Fabrication of $^{172,174}Yb$ targets on Al-backing using vacuum evaporation technique at IUAC

M. Shariq Asnain[1,*], Aquib Siddique[1], Gobind Ram[2], Mohd Shuaib[1], Abhishek Yadav[3], Indu Bala[4], R. Kumar[4], Manoj Kumar Sharma[2,] B. P. Singh[1,#] and R. Prasad[1]
[1]*Nuclear Physics Laboratory, Department of Physics, Aligarh Muslim University, Aligarh-202 002, INDIA*
[2]*Department of Physics, University of Lucknow, Lucknow-226007, INDIA,*
[3]*Department of Physics, Jamia Millia Islamia, New Delhi-110025, INDIA*
[4]*Inter University Accelerator Center, New Delhi-110067, INDIA*
*email:*asnainshariq@gmail.com , #bpsinghamu@gmail.com*

The investigation of the dynamics of fusion and break up fusion (BUF) in heavy ion (HI) induced reactions has garnered interest among researchers over the past few decades. In the fusion process, the entire projectile merges with the target nucleus, resulting in the formation of a highly excited compound nucleus (CN). The CN so formed subsequently undergoes decay by evaporating nucleons and/or alpha particles before it reaches equilibrium state. On the other hand, in the BUF process, only a portion of the projectile fuses with the target nucleus, while the remainder continues to move forward with nearly the same velocity as the incident ion beam. Both the entire fusion, referred to as complete fusion (CF) and the BUF are found to compete each other as the beam energy changes. Excitation functions (EFs) and recoil range distributions (RRDs) measurements of evaporation residues serve as crucial tools for investigating the dynamics of CF and BUF in heavy ion-induced reactions, particularly at intermediate energies [1,2]. The BUF processes may primarily be influenced by the dynamics of the entrance channel or by the nature of the composite system formed as a result of the fusion of only a portion of the colliding fragments near the target's nuclear field. Consequently, this remains an active research area at ≈ 4-7 MeV/A energies.

To arrive at concrete conclusions regarding the mechanisms underlying BUF reactions, a series of EF and RRD measurements are planned. These measurements involve the use of ^{12}C and ^{16}O beams on enriched $^{172,174}Yb$ targets and are likely to provide valuable insights into the dependence of BUF on entrance channel parameters. For the experiments, it is essential to prepare thin targets of $^{172,174}Yb$ deposited onto thin aluminium backings. For this purpose, the vacuum evaporation technique provides an effective way for the preparation of targets having a uniform thickness. It becomes intricate when the quantity of the target material is very small. Keeping in view the above aspects, thin targets of enriched $^{172,174}Yb$ were prepared by depositing the material on Al-backing using the evaporation technique in a High Vacuum evaporation chamber.

High Vacuum Evaporation Chamber

The enriched $^{172,174}Yb$ material (100 mg each) in powder form, having enrichment levels 97.10±0.1 % and 98.16±0.1 % respectively were procured from ISOFLEX, California, USA. The evaporation of target material on Al-backing was carried out in the target laboratory of the Inter University Accelerator Centre (IUAC), New Delhi, India. Vacuum of the chamber during the evaporation was achieved and sustained of the order 10^{-6} mbar using a diffusion pump. The target material was evaporated using an electron gun. The evaporator was equipped with a quartz crystal thickness monitor, which gives an estimate of the thickness of deposited material as well as the rate of evaporation.

Procedure of Fabrication

In the first step, Al-backing foils were prepared by rolling technique for the deposition of $^{172,174}Yb$ material onto them. The thickness of aluminum was determined by weighing individual Al-backing foils before deposition and after deposition by alpha transmission method employing ^{241}Am α-source. In view of limited amount of enriched sample, several attempts were made using natural Yb_2O_3 on Al-backing to identify the right position of the substrate from the copper pocket so that we may reach the required thickness. After completing

