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

- 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

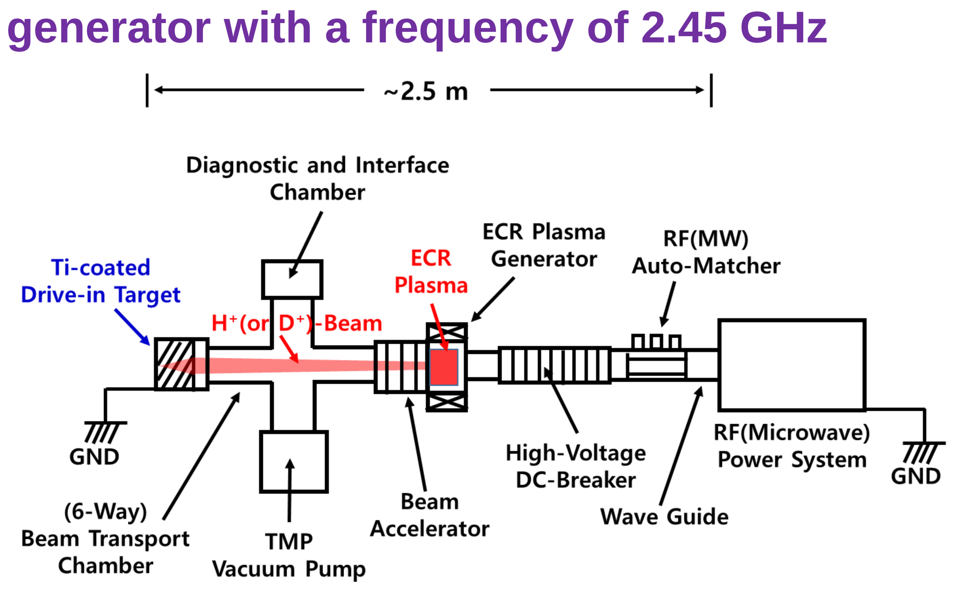


Fig. 1. Schematic structure of hydrogen ion beam test facility

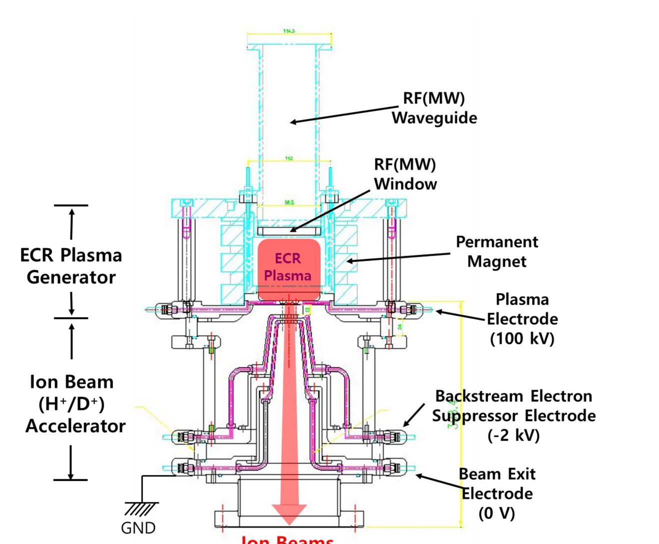


Fig. 2. Schematic structure of ECR ion source

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)

