Development of isotopically enriched ^{11}B target on Aluminum and Carbon backing

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Introduction

An experiment using ^{11}B target has been planned to study the Hoyle state of ^{12}C. This prompted us to initiate the preparation of isotopically enriched ^{11}B target. It is well known that boron is difficult to deposit due to its resistiveness towards evaporation which is mainly due to the poor thermal conductivity and low density (2.3 g/cm^3). Moreover, boron targets are extremely brittle which creates further hindrance in the preparation of self-supporting targets. Boron target can be prepared by various techniques [1-3], vapour deposition using an electron gun is a commonly used technique. Here we report the preparation of ^{11}B (90% enriched) targets on ^{12}C and ^{27}Al backing and also the self-supporting natural boron target using vapour deposition technique.

Description of the apparatus

The apparatus used to prepare ^{11}B targets consists of an electron gun (EB) assembly, one crucible hearth and a stainless steel stand for keeping the substrates as shown in Fig. 1. All these are assembled on a base plate which is kept inside a chilled water cooled evaporation chamber. The vacuum is created inside the chamber using an oil diffusion pump (DP) backed by a rotary pump. Liquid nitrogen trap is used to prevent any possible oil vapor leaking into the chamber. A tungsten filament was used as an electron source for producing the electron beam. As the current passes through the filament it starts glowing spontaneously and emits electrons randomly in all direction. An anode plate situated in front of the filament collects the electrons and forms a beam, which is accelerated through the potential difference of 5 kV, applied between the anode and the cathode. Finally, the beam is deflected by a magnetic field created using two permanent magnets through an angle of 270º which then fall inside the crucible to evaporate the sample.

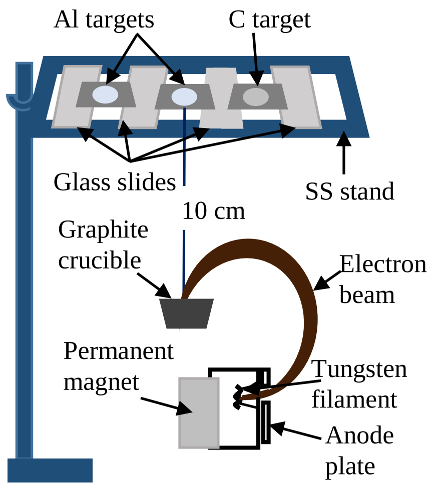

Fig. 1 Schematic diagram of the system for producing ^{11}B targets.

Preparation of ^{11}B targets

Four glass slides were kept on a stainless steel (SS) stand mounted on the base at a distance of 2 cm from each other (Fig. 1). One ^{12}C (11 μg/cm^2) and two ^{27}Al (50 μg/cm^2) targets (mounted on a SS frames) were kept in this gap between the glass slides, as the backing substrates. Both the backing targets were prepared using the evaporation technique. The slides were kept at a distance of 10 cm from the crucible loaded with boron paste. The distance was optimized by taking several trial runs.

Paste of enriched boron powder was made by mixing with ethyl alcohol and tightly kept inside the graphite crucible. Evaporation trial was also done using boron in pellet form. Spitting effect was found to be less for the sample in paste form in compared to the pellet. The boron powder spitting effect was also mentioned in Ref. [4]. Moreover, material wastage is also lower in the paste form. Care had been taken so that boron powder should not be loosely bound while producing paste to avoid spitting which may create pin holes in the targets.

After placing the source and substrates inside chamber, it was evacuated. Once the chamber vacuum reached a value of 8 x 10^{-6} mbar, tungsten filament was gradually heated by increasing the filament current. After a few minutes of initial heating at low current, it was slowly increased. This initial heating of boron paste using the electron beam helped to create a lump from the boron paste. Which made the subsequent evaporation process easier as it reduced the spitting effect. Though the vacuum initially was degraded, it slowly improved and reached at 5 x 10^{-6} mbar. Evaporation was done for 1.5 hrs. to get ~100 µg/cm^2 thick ^{11}B layer. Evaporation time in this case was much higher compared to the usual target preparation time for elements like Sn, Au etc., which is because of the poor thermal conductivity and low density of boron. The other reason was the restricted evaporation rate (0.5 – 1 Å/s) maintained to avoid spitting effect. Thicker layer of deposits can however be achieved in same duration, using a higher energy electron beam as discussed in Ref. [3]. During evaporation EB gun sweep control was switched on to move the beam spot in horizontal and vertical direction so that beams fall all over the sample and melting of any specific part can be avoided. After evaporation was over and substrates cooled down to room temperature, ^{11}B coated ^{12}C and ^{27}Al foils were taken out from the evaporation chamber (Fig. 2).

Fig. 2 ^{11}B targets on ^{27}Al backing (left), on ^{12}C backing (middle), self-supporting with natural B (right)

Thickness measurement

Thickness of ^{11}B targets is measured inside the evaporation chamber using a thickness monitor which consists of a quartz crystal as a basic transducing element. The crystal is exited into mechanical vibration using an external oscillator. Frequency of the oscillation is inversely proportional to the weight of the crystal. Addition of material on the surface of the crystal due to evaporation would lower its frequency. The thickness T_k of the evaporated foil is calculated using the following relation.

$$T_k = \frac{N_q \rho}{\rho_f}\left(t - t_q\right)$$

Where N_q is the frequency of the crystal, ρ, ρ_f are the density of quartz crystal and the foil, t, t_q are the period of the loaded and unloaded crystal (before evaporation). Target thickness was also measured using the energy loss of alpha particles [5] from ^{241}Am source for self-supporting natural boron target. Target thickness measured using energy loss technique was found to be 260 ± 6.3 µg/cm^2 for the self-supporting target, which is similar to that measured using crystal oscillation technique (256 µg/cm^2).

Conclusion

Enriched ^{11}B targets of thickness 100 µg/cm^2 on ^{12}C (11 µg/cm^2) and ^{27}Al (50 µg/cm^2) backing have been prepared by vapour deposition technique using electron gun. Self-supporting boron (natural) target of thickness 260 µg/cm^2 was also prepared. Further trial of self-supporting target preparation using enrich ^{11}B will be taken up.

References

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