Nuclear target development of oxidizing elements at IUAC

Abhilash S R*,G R Umapathy, Sunil Ojha and D Kabiraj
[1]*InterUniversity Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, INDIA*
* *email: abhilashiuac@gmail.com*

Introduction

Target development of oxidizing materials is always a challenging job. Targets of oxidizing elements, viz; Li, Ca, Pb, Nd, Gd, Sm, Ba, Ce, Pr, Bi, Er and Eu have been frequently fabricated in target development laboratory at Inter-University Accelerator Centre (IUAC) in the form of self-supporting targets or with backing targets. The fabricated targets are used in nuclear physics experiments in accelerator facility at IUAC. Minimizing the exposure of target materials to atmosphere before and after the target preparation played the significant role in the development of readily oxidizing isotopic targets. Since many of them are of rarely available, isotopically enriched materials, minimizing the material consumption and its preservation for longer duration were also important. Recent activities at IUAC in target development of oxidizing materials will be discussed in the report.

Experimental procedure

1. Development of self-supporting targets

Self- supporting targets of less oxidizing elements viz; Pb, Gd, Bi, Er, Tb, Ho, Tm and Lu were regularly fabricated in IUAC. Target development of Gd of 320µg/cm^2 by rolling is the latest development. Targets of Er, Tb, Ho, Tm and Lu of ~500µg/cm^2 thickness or above are also fabricated frequently by rolling technique. Thin self-supporting targets of Pb [1] and Bi in the range of ~200µg/cm^2 have been fabricated several times by thermal evaporation. For protecting the targets from the oxidation for longer duration, targets are preserved in Ar environment in vacuum desiccators.

2. Development and in-vacuum transfer of targets

Development and transportation of self-supporting targets of highly air-sensitive elements viz; Ca, Eu, Pr and Li are very difficult. Air-sensitive targets with backing can be fabricated using the in-vacuum transfer set-up which will ensure high vacuum environment during the evaporation, transportation to experimental chamber and irradiation in experimental chamber. Many Li and Ca [2] targets were successfully fabricated by using this method. More material consumption due to the large and fixed distance of 20cm between the source and substrate was the major limitation of the in-vacuum transfer facility; hence it was not suitable for targets of highly expensive isotopic material.

3. Targets with thin carbon capping

Targets prepared with backing and encapsulation by doing protective capping have more life and productivity. Many stable metals are used for protective coating. Carbon capping is more suitable as it results in minimum beam energy loss. The target development set-up is also simpler as compared to in-vacuum transfer set-up.

Most of the recent target developments of rare elements, Pb and Ba were done in thin carbon sandwich. The development procedure can be divided into two parts. The first part is the preparation of carbon backing and the second part is the evaporation of target material followed by the carbon thin coating. The entire operation was done in high vacuum environment. A diffusion pump based coating unit was used for the fabrication.

In the first part, the carbon film of 10-20 µg/cm^2 was fabricated by electron beam bombardment technique [3]. In the second part, the substrate, the annealed carbon slides, were placed at 5cm from the thermal evaporation source. The substrate holder is mounted with a

linear cum rotary motion manipulator. Ta tubular boats and indigenously developed graphite crucibles [4] were used to improve the evaporation yield. The target material was evaporated in the high vacuum environment by thermal evaporation. After the evaporation of target material, the substrate is rotated and placed at 15cm from the e-beam source with the help of the manipulator. Finally a carbon layer of 5-10 µg/cm^2 was deposited as protective coating by electron gun.

After venting, the target in carbon sandwich is floated in distilled water and mounted in the appropriate target holder. Target lab was successful in preparation of many targets of rare earth targets, Ba and Pb by this method. The thickness of targets varied from 100 to 400µg/cm^2 and the material consumption was varying from ~5mg to ~15mg. The targets were stable for several months in Ar environment. This procedure was capable to produce 15-24 targets in one attempt.

4. Targets with gold capping

Since carbon capping was not successful for highly air-sensitive elements like Ca, gold capping was also used for many targets. Thick backing of gold foil was used in this procedure. Initially the thick gold backing foil was prepared by rolling. The evaporation of target material and gold capping were done sequentially on the foil in the same procedure as discussed above. The thickness of gold layer deposited as protective coating was between100-200 µg/cm^2. Target lab has fabricated many targets of Pr, Eu and Ca by this method. The Pr targets were stable for several months and Ca and Eu targets had life of ~1 month in Ar environment.

5. Parting agent contamination in targets

Selection of parting agent is also an important parameter to be considered in the preparation of nuclear targets. NaCl, $BaCl_2$, KCl, CsI, teepol were the main parting agents which were regularly used in target preparation. In a recent target fabrication of isotopic Pb, carbon thin films were used as backing target (with $BaCl_2$ or KCl as parting agent).

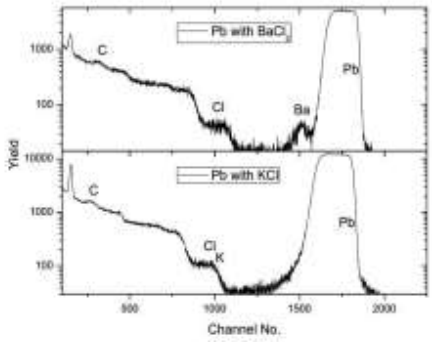

Fig.1: RBS spectra of Pb target

The carbon films and Pb targets were separately analyzed by RBS technique using PARAS facility at IUAC. The RBS characterization has shown that the C/Pb/C multi-layer targets used $BaCl_2$ as parting agent has Ba contamination and target prepared with KCl parting agent was comparatively free from high Z element contamination. Figure.1 shows the level of contamination in Pb targets in carbon sandwich.

Conclusion

Sandwiching of oxidizing targets in thin carbon film is very effective in protecting the targets for several months. Since more targets are produced in single attempts with minimum material loss, this procedure is more suitable for expensive target materials. Carbon films prepared with KCl is comparatively free from contamination of high Z elements.

References

[1] S. Goyal et al., Nucl. Inst. and Meth A 777 (2015): 70–74

[2] D Kabiraj et al., Nucl. Inst. and Meth A 362,(1995): 205-207

[3] Abhilash,et al., J Radioanal Nucl Chem 305(2015): 749-753

[4] Abhilash,et al., J Radioanal Nucl Chem 299 (2014): 1137–1139