Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Activation Evaluation of Metal Target for LSDS System

Jeong Dong Kim[a], Young Gook Kim[a], YongDeok Lee [a], Chang Je Park[b*]
[a]*Korea Atomic Energy Research Institute (KAERI) 1045 Daedeok-daero, Yuseong-gu, Daejeon, Korea*
[b]*Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul, Korea*
[*]*parkcj@sejong.ac.kr*

1. Introduction

A Lead Slowing Down Spectrometer (LSDS) system is a promising non-destructive assay technique that enables a quantitative measurement of the isotopic contents of major fissile isotopes in spent nuclear fuel [1]. The LSDS system is currently under development at the Korea Atomic Energy Research Institute (KAERI). The system is planned to utilize a high-flux (> 10^{12} n/cm^2·sec) neutron source comprised of a high energy (30 MeV) / high current electron beam and a heavy metal target. According to the electron beam irradiation at the target, a very intense neutron is generated. The high intense neutron affects the other materials through an energy transfer. As a result, the characteristic of the material is changed. Therefore, an activation analysis of the target material, shielding, and structure of the LSDS system is demanded.

In this research, the activation analysis of Ta and W targets was conducted during the electron beam irradiation and cooling time using the MCNPX/CINDER'90 codes. In addition, a characteristic evaluation of radioactive products was performed.

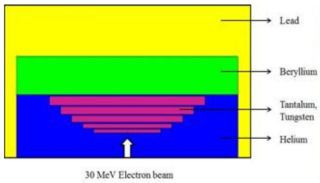
2. Experimental Procedure

2.1 Activation simulation method

The MCNPX and CINDER'90 codes were used in the activation analysis of the metal target. The MCNPX code was used to calculate the neutron flux and volume at the target. The results were used in the input of CINDER'90. The CINDER'90 code was used to calculate the radioactivity of radionuclide and to generate decay photon spectra [2.3].

2.2 Metal target dimension and simulation condition

The metal target is a cylinder type, and the target is composed of five plates with an increasing thickness from 2 mm to 6 mm with a 1mm gap. Fig. 1 shows the various radii of the targets and depicts the geometry of the plate target for the simulations. The coolant of the target is noble gas helium. Beryllium is used for the neutron reflector [4]. The irradiation time of the electron beam on the target is 10 hours and the electron beam energy is 30 MeV. The cooling period is 1 hour, and 1, 7, 30, and 90 days.



Target	Material	Radius (cm)	Thickness (cm)
1st	Ta, W	3	0.2
2nd		4	0.3
3rd		5	0.4
4th		6	0.5
5th		7	0.6
6th	Be	10	2.5

Fig. 1. Structure and material of the target.

3. Simulation result

The total activity of the Ta, and W targets is analyzed during the irradiation time of the electron beam. The radioactivity is the highest at the first plate. The total activity of the Ta target is decreased gradually by time. After 1 hour, the W target is saturated during the irradiation time. Fig. 2 shows the total activity for the irradiation time of the electron beam.

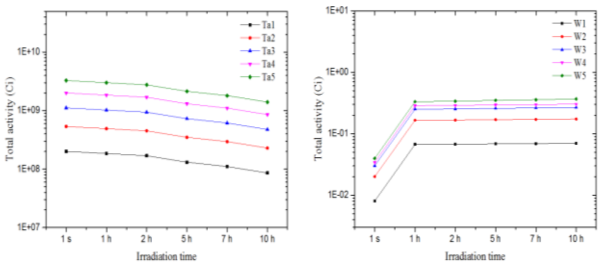


Fig. 2. Total activity of Ta and W targets for irradiation time.

Fig. 3 shows the mass of the Ta and W targets during the irradiation time. The Ta-180 nuclide mainly contributes to the activity intensity. The mass of the Ta-180 nuclide is decreased during the irradiation time. Daughter nuclides Hf-180 and W-180 are gradually increased. Therefore, the total activity of the Ta target was decreased. In the case of the W target, the W-183 nuclide mainly contributes to the activity and the mass does not change.

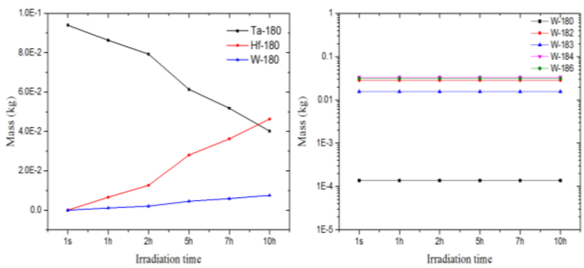


Fig. 3. Mass of Ta and W targets for irradiation time.

