Fabrication of CaF_2 target for nuclear reaction studies

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Introduction

The production of targets with the requisite uniform thickness and isotopic purity is an enormous problem for researchers while conducting nuclear reaction experiments [1,2]. A suitable target should also have strong tensile strength and seamless adhesion between the film and the substrate in addition to purity [3]. In the target laboratory of the Inter University Accelerator Centre (IUAC), New Delhi, we prepared CaF_2 targets using the vacuum evaporation method, one of many target production procedures.

Preparing a target for calcium (Ca), which is easily oxidized, is particularly challenging. For our nuclear reaction experiment, we employed a thin CaF_2 film that was 180 $\mu g/cm^2$ thick and was supported by a 20 $\mu g/cm^2$ layer of carbon. Because Ca-F bond dissociation energy (527 KJ/mol) is higher than that of Ca-O bond (402 KJ/mol), the likelihood that the CaF_2 thin film target will oxidize is lower.

Experimental Details

Fabrication was carried out in diffusion pump based coating unit (DPU) and turbo pump based coating unit (TPU) in the target development laboratory of IUAC. During evaporation, the vacuum was achieved and maintained in the range of 10^{-7} mbar. DPU is connected with a diffusion pump. It is also equipped with 2KW electron gun and resistive heating arrangement. Liquid nitrogen (LN) trap is also fitted between chamber gate valve and diffusion pump. LN condenses oil molecules of diffusion pump from moving towards the chamber. The evaporator is also equipped with a quartz crystal thickness monitor which provides thickness of deposition along with the rate of evaporation.

The carbon foil was first prepared as part of the target preparation process. A parting agent (in our case, barium chloride ($BaCl_2$)) was first coated on the glass plate using a resistive heating process before carbon was applied to the glass slides. The quartz crystal monitor was placed 21 cm from the copper crucible, while the glass slides were kept 27 cm from the resistive heating setup. After the $BaCl_2$ was successfully deposited, carbon was deposited on the glass slides using the electron gun bombardment method without affecting the chamber's vacuum. The internal stress that might have developed in the carbon slides as a result of the lattice orientation during evaporation or as a result of the adhesive force between evaporated material and substrate material was then removed by annealing the carbon slides in a tubular furnace at 325^0C in an Argon gas environment. Finally, the carbon slides were cooled to room temperature to remove the internal stress that had developed in the carbon foils. The next phase involved gently floating carbon slides on warm water to prevent them from breaking. Slides were found to successfully remove the carbon foils from the glass substrate when submerged at 45 degrees. After separation, the foils were placed in target holders. Finally, the target holders were installed within the DPU for the CaF_2 final deposition.

For CaF_2 deposition, pallet of CaF_2 was made using hydraulic press from its powder form and then placed at the tantalum boat mounted inside the DPU. Both the target frame holders and crystal monitor were placed above the resistive heating arrangement approximately at distance of 14 cm. After the arrangement, the

chamber was evacuated to a pressure 6.4×10^{-6} mbar. The current was increased slowly from 0 to 15 A in steps of 2 A after every 5 minutes interval. Deposition rate was around 7.4 nm/s. After 20 minutes, deposition was stopped and then the chamber was allowed to cool for 5 hours and later vented very slowly. It was found that CaF_2 deposition was successful and later thickness was measured using alpha-energy loss technique. A sample picture of CaF_2 film is shown in Fig. 1.

Fig. 1: A picture of carbon backed CaF_2 targets.

Result:

Thickness of the CaF_2 thin film was measured using alpha energy loss technique [4]. A 10μCi ^{241}Am source was used as alpha source. Since our targets were carbon-backed, we measured the thickness of the carbon layer from one of the glass slides that already had carbon coated on them before starting the target deposition process. The energy loss was calculated by measuring the difference between the centroid of the peak derived from the energy spectrum of the carbon's alpha particles and the matching background spectrum. Similar measurement was done for carbon backed CaF_2 thin films (Fig. 2). The total stopping power of alpha particles in CaF_2 targets and carbon foils were calculated using the SRIM code [5]. Using the formulations, thicknesses were found to be 20μg/cm^2 for carbon and 180 μg/cm^2 for CaF_2.

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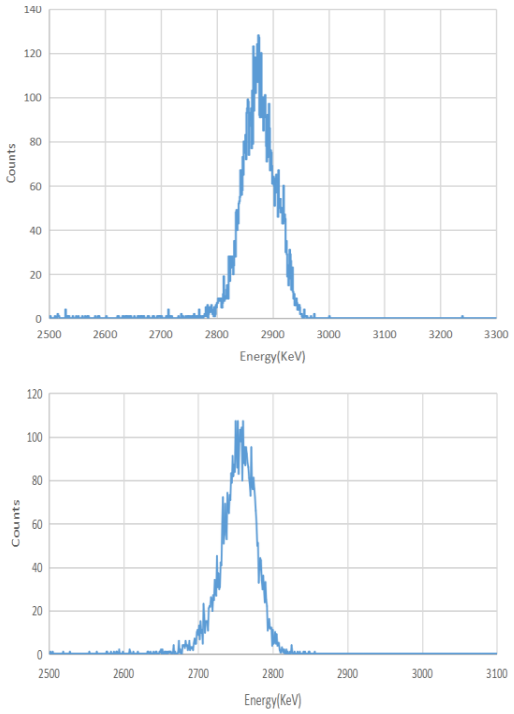

Fig. 2: Alpha energy spectrum for blank (top) and carbon backed CaF_2 film (bottom).

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