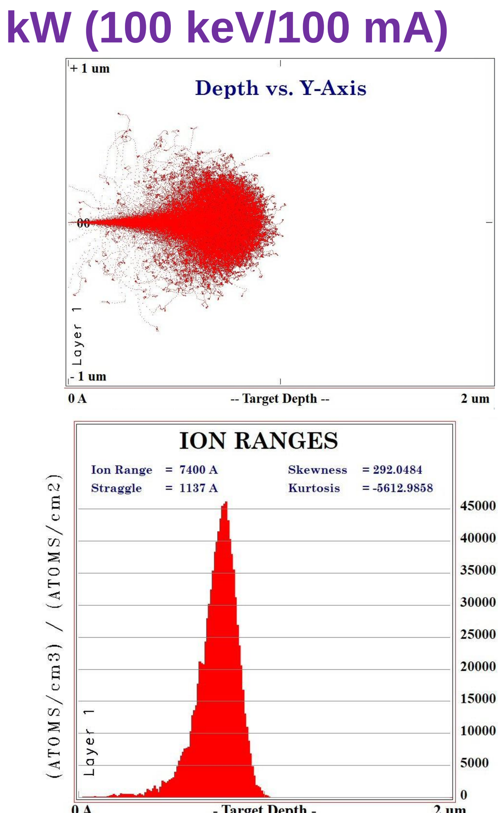


Fig. 3. Calculation results for injected depth of deuterium ion particles inside the titanium layer (by simulation of SRIM code)

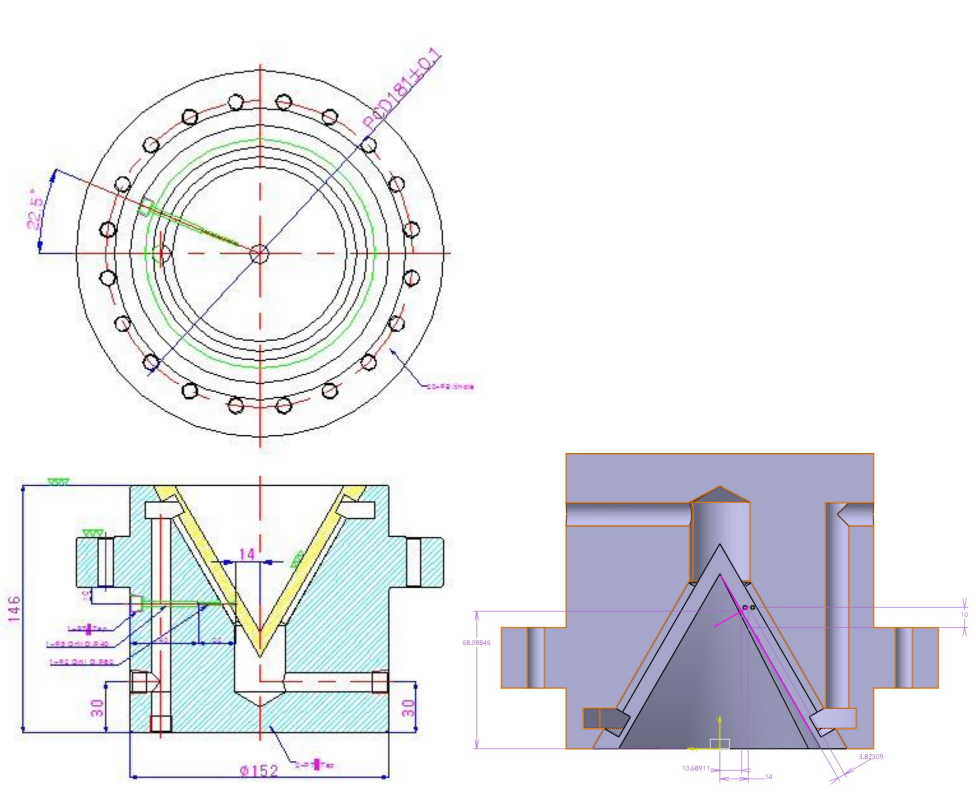


Fig. 4. Designed structures of water-cooled solid-target (including a beam target, a target supporter, and a thermocouple hole)

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℃) of target surface for deuterium ion beam irradiation of 10.7 kW
- To find a maximum temperature (73℃) of target surface and a maximum temperature (52℃) of cooling water for the case of maximum water flow rates with 2.4 m/s (42.6 kPa) and 3.8 m/s (0.9 kPa) at the inlet and outlet positions of solid-target