Table I: Total activity of Ta target (Ci)

Nuclide	Cooling period					Half-Life(s)
	1hour	1day	7days	30days	90days	
Hf-179m	5.05E-07	4.92E-07	4.17E-07	2.21E-07	4.22E-08	2.17E+06
Hf-181	2.15E-04	2.12E-04	1.92E-04	1.32E-04	4.94E-05	3.66E+06
Ta-179	2.72E-06	2.72E-06	2.71E-06	2.64E-06	2.48E-06	5.74E+07
Ta-180	7.88E+07	1.11E+07	5.36E+01	2.22E-19	1.48E-72	2.93E+04
W-181	1.42E-05	1.41E-05	1.37E-05	1.20E-05	8.50E-06	1.05E+07
Total	7.88E+07	1.11E+07	5.36E+01	1.44E-04	5.79E-05	

Table II: Total activity of W target (Ci)

Nuclide	Cooling- period					Half-Life(s)
	1hour	1day	7days	30days	90days	
W-181	2.21E-05	2.20E-05	2.13E-05	1.86E-05	1.32E-05	1.05E+07
W-183m	3.30E-08	2.94E-08	1.30E-08	5.70E-10	1.64E-13	5.20E+00
W-185	7.88E-05	7.81E-05	7.39E-05	5.98E-05	3.44E-05	6.49E+06
W-185m	3.71E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+02
W-187	2.94E-03	1.50E-03	2.23E-05	2.20E-12	1.17E-30	8.54E+04
Total	3.04E-03	1.60E-03	1.18E-04	7.84E-05	4.76E-05	

Tables I and II show the total activity results of the Ta and W targets. After a 7 day cooling period, the activity of Ta target is markedly reduced because the Ta-180 nuclide was almost depleted. It mainly contributes to the activity intensity. Relatively long-lived radionuclides Hf-181 and W-181 remained. After a 90 day cooling period, the radioactivity is approximately 5.79E-05 Ci.

The total activity of the W target is gradually decreased. After a 7 day cooling period, W-187 nuclides are almost depleted. W-181 and W-185 nuclides remained. After 90 days, the radioactivity is approximately 4.76E-05 Ci. As a result, before a 90 day cooling period, the Ta target is more radioactive characteristics than the W target.

Fig. 4 shows the total activity of the target according to the each cooling period. Before 90 days, the total activity of the Ta target is higher than that of the W target. After the 90 day cooling period, the W target shows a high activity because the half-life of a nuclide is different. The major activity products of the Ta target are W-181 and Hf-181 nuclides. In case of the W target, the major activity products are W-181 and W-185 nuclides. A W-181 nuclide is produced as a result of the activation of the Ta and W targets. The half-life of W-185 is longer than the Hf-181 nuclide. Therefore, after a 90 day cooling period, the total activity of the W target is higher than that of the Ta target.

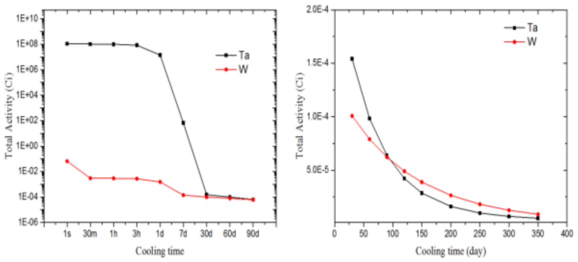


Fig. 4. Total activity of target for cooling of 90 and 350 days.

4. Conclusions

The total activity of the Ta target is gradually decreased and that of the W target is saturated during the irradiation time. The Ta-180 nuclide mainly contributes to the activity intensity. The mass of the Ta-180 nuclide is decreased during the irradiation time. The W-183 nuclide mainly contributes to the activity and the mass does not change. Before the 90 day cooling period, The Ta target indicates higher radioactivity characteristics than the W target. After a 90 day cooling period, the W target shows a high activity.

In the future, the radioactivity assessment of the target according to cooling gas will be performed.

5. ACKNOWLEDGMENTS

This work was supported by the Nuclear Research Foundation of Korea (NRF) grant funded by the Ministry of Science, ICT and future Planning (MSIP) of Korea under project No. 2014030151.

REFERENCES

[1] Y.D. Lee, C.J Park, H.D. kim, K.C. Song, "Design of LSDS for Isotopic Fissile Assay is Spent Fuel," Nuclear Engineering and Technology, 45, 921-928, 2013

[2] W.B Wilson, S.T Cowell, T.R. England, A.C. Hayes, P. Moller, "A Manual for CINDER'90 Version 07.4 Codes and Data," Los Alamos National Laborator report LA-UR-07-8412,2008.

[3] D.B. Pelowitz, MCNPX User's Manual, LA-CP-05-0369, Los Alamos National Laboratory, 2005.

[4] C.J. Park, M.K Jaradat, L. Alawneh, Y.D. Lee, "Metal plate target design for the lead slowing down time spectrometer(LSDTS), Annals of Nuclear Energy, 49, 218-222, 2012.