



Double-layered target and identification method of individual target correlated with evaporation residues



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ABSTRACT

A double-layered target system and an identification method (target ID) for individual targets mounted on a rotating wheel using correlation with evaporation residues were newly developed for the study of superheavy elements (SHE). The target system can be used in three modes: conventional single-layered mode, double-layered mode, and energy-degrader mode. The target ID method can be utilized for masking a target, measuring an excitation function without changing the beam energy from the accelerator, and searching for SHE nuclides using multiple targets during a single irradiation.

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1. Introduction

When studying superheavy elements (SHEs), it is essential that a target system can withstand high-intensity beams and can monitor the status on-line. In particular, when using low-melting-point target substances, melting of the target must be avoided during the lengthy irradiation.

We have developed a gas-cooled rotating-target system for studying SHE using gas-filled recoil ion separators GARIS and GARIS-II as a key for solving the target-melting problem (including issues with backing material) [1,2]. The gas filling in the separator is effectively treated as coolant for the target. We also recently developed a double-layered target system to further improve these cooling effects: a double-layered target system offers the advantage of dividing the energy loss in the target (see Section 2.1). Moreover, we developed an identification method for individual targets mounted on a rotating wheel using correlation with evaporation residues. To monitor the status of each target mounted on the rotating wheel is important for improving the quality of experiments.

2. Double-layered target

2.1. Design and operating principles

The basic design and operating principles of a double-layered target are given in Figs. 1 and 2. A new rotating wheel with two distinct sectors A and B was developed, and a photograph of a double-layered target is shown in Fig. 3. One of the three available modes is chosen according to experimental intent. A single-layered target, as shown in Fig. 2(a), is the conventional choice for SHE study [1]. By dividing the conventional single-layered target into two layers as shown in Fig. 2(b), the energy loss in each target is reduced by half, and thus its increase in temperature is also reduced by half. This is also helpful for target cooling in that the total surface area of the target is doubled. Moreover, the helium filling in the recoil separator effectively acts as a gas coolant. The angular spread of evaporation residue in the target is practically the same in both scenarios (single-layer and double-layer), because the total target thickness does not change. Therefore, an acceptable beam intensity for the double-layered mode is expected to be twice that required for the single-target. If the first layer is replaced with an energy degrader as shown in Fig. 2(c), the bombarding energy in the target can be tuned without changing the accelerator's beam energy.

2.2. Performance test using double-layered mode

The performance of the double-layered target was investigated by measuring the yield of ^{254}No produced via the $^{208}\text{Pb}(^{48}\text{Ca}, 2n)$ reaction.

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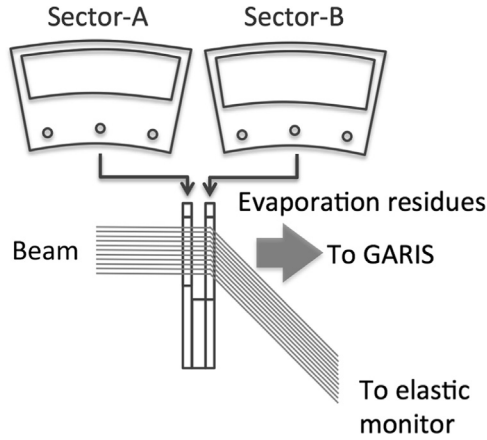


Fig. 1. Structure of a double-layered target.

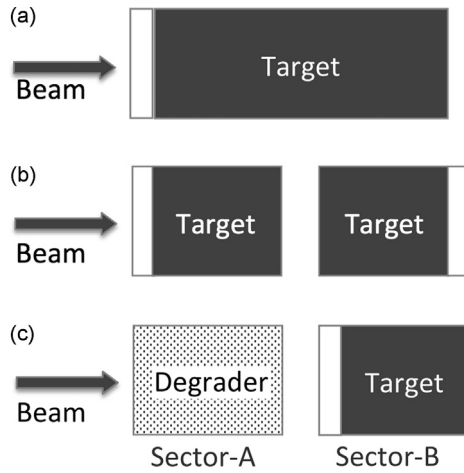


Fig. 2. Operational concepts of a double-layered target system. (a) a single-layered mode, (b) a double-layered mode (conventional single-layered target was separated into two layers of target), and (c) an energy degrader mode (combination of a single-layer target with an energy degrader).

