flow			
46.756 41.404 36.052 30.701 25.349 19.997		73.022 65.596 58.171 50.745 43.319 35.894 28.468		Target_v1.2	Properties 7 29-9 6 407 6 40 7 40 7 40 7 40 8 40 8 40 8 40	Temperature To 502 65.596 64.171 50.745 43.319 28.468 C]	Temperature 73 622 64 338 65 655 96 587 39 804 20 805 (0)	Terroper Counter Volume 52:108 46:756 41:454 50:052 50:751 25:349 19:997		Vageo2y 7.118 5.932 4.746 3.559 2.373 1.166 (0.000 (m e^-1]			

Fig. 5. Designed structures of water-cooled solid-target (including a beam target, a target supporter, and a thermocouple hole)

Fabrication of Titanium Drive-in Solid-Target

- For titanium layer coating of $\sim 10 \ \mu m$ on the surface of deuterium beam injection by using the PVD (physical vapor deposition) process with the method of plasma ion irradiation technology
- Measurement of coated layer thickness by the FE-SEM (field emission-scanning) electron microscope)
- Estimation for four samples of titanium-coated layer before the fabrication of solidtarget



Fig. 1. Schematic structure of hydrogen ion beam test facility

Fig. 2. Schematic structure of ECR ion source

Titanium Drive-in Solid Target

• For determination of titanium-coated thickness in solid-target through the SRIM code (SRIM-2008 code for 2-D) simulation

- To find the injected depth (less than 1.1 µm) of deuterium ion beams on the titanium target with a beam energy of 100 keV

- To determine the coated thickness of titanium layer (~10 µm) on the solid-target • For design of water-cooled titanium-copper solid-target with an injected beam power of 10 kW (100 keV/100 mA)



Fig. 6. structures of fabricated and assembled water-cooled solid-target





(a) Target Samples





Korea Atomic Energy

Research Institute



(e) Sample-4 (d) Sample-3 (t~3.4 µm) (t~4.27 µm)

Fig. 7. A photo of titanium

Fig. 8. Measured thickness of titanium-coated layers for four samples through the F-ESES technology

Conclusions

(t~9.5 µm)

• A solid-target was developed for a compact fast neutron generator in the KAERI, made by an OFHC-copper material including the water cooling structure • The solid-target was shaped in a circular cone-type with an entrance diameter of 10 cm to reduce the heatload (per unit-area) of target - Target surface was coated as a titanium layer with a thickness of 4~10 µm Heatload performance of solid-target was confirmed by calculation of heatload distribution with a beam heat-power of 10 kW on the surface of solid target

Fig. 3. Calculation results for injected depth of deuterium ion particles inside the titanium layer (by simulation of SRIM code)

Fig. 4. Designed structures of water-cooled solid-target (including a beam target, a target supporter, and a thermocouple hole)

- Peak power density of 5.3 MW/m² and maximum temperature of 70°C at target surface

KAERI

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