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Fabrication of ^{121}Sb isotopic targets for the study of nuclear high spin features

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ABSTRACT

Isotopic ^{121}Sb targets with ^{197}Au backing have been prepared by Physical Vapor Deposition (PVD) method using the diffusion pump based coating unit at target laboratory, Inter University Accelerator Centre (IUAC), New Delhi, India. The target thickness was measured by stylus profilo-meter and the purity of the targets was investigated by Energy Dispersive X-ray Analysis (EDXA). One of these targets has been used in an experiment which was performed at IUAC for nuclear structure study through fusion evaporation reaction. The excitation function of the ^{121}Sb(^{12}C,$yxn\gamma$) reaction has been performed for energies 58 to 70 MeV in steps of 4 MeV. The experimental results were compared with the calculations of statistical models : PACE4 and CASCADE. The methods adopted to achieve best quality foils and good deposition efficiency are reported in this paper.

1. Introduction

In nuclear structure studies, the fusion evaporation reaction by the decay of Compound Nucleus (CN) was used to populate the high spin states of the nucleus of interest [1,2]. In order to explore the high spin phenomenon, a large statistical data from in-beam gamma-ray spectroscopy is required. To achieve this, target foils of good qualities and desire thickness are needed depending upon physics interests of the experiment. For an experiment in the Indian National Gamma Array (INGA) [3,4] facility at IUAC, New Delhi, isotopic ^{121}Sb target was required to investigate the nuclear high spin phenomenon like — signature splitting, magnetic rotation, anti-magnetic rotation, chiral rotation, etc. [5] by in-beam γ-ray spectroscopy. The life-time measurements using Doppler Shift Attenuation Method (DSAM) [6] are useful to measure the transition probabilities of the nuclear excited states. In DSAM method, the recoiled nucleus should be stopped, and for this purpose a thin target with a thick backing of high Z material is preferred. The ^{197}Au was found to be ideal for current physics interest and was chosen as the backing material for the present target fabrication [7].

In literature, there are few reports on the fabrication of different Sb targets. F. A. Burford *et al.,* [8] fabricated self supporting and backed Sb foils by using the electroplating method. The thin targets of thickness upto ~ 240 μg/cm^2 was achieved by ion implantation method [9]. Further, there is also report on the fabrication of sandwich type Sb target by evaporating Sb on Pb metal [10]. In year 1989, N. Ueta and W. G. P. Engel [11] applied Physical Vapor Deposition (PVD) method using a crucible boat to make Au backed Sb foils with a poor efficiency of deposition. In year 2014, the same PVD method was also adopted by J. P. Greene *et al.,* [12] for fabrication of self support and backed Sb targets.

In the present work, in order to fulfill the requirements of the experiment, isotopic ^{121}Sb targets having thickness between 1250–1350 μg/cm^2 were deposited on the ^{197}Au foils using the PVD method. The methods adopted and the technical setup used to improve the efficiency of the deposition was discussed in the following sections.

2. Fabrication setup

The target fabrication was done using the diffusion pump based coating unit at the IUAC. This coating unit can attain a vacuum of the order of $\sim 3 \times 10^{-7}$ Torr [13]. In this chamber, evaporation can be done by two different methods — resistive heating method and electron beam bombardment method. The first method is usually used for the evaporation of low melting point materials while the second one is applicable for high melting point materials. The chamber is also equipped with a quartz crystal monitor which can be used to monitor the film thickness and the deposition rate during the deposition process. The distance between the material boat and the substrate holder can be adjusted as per the requirement of the deposition. A liquid nitrogen (LN2) cold trap system is also equipped with the evaporation chamber to minimize the oil contamination from the rotary and diffusion pump.

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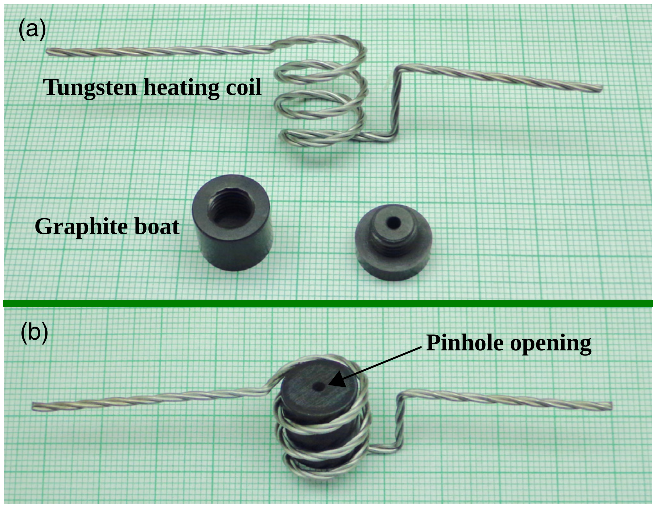

Fig. 1. (a) Tungsten heating coil basket and graphite boat (b) Assembled of the basket and the graphite boat.

3. Fabrication details

3.1. Rolling of gold (^{197}Au) foils

The ^{197}Au backing foils were prepared using the target rolling machine which is also available at the target laboratory of IUAC [14]. In this rolling technique, the first requirement is to prepare a folded polished Stainless Steel (SS) plate with perfectly parallel surface to avoid any angular stress on the foil under pressure during the rolling. Then, a piece of ^{197}Au foil was kept in between the folded surface of SS plate, and the rolling of this foil was done by applying uniform pressure on the SS plate until the desired thickness was achieved. The Au foils of 10 to 12 mg/cm^2 thickness were prepared to use them as the backing material. The thickness of the foils were obtained by measuring the weight of the foil with an electric micro-balance and by calculating the area of the foil using graph-paper.