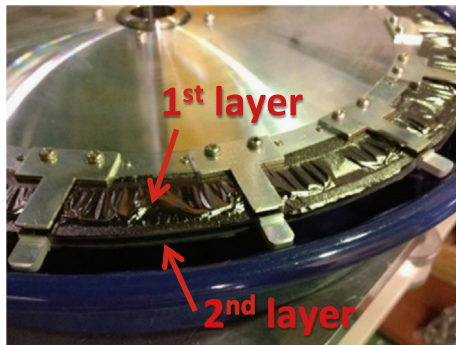


Fig. 3. Photograph of the double-layered target wheel.

First, we measured the yield of ^{254}No using the single-layered targets of varying thickness. Saturation of the ^{254}No yield began to occur when the target thickness was greater than $500 \mu\text{g}/\text{cm}^2$ (Fig. 4). This result suggests that the saturation arises from the narrow width of the excitation function, which is a particular point of cold-fusion reactions. Furthermore, the multiple scattering of ^{254}No inside the thick target appears to affect saturation.

Next, we used a double-layered target (thickness of 560 and $540 \mu\text{g}/\text{cm}^2$). The yield obtained using the double-layered target was in good agreement with the expected value, which was extrapolated from the data points from the single-layered target. Thus, we decided to apply the double-layered target to the $Z=113$ search experiment beginning on July 14, 2012. The third decay chain of $Z=113$, observed on August 12, 2012, was obtained using this double-layered target [3]. The double-layered Bi target ($380 + 380 \mu\text{g}/\text{cm}^2$) withstood a ^{70}Zn beam at 500 pA over the course of a five-day irradiation.

3. Target ID

3.1. Design and concepts

Several pieces of sector-shaped targets mounted on a rotating wheel have been employed for SHE production experiments with high-intensity beams. Thus far, it has not been possible to distinguish the thickness difference between each target. As such, we used their average thickness in our GARIS experiments. To address this, we developed a new wheel frame with an extra ID tag placed between the spoke-position-indicator tags on its circumference, as shown in Fig. 5. Conventionally, ID information has been used for a on-line monitoring to check for damage due to evaporation, deterioration, and sputtering, all of which are caused by beam-irradiation [4–6]. In this study, the ID data was used as a tagging signal to identify each target on the rotating wheel by correlation with evaporation residue. This process is detailed in Section 3.3.

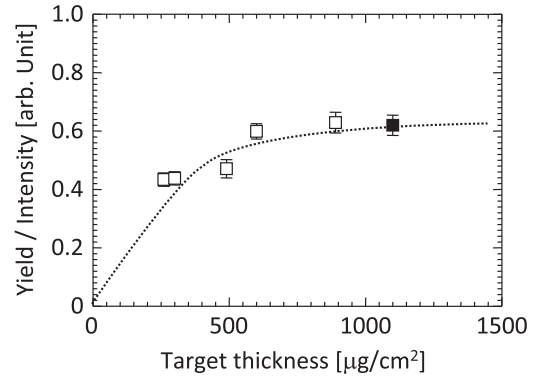


Fig. 4. Yield curve of ^{254}No as a function of target thickness. Open square: results obtained using single-layered target; closed square: double-layered target results. The dashed line serves as a visual guide.

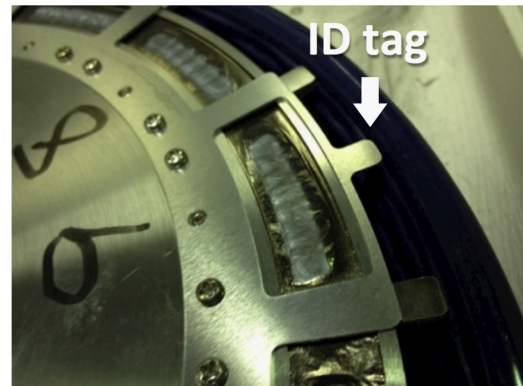


Fig. 5. Newly designed wheel frame with an extra ID tag placed between the spoke-position-indicator tags on the circumference of the wheel.

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