Radiation Dose Assessment in Pre-Separator Room in ISOL Due to Accumulation of Rare-Isotopes

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1. Introduction

A Korean heavy-ion accelerator complex called RAON is currently under development. Isotope Separation On-Line (ISOL) system can produce rare isotopes (RI) beams of high purity and intensity by shooting 70 MeV proton beam from cyclotron driver onto a Uranium Carbide (UCx) to induce nuclear fission reaction process and it is preferentially considered in order to produce RI beam in RAON. Normally, the pre-separator room as shown in Figure 1 is considered to be extremely high-level radiation zone. Because most of the unwanted contaminants from UCx is removed in pre-separator room besides desired isotopes for ISOL system. During the transport of RI beams, those are likely to be deposited in pre-separator room. Therefore, RI beams are important radiation source to be protected as well as prompt neutrons from UCx target on operation. Radiation safety by accumulation of RI beams should be carefully reviewed in pre-separator room and near the RI beam line. However, it is not easy to evaluate the residual dose occurred from accumulation of RI beams due to absense of an established analytical methode. We have evaluated the radiation dose in pre-separator room by RI beams accumulation.

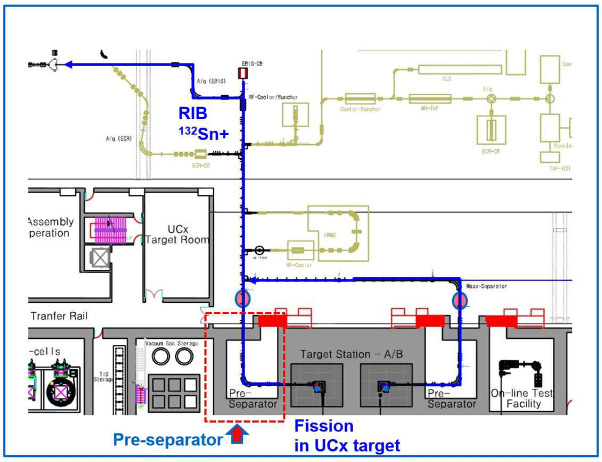

Fig. 1. pre-separator room in ISOL building.

2. Methods and Results

Basically, traditional computing codes for calculation of residual dose are not considering the transport of specific RI beams. For proper evaluation on the radiation risk from RI beams, we need to accurately know how much amount of RI beams is transported and deposited in pre-separator. But, there are so many uncertainties to calculate the amount of RI beams transported. In this study, we have employed a modified FISPACT, which has been developed in Hanyang University, in order to evaluate the radiation dose in pre-separator room from accumulation of RI beams.

2.1 Modified FISPACT

FISPACT is an inventory code that has been developed for neutron-, deutron-, and proton-induced activation calculation [1]. In pre-separator room, we consider both neutron activation and RI accumulation transported from the target chamber in order to evaluate the radiation dose inside pre-separator room. The radiation dose from neutron activation can be easily calculated by the established method. However, conventional inventory codes such as FISPACT, CINDER, and D-CHAIN, does not consider the transportation of rare isotopes and gamma-rays from only partial transported elements. Hanyang University has modified conventional FISCPAC code to calculate the residual gammas from single rare isotope [2].

This modified code has been used to calculate the residual gamma of rare isotopes presumably transported from UCx target chamber.

2.2 Transportation of Rare Isotopes

RAON ISOL system prepares the three ways, which are the surface ion (SI) source, the forced electron beam induced arc discharge (FEBIAD), and the resonant ionization laser ion source (RILIS), to ionize the rare isotopes produced from fission.

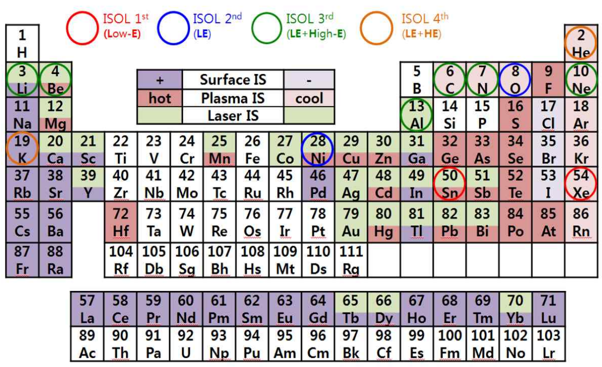

Fig. 2. Priority of beam development according to user requirements at RISP and previously realized ion sources

Figure 2 shows the priority of the beam development schedule according to user requirements in a periodic table which also contains previously realized ion sources based on CERN ISOLDE data [3].

Based on previously realized ion sources in the periodic table, we have estimated rare isotopes transported to pre-separator according to ionization method among entire ~700 RIs from fission of UCx as shown in Figure 3. From the result, it is expected that SI can deliver 281 RIs into the pre-separator. RILIS and FEBIAD may deliver 237 and 193 RIs into the pre-separator, respectively.

