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Fabrication and characterization of enriched ^{154,144}Sm and ^{142,148}Nd targets on Al-backing for nuclear physics experiments at IUAC, New Delhi, India

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The enriched targets of stable isotopes ^{154,144}Sm and ^{142,148}Nd have been fabricated for the measurements of excitation functions and recoil range distributions studies using different heavy ion projectile at IUAC, New Delhi. These targets have been fabricated by electron gun evaporation on Al backing. A very thin capping has been applied to prevent material from getting oxidized and eventual deterioration of material itself. The enriched ^{154,144}Sm and ^{142,148}Nd samples have been capped by carbon and aluminium, respectively. These samples of multiple thicknesses have been prepared using a high vacuum evaporation chamber facility. The thickness and uniformity of the different samples have been measured by Rutherford backscattering spectrometry (RBS) and energy dispersive x-ray spectroscopy (EDXS). These measurements also confirm that there are no unwanted impurities in the prepared targets. Large number of sandwiched targets, more than 30, of ^{144,154}Sm and ^{142,148}Nd isotopes have been successfully fabricated in a single evaporation. In the present study, the sandwiched targets have been fabricated using high vacuum evaporation technique. This technique is a very useful and cost efficient method to prepare large number of thin isotopic enriched targets having oxidizing property for experimental nuclear physics.

Keywords: Vacuum evaporation, Thin film, Oxidized target fabrication, Rutherford backscatterings pectrometry, Energy dispersive x-ray spectroscopy

1 Introduction

It has been possible to study the nuclear structure and nuclear reaction dynamics in heavy ion interaction with the advancement of modern accelerators. Several modes of nuclear reactions are possible in heavy ion collisions at energy above the coulomb barrier. The complete fusion (CF) and incomplete fusion (ICF) reactions are the two dominate modes of reaction at these energies[1]. The first experimental evidence of ICF reactions in the break-up of the projectile at beam energy ~10.5 MeV/nucleon was reported by Britt & Quinton[2]. The CF and ICF processes can be classified on the basis of driving input angular momenta (ℓ) involved during interaction of projectile with target. In the sharp cut-off approximation[3], the driving input angular momentum "ℓ" is imparted in the range $0 \leq \ell \leq \ell_{crit}$ for CF process. In this process, the attractive nuclear potential overcomes the repulsive Coulomb and centrifugal potentials in central and near-central collisions. As a result, at relatively lower values of energy and impact parameter, the projectile completely fuses with the target and forms a fully equilibrated compound nucleus (CN). This CN nucleus may decay by emitting light particles. However, when projectile collide with target at relatively higher value of energy and impact parameter, the repulsive centrifugal potential increases. Hence, the attractive nuclear potential is unable to capture the entire projectile. In this condition, only a part of the projectile fuses with the target nucleus and remnant behaves as a spectator. This process is termed as incomplete fusion (ICF) or breakup fusion (BUF). It is not well established how different entrance channel parameters affect the ICF dynamics at intermediate energies. As such, this phenomenon is still an active area of investigation.

A series of experiments has been planned to perform EFs and FRRDs measurements using the alpha and non-alpha clusters ion-beam with enriched ^{154,144}Sm and ^{142,148}Nd targets. These studies will provide some definite conclusions about the role of various entrance channel parameters namely; mass-asymmetry of the system, coulomb factor (Z_PZ_T), target deformation etc. on ICF dynamics. Thin targets

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of ^{154,144}Sm and ^{142,148}Nd deposited onto Al-backings are required. The uniformity in thickness of the targets is an essential factor for any experiment. For this purpose, the vacuum evaporation technique provides an effective way for the preparation of targets having the uniform thickness. It becomes most important when the availability of the target material is very limited. Keeping in view the above aspects, an attempt has been made to prepare thin targets of enriched ^{154,144}Sm and ^{142,148}Nd by depositing onto thin Al-backings using the evaporation technique in a high vacuum evaporation chamber.

2 Fabrication of Enriched ^{144,154}Sm and ^{142,148}Nd Targets

The evaporation of enriched ^{154,144}Sm and ^{142,148}Nd target materials on thin Al-backings was carried out in high vacuum evaporator chamber in the target laboratory of Inter University Accelerator Centre (IUAC), New Delhi, India. Vacuum of the chamber during the evaporation of materials on Al-backings was achieved and sustained of the order of 10^{-6} mbar using turbo pumps, which is connected to the vacuum chamber. The target materials were evaporated using two methods (i) resistive heating and (ii) a 2 kW electron gun for multilayer deposition. Both techniques were used one after another[4]. The evaporator was equipped with a quartz crystal thickness monitor, which gives the thickness of deposited material as well as the rate of evaporation on the crystal. An inside view of the evaporation chamber and the set up within it is shown in the Fig. 1.