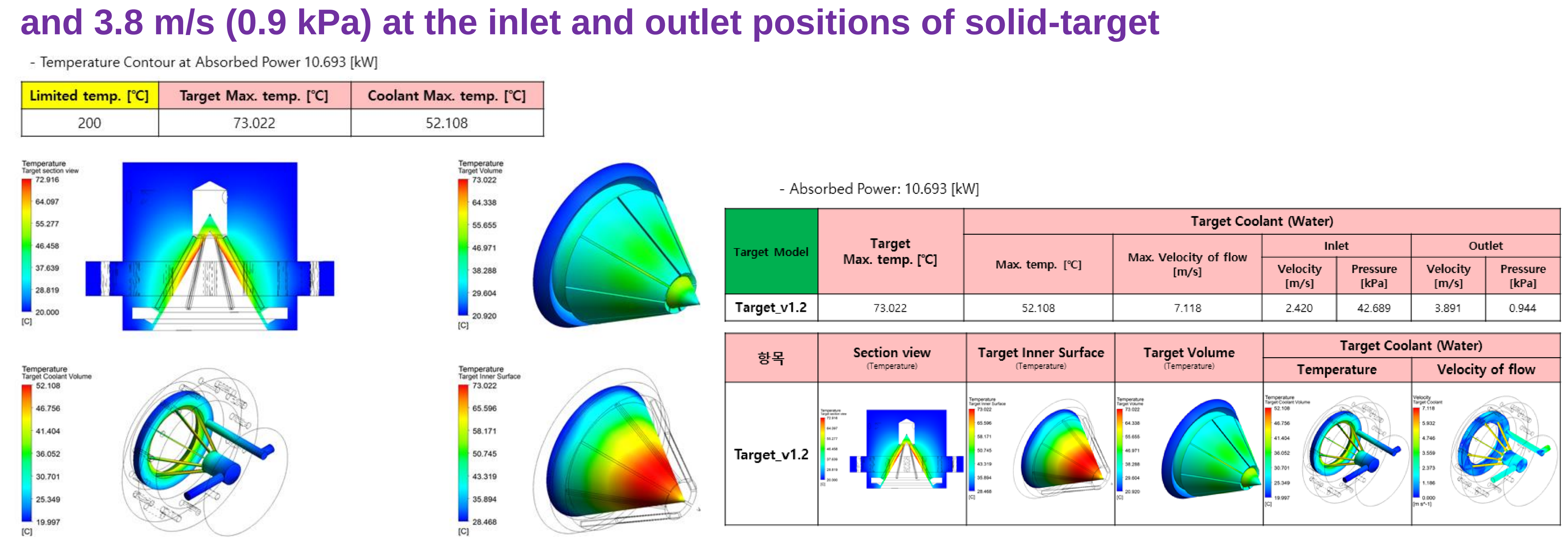


Fig. 5. Designed structures of water-cooled solid-target (including a beam target, a target supporter, and a thermocouple hole)

Fabrication of Titanium Drive-in Solid-Target

- For titanium layer coating of ~10 μm 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 solid-target