3.2. Deposition of antimony (Sb)

The isotopically enrich (99.45%) ^{121}Sb was deposited on ^{197}Au foil of 10–12 mg/cm^2 thickness. The Sb has melting point of 630.74 °C, therefore the resistive heating method was adopted for the deposition. A specially designed pin-hole graphite boat (1 mm opening diameter) [15] was used as shown in Fig. 1(a). For expensive isotopic materials, such kind of crucible with pin-hole opening is helpful in minimizing the amount of material waste in evaporation, compare with the ordinary crucible. The boat was heated by keeping it inside a basket made of tungsten heating coil (see Fig. 1(b)). The efficiency of the collection can be improved by maintaining minimum distance between the graphite boat and the substrate holder, thereby reducing the solid angle coverage of the evaporating material. In the present deposition setup, a layer of SS plates was kept in between the graphite boat and the substrate holder leaving a small gap for the evaporating material (see Fig. 2(a)). These SS plates act as a heat dissipater and helps in reducing the distance between the boat and the substrate holder. A glass slide was also kept on the substrate holder to measure the thickness of the deposited films using a profilo-meter (details are given in the next section). The setup was arranged in such a way that two foils of almost equal thickness can be deposited in a single deposition run with a least quantity of the isotopic material. A photograph of the inner view of the coating unit with the deposition setup is shown in Fig. 2.

The setup parameters such as deposition efficiency and the amount of material required for the desired thickness were optimized by conducting several trials with the natural Sb. During the natural Sb deposition,

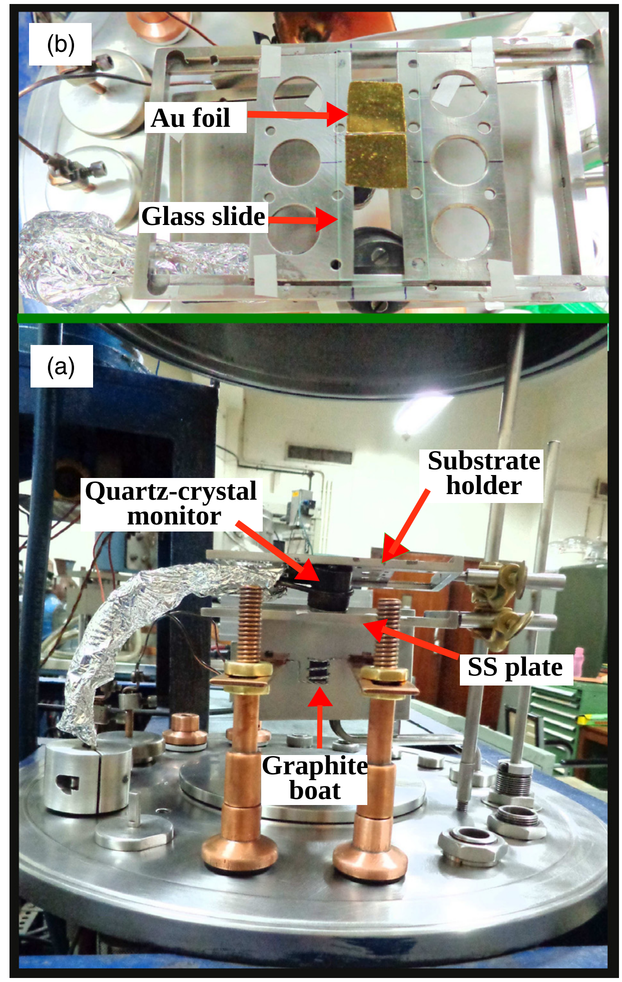

Fig. 2. (a) Diffusion pump based coating unit at IUAC with the present deposition setup. (b) Upper view of the setup showing the substrate holder.

1.7 mg/cm^2 thickness of Sb was achieved using 5.3 mg of material at a distance of 1 cm between the graphite boat and the substrate holder. Finally, the deposition was done with enriched isotopic ^{121}Sb. The distance between the graphite boat and the substrate holder was kept at 5.8 cm and the SS plate was kept at a distance of 3 cm from the graphite boat. Two backing ^{197}Au foils were mounted on the substrate holder and the Sb of required thickness was deposited on it. The deposition was started with 68 A current provided by 10 V voltage supply and it was slowly increased up-to 88 A. The deposition rate and the thickness of the deposited films were monitored with the quartz crystal monitor. A constant deposition rate of 0.1 nm/sec was maintained throughout the deposition to result a uniform thickness and best quality target foils. Fig. 3 shows the photograph of the prepared target foils.

In the previous work by J. P. Green *et al.,* a 8 cm distance was reported between the boat and the substrate. In our work, this distance was reduced up-to 5.8 cm by deploying the SS plate as a heat dissipater and helps us in improving the efficiency of the deposition.

4. Characterization

4.1. Thickness measurement

The thickness of the fabricated Sb targets was obtained from the deposited Sb film on the glass slide using a stylus profilo-meter. The profile of the stylus profilo-meter gives a vertical displacement due to a step between the film and the glass substrate, and therefore this