The available enriched isotopic materials of ^{144}Sm (≈93.7%), ^{154}Sm (≈98.9%), ^{142}Nd (≈93.7%) and ^{148}Nd (≈98.9%) were in the form of metallic flakes. Due to the limited amount of isotopic material available, we started our fabrication trials with natural Samarium (Sm) and Neodymium (Nd) to optimize the parameters for evaporation of enriched materials. As both Sm and Nd have oxidizing property, it is hard to fabricate their self-supporting targets. So, these targets were fabricated on aluminium backings of thickness lying in the range ≈ 1-1.8 mg/cm^2. These Al-backing foils were prepared by rolling machine and their thickness was determined by the weighing method as well an alpha transmission technique[5].

The first few testing of target fabrication using natural Sm and Nd revealed a critical issue. The issue was, after the deposition of the required thickness of material over the Al- backing foil, 'Sm' as well as 'Nd' material got oxidized very quickly once these were taken out from the evaporation chamber by breaking the vacuum after the evaporation. To minimize the oxidation the concept of sandwiched targets was taken by capping the target with a thin layer of Aluminium (Al)/carbon (C)[6]. After the successful testing and optimization of fabrication parameters with natural Sm and Nd, the isotope fabrication was attempted. It is important to make sure about the fabrication probability with natural material before attempting the isotope fabrication. This would not only save the cost but it will also give the high rate of successful isotopic target fabrication with the required target thickness for experimental nuclear physics and other experimental purposes. With 100 mg of each isotopic material of ^{154,144}Sm and ^{142,148}Nd, 40, 39, 35, and 30 sandwiched targets were prepared of each isotope respectively in a single evaporation. These targets pasted on stainless steel (SS) holders are shown in Fig. 2.

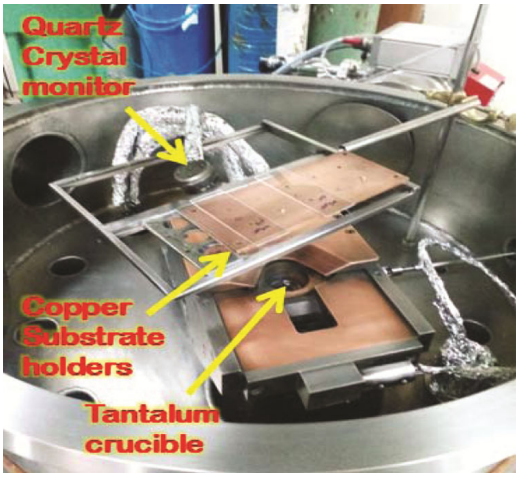

Fig. 1 – Inside view of the high vacuum evaporation chamber and arrangement

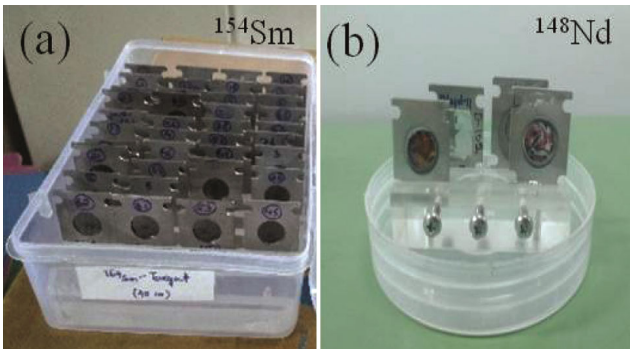

Fig. 2 – Fabricated sandwiched target of ^{154}Sm and ^{148}Nd at target lab of IUAC, New Delhi.

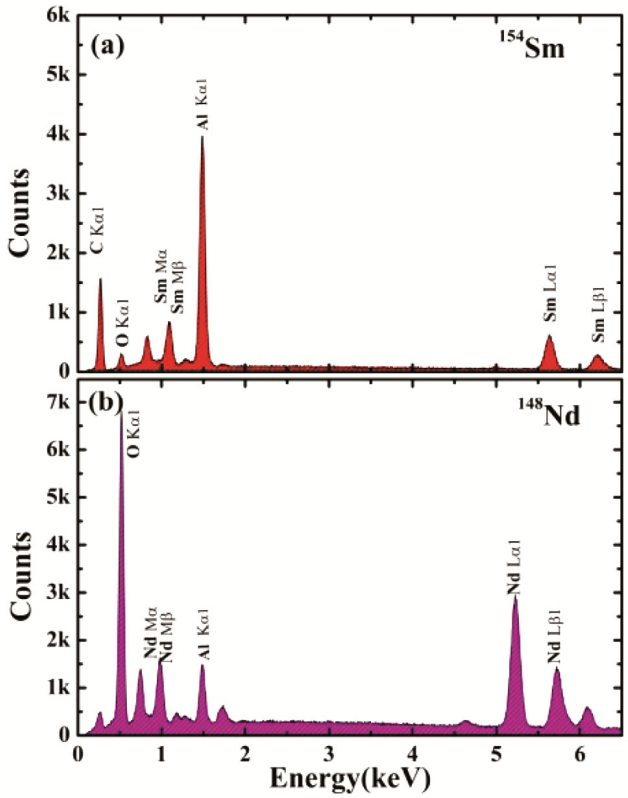

Fig. 3 – EDXS spectrum for the (a) ^{154}Sm sandwiched targets having C as capping, Al as backing material and (b) ^{148}Nd sandwiched targets, having Al as capping and Al-as backing material.

