Role of Crucible Source in Fabrication of Enriched ^{28}Si Target Development

Subodh[1],* Abhilash S. R.[2], B. R. Behera[1], R. P. Singh[2], Madan Sharma[3], and G. R. Umapathy[2]
[1] *Department of Physics, Panjab University, Chandigarh - 160014, INDIA*
[2] *Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA and*
[3] *IIT Delhi, INDIA*

Introduction

Targets in Nuclear physics experiments are an indispensable ingredient for a successful experiment. The experiment demands a uniform and stable target with high elemental and isotopic purity. Our experiment aims to study gamma-ray spectroscopy in the mass region A∼40. For this experiment in the Indian National Gamma array [1] and Charge particle Detector array at IUAC, New Delhi, a ^{12}C beam will be bombarded on a ^{28}Si target to investigate the nuclear high spin phenomena by in-beam gamma-ray spectroscopy. Isotopic impurity in the target may lead to more background in the data; hence, a highly enriched ^{28}Si target was proposed. Target thickness in the range of 400 μg/cm^2 to ∼1 mg/cm^2 and backing as ∼6-7 mg/cm^2 is preferred to stop the recoils and to pass the charged particles. The energy loss calculations were carried out using the SRIM code [2]. ^{197}Au foil was chosen as the backing material, and the fabrication parameters were optimized through natural Silicon target fabrication.
The isotopically enriched 99.991% 100 mg ^{28}Si material was available with Target laboratory at IUAC, New Delhi. Hence, the same was used to fabricate isotopically enriched ^{28}Si targets.

Experimental Technique

Rolling of Gold (^{197}Au)

Cold rolling of ^{197}Au backing foils was carried out using a rolling machine setup at IUAC, New Delhi. The polished stainless-steel plates with a parallel surface were used for rolling to avoid any angular stress inside. The Au foils of thickness 6.6 mg/cm^2 and 7.20 mg/cm^2 were obtained with this practice and used for further evaporation.

High vacuum Evaporation technique

Initially, 100mg ^{28}Si material was available in powder form; hence, an intense electron beam could lead to instant evaporation of material which might cause wastage of limited available material. Therefore, a material pellet was formed using an in-house pellet press die. The high vacuum e-beam facility of IUAC, New Delhi, with the optimized evaporation parameters from natural silicon fabrication trials, was used. To avoid instant evaporation, the source material was scanned with lower values of electron beam emission current (∼5-10 mA) which asserts uniform temperature in crucible depth. Also, the instrumentation restricted us from carrying out slow evaporation of target material at the rate of 0.1 A°/s [3].

Introduction of In-house fabricated specially designed Graphite crucible

The significant challenges before evaporation are the higher cost and lower availability of isotopic material. To minimize material wastage and to increase the collection efficiency at the substrate, a slight solid angle must be provided to vapor flux [4]. Also, carbon contamination in the sample should be reduced by a significant amount. To overcome these challenges, a specially designed graphite crucible was proposed. This graphite crucible was designed and fabricated at IUAC, New

*Electronic address: subodhlookhi@gmail.com

Delhi (Fig.1). This crucible was first tested

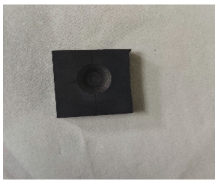

FIG. 1: Graphite crucible fabricated at IUAC, New Delhi.

with 100mg ^{Nat}Si material. ^{Nat}Si target of thickness ∼600 μg/cm^2 was fabricated using this crucible. To check the purity of the sample, EDX (Energy Dispersive X-ray) technique was carried out, which revealed carbon contamination as ∼2%. This crucible helped us to reduce the carbon contamination and greater collection efficiency and hence, adopted for final ^{28}Si evaporation. Two ^{28}Si targets were fabricated with this technique.

Characterization

Initially, ^{28}Si target thickness was measured with stylus profilometer at IUAC, New Delhi. Using that the thickness of ^{28}Si target was calculated as ∼500 μg/cm^2. This target is going to be used in our final experiments hence to be more precise about thickness, RBS measurements were carried out on both the targets of ^{28}Si with RBS technique available at IUAC, New Delhi [5] laboratory, . While carrying the observations, the scattering chamber was maintained at the order of 10^{-6} mbar. The simulation of the data was carried out using XRUMP [6]. The thickness of both ^{28}Si targets from RBS measurements was 440 ± 12 μg/cm^2 and 462 ± 12 μg/cm^2. The RBS spectrum of both the targets at two different positions on the sample is shown below in figure 2.

Conclusion

The advantage of a specially designed in-house graphite crucible in reducing carbon contamination and increasing the collection efficiency is described. Using this crucible, ^{28}Si targets were fabricated successfully. The surface profilometer and RBS measurement were carried out to verify the target thicknesses. More characterizations of the ^{28}Si targets must be carried out for surface morphology and purity analysis.

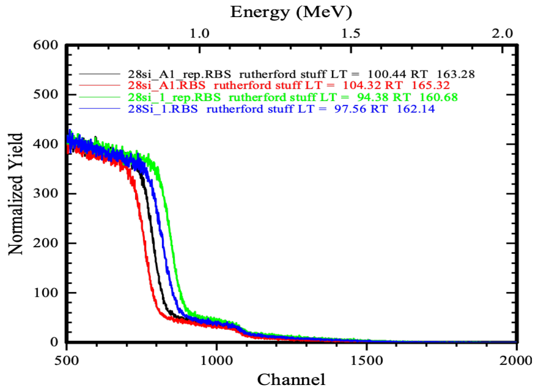

FIG. 2: RBS spectrum of both ^{28}Si Targets.

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