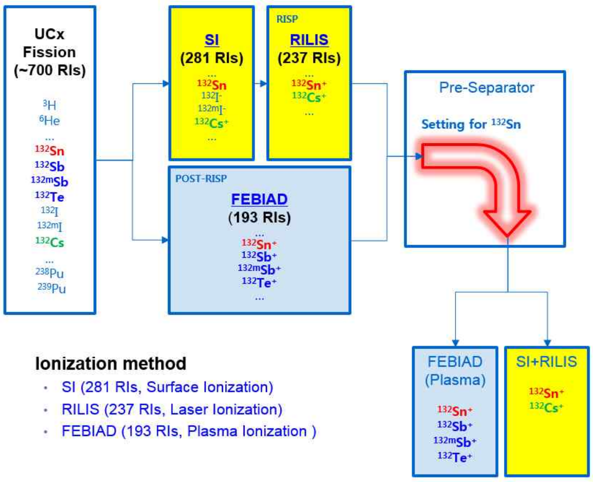

Fig. 3. Rare isotopes transported to pre-separator according to each ionization method (SI, RILIS, and FEBIAD)

2.3 Residual Dose in Pre-Separator Room

Rare isotopes estimated based on each ionization method have been used for input of the modified FISPACT in order to calculate of the residual gamma. In this calculation, we assumed that each ionization method may transfer all the RIs with 100% reported by CERN ISOLDE into the pre-separator among rare isotopes produced from UCx fission.

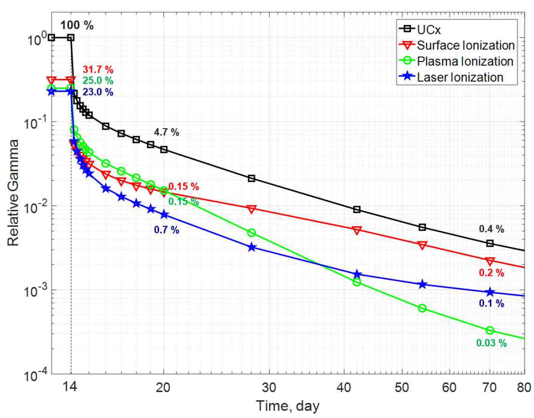

Fig. 4. Variation of total gammas from rare isotopes occurred by each ionization method in pre-separator

Figure 4 shows the variation of total gammas from each RIs in pre-separator estimated from different method. When applying SI method, the amount of residual gamma can be dropped into ~ 32% of UCx target. For more accurate calculation, we need to apply individual release and ionization efficient of RIs rather than assuming that RIs are transported to pre-separator with 100% . However, it is extremely difficult to study release and ionization efficient of several hundreds of RIs. Therefore, we assumed that only 10% RIs from each ionization method are transported to pre-separator.

Figure 5 shows the side and top-side view of target station for calculation of radiation dose. Figure 6 is the radiation dose map at the height of beam line when we have 2 weeks operation and 70 days cooling. The left figure is the case when we applied the 100% RIs transported from SI method. The right one is when we applied 10% only.

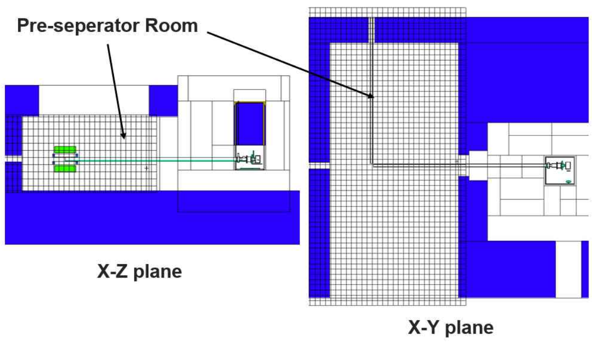

Fig. 5. Side and top-side view of target station in ISOL building for radiation dose mapping.

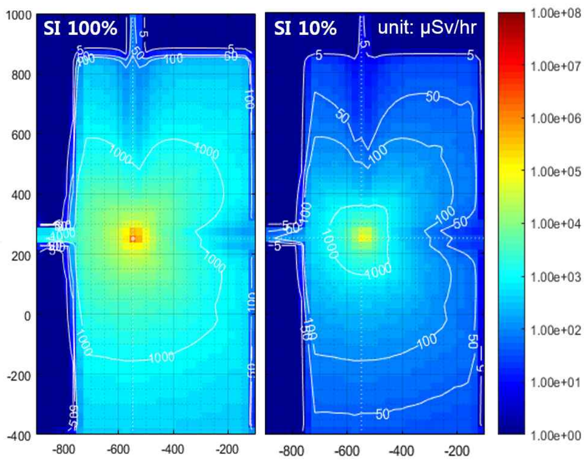

Fig. 6. Radiation dose map after 2 weeks operation and 70 days cooling when we apply 100% and 10% RIs from SI method, respectively.

3. Conclusions

Using the modified FISPACT code and RIs assumed to be transported to pre-separator by each ionization method, we have evaluated the radiation dose in pre-separator room. Radiation dose from RI accumulation is more significant than neutron activation dose. For stable maintenance and operation, it is critical to understand the radiation impact from the RI accumulation in ISOL building.

REFERENCES

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[3] RAON Accelerator and Experimental System Technical Design Report Volume 4 Experimental Systems, RISP/IBS, Vol.4, p.47, 2013.