Development of CaF_2 target and its thickness determination using a new approach

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Preparation of target and its thickness measurement is crucial for nuclear astrophysics experiments. An error in thickness may lead to the error in the nuclear reaction cross section and reaction rate. A calcium fluoride (CaF_2) target of thickness ≥ 1mg/cm^2 was required for the beam energy calibration at the Facility for Research in the Experimental Nuclear Astrophysics (FRENA) in SINP. Target was prepared using the Physical Vapor Deposition method with an electron beam [1]. In this study, we report the preparation of a thick CaF_2 target on an aluminum (Al) backing. Energy spectrum of the Alpha (α) particle was simulated using the SRIM-software after passing through the target and compared with the measured experimental data to determine the target thickness.

Target preparation was first tried by evaporating CaF_2 on the aluminum (Al) coated glass slide. But this trial was not successful as the foil was damaged while separating it from the glass slide. In a second attempt, CaF_2 was evaporated on the Al foil mounted on the target frame. Here Al foil was used as a backing film which was also prepared using the vapour deposition method. Prepared target is shown in the inset of Fig.1.

The thickness of the prepared target was initially determined using the energy loss technique [2]. A ^{241}Am source which emits α-particles and a silicon surface barrier detector (thickness 500 µm) to detect their energy were used for this measurement. As these charged particles passed through the target, they exhibited a shift toward lower energy (see Fig. 1). This shift occurs due to the energy loss of charged particles. This particle either lose part or all of their kinetic energy depending on the thickness of the film they traverse. The thickness of the CaF_2 target, including the Al-backing, was determined by calculating this energy loss (E_{loss}) and obtaining the stopping power with the help of LISE++ software [2]. The measured thickness of CaF_2 was found to be 5.0 ± 0.34 µm (1.61 ± 0.11 mg/cm²) considering the Al-backing thickness as fixed. Here, the thickness of the Al backing was measured to be 0.52 µm (140 µg/cm²) with a digital thickness monitor during evaporation.

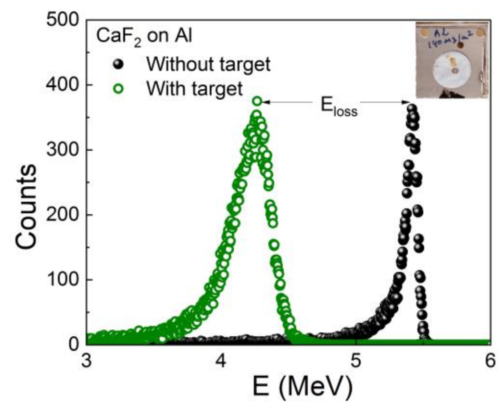

Fig. 1 Energy spectra of ^{241}Am α-source measured with a Si-detector for with and without target condition. Fabricated CaF_2 target is shown in the inset.

Determining target thickness of a multilayer film of different elements using the above mention technique may not be precise and lead to erroneous result. Hence, a different approach was adopted. In this work, target thickness has been determined by comparing the measured α-spectrum after alpha pass through the target with the simulated spectrum generated using the SRIM-software [3]. In this simulation two branches of α decay for ^{241}Am [$E\alpha_1$ =5.486 MeV, BR (branching ratios) = 84.8% and $E\alpha_2$ =5.443 MeV, BR = 13.1%] were considered. The 3rd branch was ignored as the BR percentage is very less compared to the other branches. The simulated spectra for the two α-energies are shown in Fig. 2(a). Weighted sum of these two spectra were considered to generated the resultant spectra which is shown in Fig 2(b). This was then folded with the detector resolution which is 2.5% measured for the present experimental setup. But the simulated spectra did not match well with the measured data even after considering the detector resolution. The target thickness value for the CaF_2 layer was then tuned in the simulation keeping the backing thickness constant. An excellent match between the simulation and measured data was obtained for a thickness of 5.3 μm, which is shown in Fig. 2(c). Target thickness of CaF_2 layer found in this method is slightly higher (5.6%) than that determined using the energy loss method.

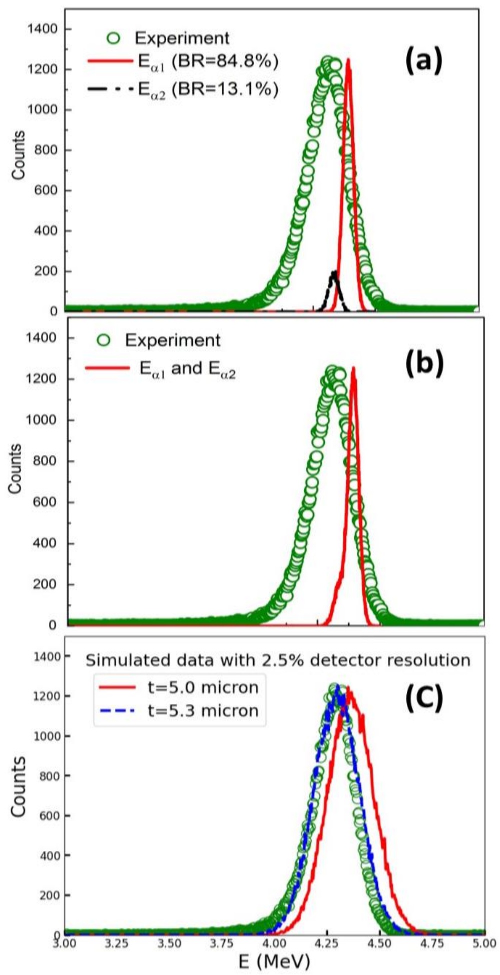

Fig. 2 Comparison of experimental data with the simulated data for (a) two distinct energy peaks of ^{241}Am, (b) weighted sum of the two components, and (c) after folded with the detector resolution for a target of thickness 5.0 μm and 5.3 μm.

A multilayered thick target, such as the one used in the present case, not only distorts the incident beam energy but also degrades the spatial distribution of the beam. To observe how the beam distribution changes at different target depths, a simulation was done to determine the lateral positions (Y-Z plane) of transmitted α-particles. The incident beam was considered along the positive X-direction. Fig. 3(a) and 3(b) shows the lateral spread of α-particles after passing through the Al and CaF_2 layers, respectively. The lateral beam spread is considerably greater after passing through the CaF_2 layer compared to the Al layer. This increased spread is due to the greater energy straggling encountered in the thicker CaF_2 layer compared to the relatively thin Al layer.

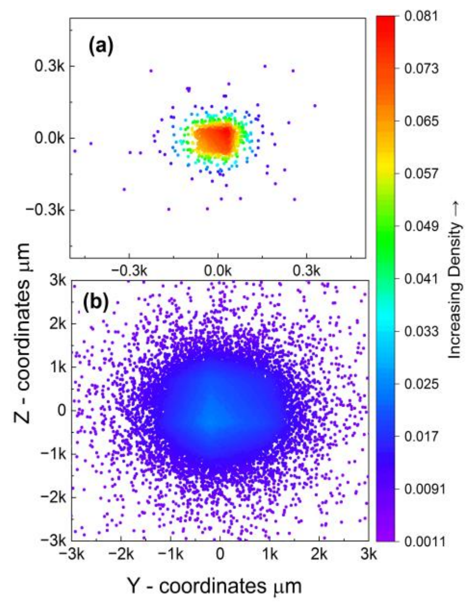

Fig. 3 Transverse α-beam profile after it passed through the (a) Al and (b) CaF_2 layer. Beam direction is along the X-axis.

References

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