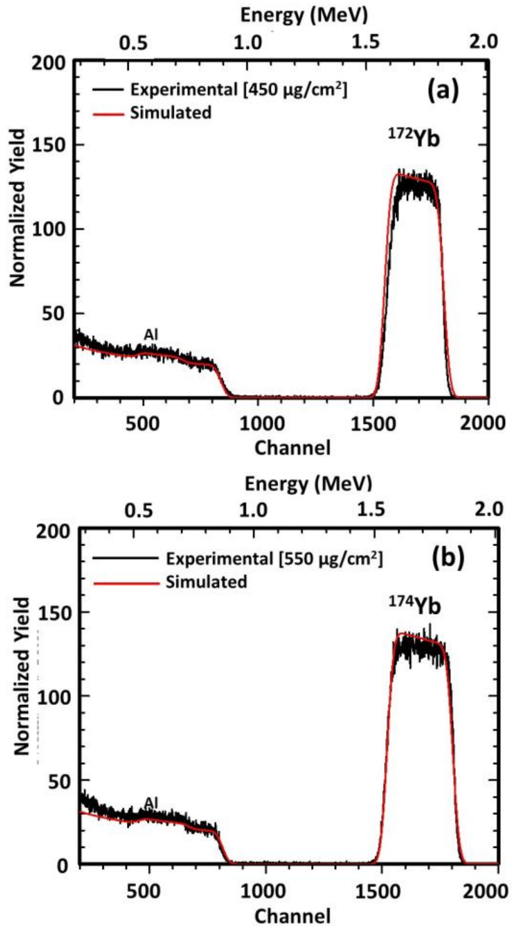

Fig. 1: RBS spectra for (a) ^{172}Yb (450 μg/cm^2) (b) ^{174}Yb (550 μg/cm^2)

the testing with natural Yb material, the setting of all essential parameters for the enriched ^{172,174}Yb material evaporation on Al-backing was done. Using the previously optimized successful method of deposition for natural Yb, the evaporation of ^{172}Yb was done on the aluminum foils kept at 5.5 cm from the e-gun, having deposition rate of 0.1 Å/s at a high voltage of 8.07 kV and a maximum of 120 mA current. A total of twenty four (24) ^{172}Yb targets were successfully deposited on aluminum foils and then pasted on rectangular target holders for experiments. Similarly, eighteen (18) isotopic targets of ^{174}Yb were prepared at 8.07 kV high voltage and 120 mA e-gun current by utilizing 100 mg of ^{174}Yb isotope. The isotopic targets (^{172}Yb and ^{174}Yb) were kept inside separate desiccators in different boxes for long-term preservation.

RBS of Ytterbium Targets

The only method that permits the quantification analysis of test target foils without a standard target as a reference is the Rutherford back-scattering spectroscopy (RBS). In the present work, the RBS measurements were carried out using PARAS (Pelletron Accelerator for RBS-AMS System) setup at the IUAC, New Delhi where 2.0 MeV α-particle beam from 1.7 MV Tandem accelerator was allowed to fall normally on the Al-backed Ytterbium targets to measure the yield and energy distribution of back-scattered α-particles by the silicon surface barrier detector (SSBD). The detector setup was coupled with a 2k multichannel analyzer to generate an electrical signal. The recorded energy spectra and yield were analysed using the RUMP [3] software. In the RBS spectrum, the peaks emerge in accordance with scattering cross-sections that correspond to the scattering elements involved. As shown in Fig.1, the peak of Yb is clearly observed in the RBS spectra as expected. Further, the counts at the lower channel number indicate contribution of the Al substrate. The thickness of ^{172}Yb was found to be 450 $\mu g/cm^2$ and that of ^{174}Yb was 550 $\mu g/cm^2$. Similarly, the thicknesses of all targets were obtained using RBS technique. Further, the measured RBS spectra show no detection of any other heavy elemental impurities in the fabricated targets thus indicating the high quality of enriched targets employed in the present experiments.

The authors thank the Director, IUAC, New Delhi and the Chairperson, Department of Physics, AMU, Aligarh, for providing all the necessary facilities to carry out this work. BPS and MSA thank the DST for providing financial support under project CRG/2020/000136.

References

[1] M. Shariq Asnain et al., Phys. Rev. C **104**, 034616 (2021).

[2] M. Shariq Asnain et al., Phys. Rev. C **106**, 064607 (2022).

[3] L. R. Doolittle, Nucl. Instr. And Meth. **B9**, 344 (1985).