# The Fabrication of Prototype Target Stack and Preliminary Thermal Analysis of the 100 MeV Isotope Production Facilities at PEFP

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## 1. Introduction

The Proton Engineering Frontier Project have a plan to construct 100-MeV Proton Linear accelerator and also, will construct radioactive isotope production facility using 100MeV proton beam for medical application. Sr-82, Cu-67 and Ge-68 were selected as the objective radioisotope in this facility. They are promising radioisotope for the PET imaging and cancer therapy.

To produce Sr-82, Cu-67 and Ge-68, RbCl, Zn metal and Ga metal were chosen as a target materials which they have claddings of SUS-304 steel or Inconel. and also to produce these radioisotopes at the same time, we have introduced target stack in tandem [1].

Table 1 indicated the general characteristics of the designated radio-isotopes.

Table 1. Characteristics of the designated radio-isotope

| Isotope | material | Nuclear reaction | Half-life | Emitting radiation |
|---|---|---|---|---|
| Sr-82 | RbCl | natRb(n,xn)82Sr | 25.5d | Positron |
| Cu-67 | Zn | 68Zn(p,2p)67Cu | 2.6d | Electron |
| Ge-68 | Ga | natGa(n,xn)68Ge | 270d | Positron |

## 2. Methods and Results

### *2.1 Fabrication of Prototype Target Stack*

To design RI target, we have derived the optimum thickness of target materials considering the beam energy loss by the beam window, cooling water and target claddings through SRIM calculation [2].

First we fixed the thickness of the inconel beam window, each cooling channel and target capsulations as 0.5 mm, 5 mm and 0.3 mm. and then, we optimized the thickness of target materials such as RbCl, Zn metal and Ga metal by using iterative SRIM calculation.

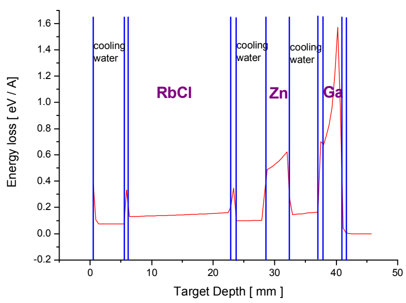


Fig. 1. the energy loss of proton beam at target stacks

Figure 1 and Table 2 shows configuration of prototype target stacks. As a result of SRIM calculation, we optimized the thickness of RbCl, Zn metal and Ga metal as 17 mm, 4 mm and 3 mm. and this result also indicated the energy loss of 20MeV occurred at each target stacks. Thus we can estimate the quantity of heat dissipation at each target.

Table 2. Material, thickness of designed arget stack

| Layer | Thickness [mm] | Energy |
|---|---|---|
| Beam window | 0.5 | 103~100.88 |
| cooling water | 5 | 100.88~97.17 |
| Inconel cladding | 0.3 | 97.17~95.85 |
| RbCl | 17 | 95.84~69.67 |
| Inconel cladding | 0.3 | 69.67~68.01 |
| cooling water | 5 | 68.01~62.9 |
| Zn metal | 4 | 62.9~41.93 |
| cooling water | 5 | 41.93~34.92 |
| Nb cladding | 0.3 | 34.92~30.99 |
| Ga metal | 3 | 30.99~2.96 |
| Nb cladding | 0.3 | 0 |
| cooling water | 5 | 0 |

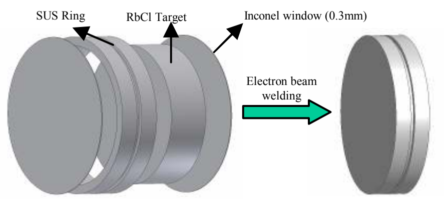


Fig. 2. Fabrication of Target stack

Target materials for radioisotope production have disk type solid with dia. 90 mm. that target disk is encapsulated by metal washer and window which is made of Inconel alloy. Since target material and high temperature cooling water are corrosive.

The target materials is centered in the washer and sandwiched by two windows. And then, the Inconel washer and windows will be electron-beam welded under vacuum environment. (Fig.2)

These target stacks are placed in the cooling water gap between two target stacks. And then, the fast water flow can induce vibration of target stack. Thus the fabricated target stacks have to be mounted robustly at the target carrer. Fig 3 indicates fabrication of target holder for supporting target stack.