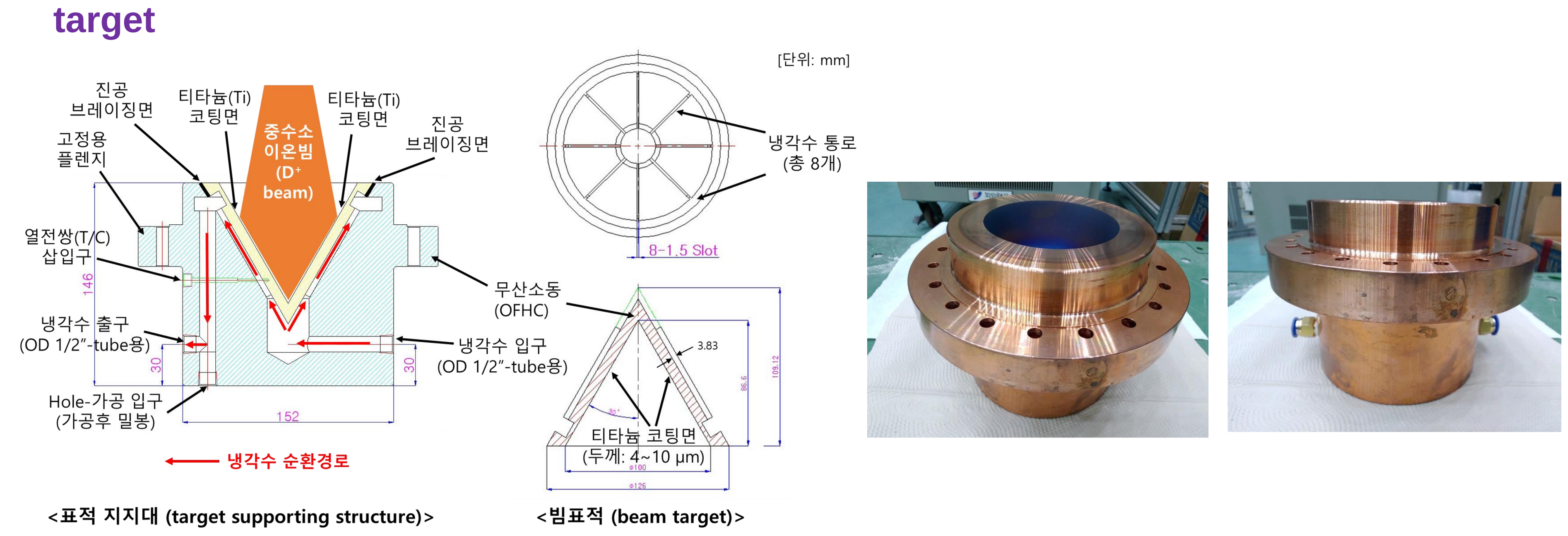
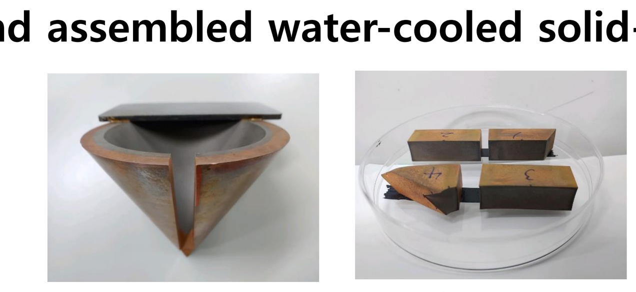
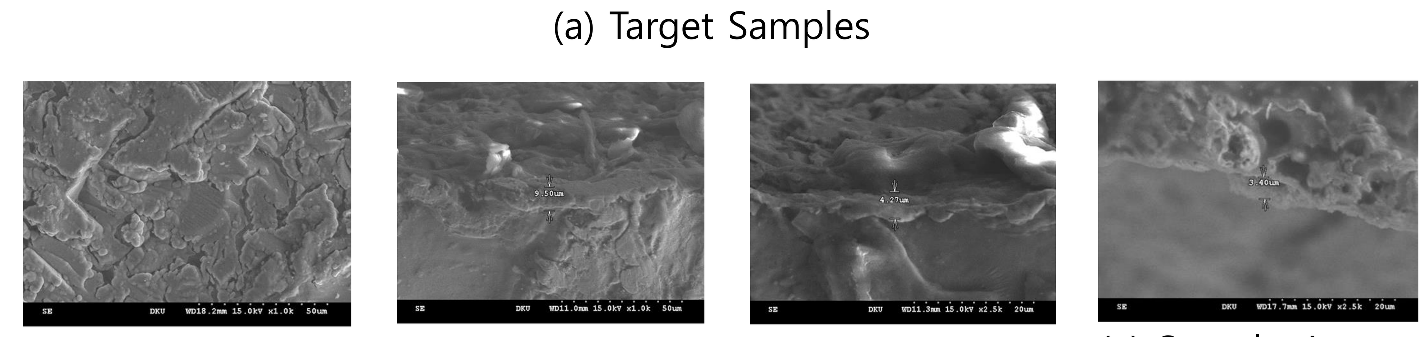


Fig. 6. structures of fabricated and assembled water-cooled solid-target

Fig. 7. A photo of titanium coated beam target



(a) Target Samples



(b) Sample-1 (Not measured) (c) Sample-2 (t~9.5 μm) (d) Sample-3 (t~4.27 μm) (e) Sample-4 (t~3.4 μm)

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

Conclusions

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