Fabrication of thin ^{166}Er using evaporation technique

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Introduction

Fabricating thin targets with precise thickness is vital for nuclear physics experiments. However, preparing and storing rare earth metal targets presents significant challenges due to their high chemical reactivity. For our upcoming experiment, which focuses on fusion-fission studies in the medium mass region through the mass and angular distribution of fission fragments, we required targets made from ^{166}Er. Erbium reacts slowly with both oxygen and moisture at room temperature. The chemical reactivity of lanthanides like erbium adds complexity to the fabrication and storage process, demanding significant efforts [1]. Initially, we employed the electron bombardment technique; however, the deposition results were unsatisfactory. Consequently, we switched to the thermal evaporation method [2], which enabled us to successfully fabricate thin ^{166}Er targets using a 53 g metal pellet of ^{166}Er. Due to very high cost of enriched isotopic material and its low abundance, film fabrication methods using naturally abundant isotopes of erbium were tested before utilizing enriched isotopes. G. Mohanto et al. [2], described the fabiration of ^{170}Er by using high vaccum deposition technique. Suhail A. Tali et al. [3], reported the fabrication of ^{166}Er targets by rolling technique. Here, we describe the procedure for preparing ^{166}Er target with a thickness of $\sim$ 250 μg/cm^2, sandwiched between two thin layers of carbon with thicknesses of 15 and 10 μg/cm^2, respectively. The following section provides a detailed description of the apparatus and methodology used in the target fabrication process.

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Experimental Details

Thin films were obtained using a physical vapor deposition process carried out with a diffusion pump-based coating unit at the target laboratory of inter-university accelerator centre (IUAC), New Delhi. This unit includes both a resistive heating setup and a single-pocket electron-beam gun powered by a 2 kW power supply, enabling the simultaneous fabrication of multi-layered thin films. A quartz crystal deposition rate monitor was employed to estimate the film thickness in nanometers. A set of cleaned glass slides was used for thin film deposition. To facilitate easy and effective separation of the film layers from the glass slides, a layer of water-soluble barium chloride ($BaCl_2$) was deposited on the slides, serving as the parting agent. The $BaCl_2$ powder was compressed into hard pellets of thickness 10 mm using a hydraulic pellet press, applying a force of no more than 10 kg/cm^2. The $BaCl_2$ was then evaporated using a resistive heating technique in a chemically inert tantalum (Ta) boat, chosen for its high melting point. A $BaCl_2$ layer of approximately 120 nm was deposited at a rate of 0.1 nm/s onto the glass slides. A graphite pellet was placed on a copper hearth at an optimal distance from the electron-beam emitter. The current from the electron gun power supply was gradually increased from 20 mA to 140 mA (10 KV) and then held steady. The deposition rate for carbon was maintained at 0.1 nm/s until a thickness of $\sim$ 15 μg/cm^2 was achieved.

After deposition, the chamber was allowed to cool before being vented. The slides were then removed and subjected to heat treatment in a programmable Thermolyne™ quartz tube furnace to relieve inter-lattice stress, reduce hardness, and prevent foil breakage. The annealing process was conducted at a gradually

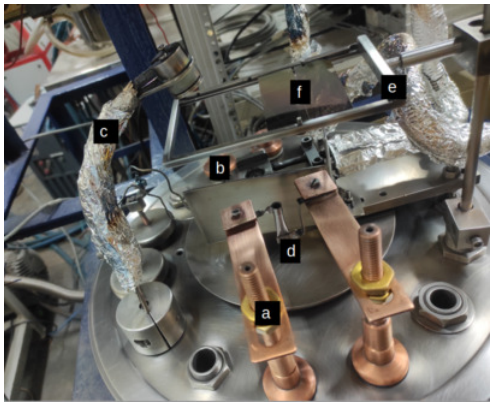

FIG. 1: Inside the vacuum chamber; (a) resistive heating arrangement, (b) electron beam arrangement, (c) quartz based thickness monitor, (d) tantalum (Ta) U-boat (e) substrate holder, (f) $BaCl_2$ and carbon coated slides.

ramped temperature of 350°C in a constant inert gas flow environment for approximately 60 minutes. The annealed glass slides, coated with the parting agent and carbon layer, were placed back into the deposition chamber. An erbium metal sheet was cut to fit into a tantalum (Ta) U-boat, which was then positioned in the resistive heating setup. A graphite pellet was also placed on the copper hearth for deposition of another thin carbon layer after the erbium deposition. The substrate holder was maintained at a distance of 6.5 cm during erbium deposition to maximize material utilization (as shown in the inside view of the bell jar in Fig. 1). Over ten trials were conducted using naturally abundant erbium to precisely determine the optimal deposition parameters. The erbium-coated glass slides were positioned above the copper hearth using a rotatable feed-through mechanism, without breaking the vacuum. A thin carbon layer, approximately 50 nm thick ($\sim$ 10 μg/cm^2), was deposited using the electron beam emitter. The glass slides were then removed from the chamber, and the films were scored into uniform sizes using a diamond tip pen. Each slide was gently dipped into a hot water bath at an angle of $\sim 45^\circ$ relative to the water surface. This allowed the thin films to easily separate from the slides and float on the water surface. The floating films were then carefully lifted onto 3 cm $\times$ 2.5 cm stainless steel (SS) frames. After floating, target mounted frames were stored under vacuum in a desiccator.

Conclusion

^{166}Er targets were prepared successfully having thickness $\sim$ 250 μg/cm^2, sandwiched between two C layers with thicknesses of 15 and 10 μg/cm^2, using thermal evaporation technique. The prepared targets will be used for the fission fragment mass distribution measurements in medium mass region.

References

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