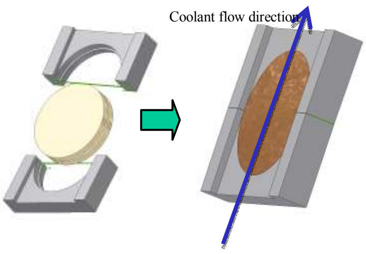


Fig. 3. Fabrication of Target holder

This fabrication of target stack is conducted in the processing hot-cell remotely for the radiation safety. These fabricated target stacks are should be carried from Hot-cell to irradiation chamber for the proton beam irradiation. Thus target stack have to be mounted in the target carrier. Figure 4 shows designed target carrier and their fabrication concept.

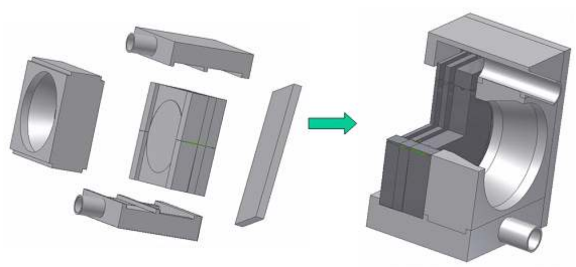

Fig. 4. Target carrier and Fabrication

Figure 5 shows that docking concept between beam window and target carrier to supply cooling water and prevent leak of cooling water.

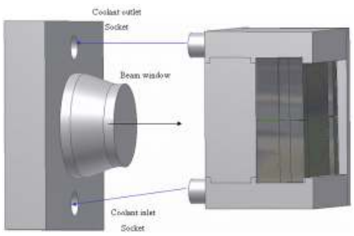


Fig. 5. Docking concept between beam window and target carrier

*2.2. Preliminary Thermal Analysis for Target cooling*

During the irradiation, 100-MeV proton beam loss their kinetic energy in the target stack. Thus massive heat generate in the target stack proportional to beam current. Excessive beam current can be cause the rupture of target stack and leakage of radioactive species. Thus target stack have to be designed to endure heat load. Figure 6 shows target stack configuration and cooling water flow.

If the beam current is 300 μA, 10 kW heat load can be apply to the target stack. To cool the target stack 43 liter/min of flow is required and temperature variation is 20 degree.

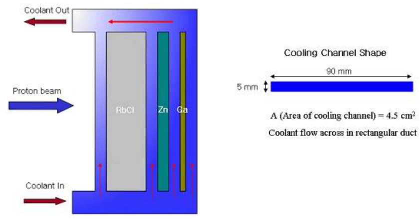


Fig. 6. The flow of cooling water in the target stacks.

We estimated the temperature of target materials by using the heat transport mechanism in nuclear fuel element. These results are shown as Table 3.

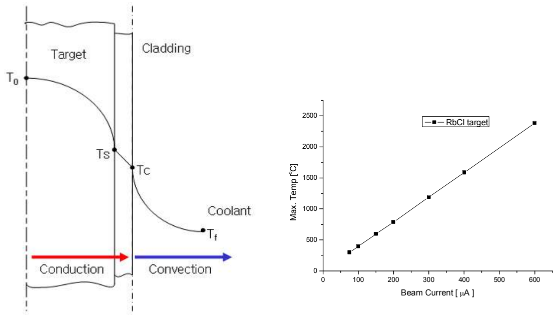


Fig. 7. Heat transfer between target and cooling water

Table 3. Estimated temperature of target materials.

| | RbCl | Zn | Ga |
|---|---|---|---|
| Melting point | 718 | 419.53 | 29.76 |
| Boiling point | 1390 | 907 | 2204 |
| Max. Temp. | 1215.2 | 293.6 | 330.5 |

## 3. Conclusions

In this paper, we optimized the fabrication method of target stack and have investigated the heat transfer behavior in the target stack. The result shows that the designed and fabricated target stacks can endure against the 10kw heat load at the 300 μA beam current.

## Acknowledgement

This work is supported by the Ministry of Education, Science and Technology of the Korean Government.

## REFERENCES

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