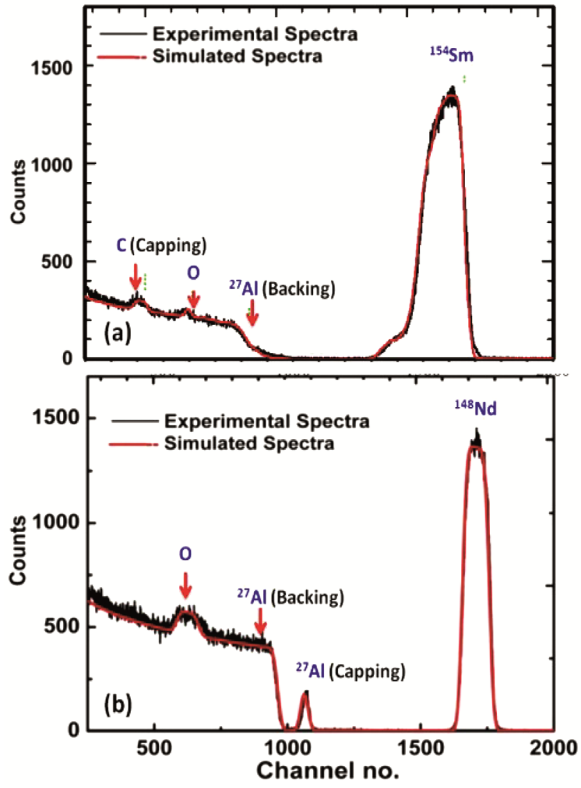

Fig. 4 – RBS spectrum of the (a) ^{154}Sm sandwiched target having C-capping, Al-backing material and (b) ^{148}Nd sandwiched target having Al-capping and Al-backing material. The red line is simulated to the experimental RBS data.

3 Characterizations of Fabricated Enriched ^{144,154}Sm and ^{142,148}Nd Targets

The purity of fabricated enriched targets of ^{154,144}Sm and ^{142,148}Nd was checked by energy dispersive x-ray spectroscopy (EDXS) measurements done at IUAC, New Delhi using field emission scanning electron microscopy (FESEM) facility of model number FESEM - JOELs JSM7610F and EDXS model used as EDAX-AMETEK with paltrier cooled - silicon-drift detector (SDD)[7]. As a representative case, the EDXS spectra of ^{154}Sm and ^{148}Nd are displayed in Fig. 3 (a and b). As can be seen from the Fig. 3(a), there is signature of C, O, Al and Sm elements in the ^{154}Sm isotope. Carbon is the capping material, Al is the backing material and oxygen may come due to the partial oxidation in Sm. From the Fig. 3(b), there is signature of O, Al and Nd elements in both ^{148}Nd isotopes. Al is the capping and backing material, oxygen may come due to the partial oxidation in Nd. This indicates the fabricated targets are in pure form. Further to check the thickness and purity, Rutherford backscattering spectrometry (RBS) measurements were also done for the fabricated targets using NEC's 5SDH-2 tandem accelerator at IUAC, New Delhi using 2 MeV He^+ beam. The RBS spectrum of ^{154}Sm and ^{148}Nd are shown in Fig. 4(a and b). Figure 4(a) confirms the presence of elements target material Sm with Al backing, C capping and O in the surface. Figure 4(b) confirms the presence of target material Nd with Al backing, Al capping and O in the surface. RUMP code was used for analysis/simulation[8-9]. From the RBS measurement the thickness of the fabricated targets of ^{144,154}Sm and ^{142,148}Nd were in the range of 200-700 μg/cm^2.

4 Conclusions

In the present work, the isotopically enriched targets of ^{154,144}Sm and ^{142,148}Nd have been fabricated in high vacuum evaporator chamber at target development laboratory, IUAC, New Delhi. These very thin targets (thickness ≈200-700 μg/cm^2) were used in many experiments for the measurements of excitation functions and recoil range distributions studies using different heavy ion projectiles. These

targets were fabricated by electron gun evaporation on Al backings of thickness ≈1-1.8 mg/cm^2. As samarium and neodymium are both oxidizing in nature, a very thin layer of carbon/aluminium (10 μg/cm^2) has been applied after the Sm/Nd-isotopes deposition over the thick Al-backing foils as capping to prevent the oxidation after the fabrication. The thickness and uniformity of the different samples were measured by Rutherford backscattering spectrometry (RBS) and energy dispersive x-ray spectroscopy (EDXS). These measurements also confirm that there are no unwanted impurities in the prepared targets. In the present work, large number of sandwiched target, nearly 35, of ^{144,154}Sm and ^{142,148}Nd isotopes have been successfully fabricated in a single evaporation. The present study also suggests that the sandwiched targets will be the most effective method to prepare large number of thin isotopic enriched targets having oxidizing nature for experimental nuclear physics.

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