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A study of isotope target capsule crushing device for exposure reduction

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1. Introduction

In these days, Therapeutic radionuclides such as Lutetium-177(^{177}Lu) are emerging as an important factor for treatment of the malignant tumor such as breast, prostate, colon, and brain. Its demand is also increasing because of its high theranostic potential [1]. ^{177}Lu emits β^- particles ($E_{\beta,max}$ = 498 keV) with a soft tissue penetration range of less than 3 mm and γ-rays (E_γ = 208 keV (11.0%) and 113 keV (6.4%)) suitable for imaging [2].

^{177}Lu can be produced in high yield by the ^{176}Lu(n,γ)^{177}Lu reaction. However, this production method has a limitation in that carrier ^{176}Lu are mixed and by-products ^{177m}Lu with a long half-life ($t_{1/2}$ = 160 d) are produced. In this respect, no-carrier added (nca) ^{177}Lu is preferred in medical fields as it has high specific activity and high radionuclide purity. The nca ^{177}Lu can be produced by the ^{176}Yb(n,γ) ^{177}Yb → ^{177}Lu reaction by irradiating neutrons to an enriched $^{176}Yb_2O_3$ target [3,4]. The critical process is the radiochemical separation of nca ^{177}Lu from macroscopic amount of Yb target with adjacent atomic number.

The target capsule for producing radionuclides is made of quartz materials to resist thermal neutron atmosphere. Quartz has excellent mechanical strength and chemical resistance. Its softening point is 1,683 ℃ in case of 99.99% purity. After neutron irradiation, it should go through the process of recovering the target materials (e.g. Metal oxide powder) in the capsule. Generally, recovery process is done with cutting in the middle of the capsule with diamond cutter in hot cell, pouring into new vial and dissolving with d-strong acid under the heating condition. This process is shown Fig. 1. During these works, hot cell contamination by powder dust and bubble is expected and also there may be concern about exposure of operators.

In order to reduce these drawbacks and meet the demand for many therapeutic radionuclides in the near future, it is required to develop simpler and more convenient target recovery systems. To proceed with RI production in a more convenient way, we would like to introduce the following research.

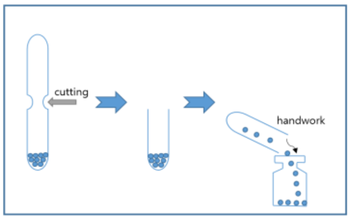

Fig. 1. The existing methods of target material production

2. The development equipment system

2.1 Development purpose.

The aims of crushing device are as follows.

1. Designed to allow operators to perform easy tasks with manipulators outside the hot cell for cutting and melting neutron-irradiated target capsules.
2. Designed with a mechanical structure rather than a pneumatic or hydraulic system, making it easy to prevent the breakdown and repair.
3. Designed to reduce the radiation exposure of operators.
4. Simultaneously performed crushing and dissolving

To solve the problems, a simplified and semi-automated system was designed for the cutting and dissolving process. Instead of cutting the middle of the target capsule, it is a system in which target powder is freely drop down by crushing the bottom of capsule. By adding 1~2 ml acid to the vial serving as a target reservior, the target powder may be prevented from scattering and contamination. The concept is shown in Fig. 2.

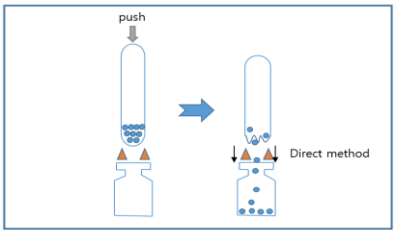

Fig. 2. The concepts of crushing device

To uniformly crush the bottom of quartz capsule, a part with 3 crushers was designed like Fig. 3. Crushed quartz debris can play the role of 'boiling chips' when dissolving process is done.

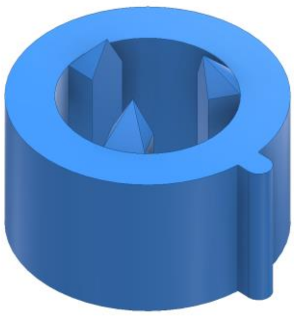

Fig. 3. Wedge of crushing

2.2 Crushing device test

A testing device (crushing wedge) was manufactured to check the feature of crushing and shape of the capsule. After hitting the upper part of the quartz capsule with a rubber hammer, it could be identified that the fragments of the quartz capsule and the target material are dropped into the vial with mixed state. As a result, it was confirmed that only the lower part was crushed accurately and the upper part remained in its original shape. The test process is like Fig. 4

Fig. 4. Prototype of crushing device and testing results

2.3 Target crushing integrated system

This system consists of total 3 parts; crushing part, cooling part and dissolving part like Fig 5. The outer main body was made of STS316L for corrosion resistance. Crushing wedge (Fig. 3.) was also made of STS316L. The cooling unit used a peltier device for reducing the system size and dissolving unit used lab-made electric heater. The quartz capsule was manufactured in a straight shape for the safety of upper region of capsule when crushing process is done. The vial was located in the same axial direction to the quartz capsule and wedge when target substance and quartz debris collect into the vial. 2~3ml of concentrated nitric acid was added to the vial for dissolving target. It was also manufactured that the vial and the crushing part were in close contact with each other.

3. Conclusion

In the field of nuclear medicine, many radioisotopes have been used as open source state and its demand is also increasing recently. In the production of radioisotopes, securing the safety of operators should be the top priority and research for reducing contamination should be conducted. In this view point, target crushing system will provide safe and convenient way for radioisotopes.

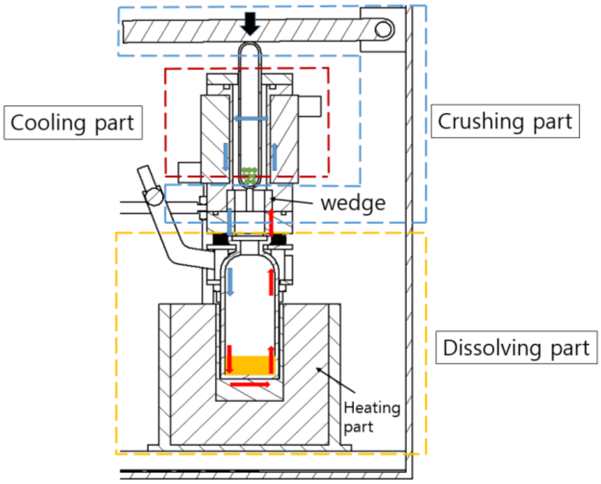

Fig. 5. Target crushing integrated system

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