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Fabrication of calcium-gold and calcium-lead targets for ion beam experiments at TRIUMF ISAC-II

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Abstract Multi-layer thin targets are vital in low-energy nuclear physics experiments employing the use of accelerated beams. In this paper, we describe the fabrication of encapsulated calcium targets produced by evaporation on gold and lead backings for radioactive beam experiments at TRIUMF's ISAC-II facility.

Keywords Calcium targets · Multilayer targets · Ion beam

Introduction

Multi-layer thin targets play an important role in low-energy nuclear physics experiments with accelerated beams. For example, targets with an evaporated thin reaction layer on a heavy stopper backing material are used in excited-state nuclear lifetime measurements. The typical challenges in fabricating such targets are providing a uniform deposition of the reaction layer with good adhesion to the backing and with minimal mixing of layers. In addition, further challenges were presented when a chemically reactive element such as calcium was employed. Due to being an alkaline earth metal, calcium is a reactive element at standard pressure and temperature.

Gamma-ray spectroscopy plays a major role in quantifying the evolution of nuclear structure for exotic radionuclides. TRIUMF ISAC gamma-ray escape-suppressed spectrometer (TIGRESS) is the key driver for such experimental studies using accelerated beams provided by the ISAC-II facility. A rich set of auxiliary particle detector arrays complement and enhance these spectroscopy studies and compliment this experimental program devoted to transition rate measurements, which play an important role in our understanding of the nucleus and provide stringent benchmark tests of nuclear models.

TIGRESS Integrated Plunger (TIP) shown in Fig. 1) is a new TRIUMF experimental program for recoil distance method lifetime studies. TIP offers great flexibility for nuclear structure studies via doppler-shift lifetime and Coulomb excitation measurements utilizing a diverse set of ancillary charged-particle detectors and a variety of reaction mechanisms.

In a recent measurement at the ISAC-II facility of TRIUMF, experimenters required encapsulated calcium reaction targets evaporated onto stopper backings of gold and lead. The ^{36}Ar(^{40}Ca,2α)^{68}Se* reaction was used for the lifetime study of excited states in ^{68}Se using coincident gamma-ray and charged-particle spectroscopy with the TIP device [1]. As these measurements are affected by oxygen in the target, the required calcium targets had to be of highest achievable purity.

In the following we describe the fabrication of high purity calcium targets on gold and lead backings that were used successfully in ^{68}Se* lifetime experiments.

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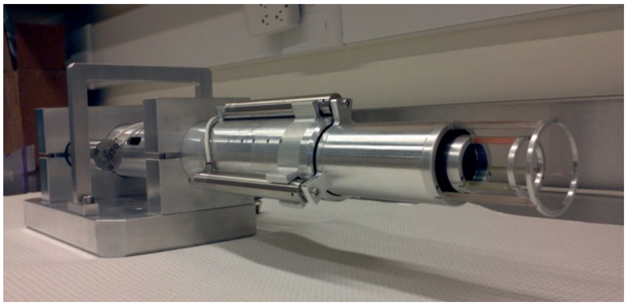

Fig. 1 The TIGRESS Integrated Plunger device

Materials and methods

Materials

Calcium granules were purchased from Alfa Aesar, calcium ingots from Sigma-Aldrich. Lead foils were purchased from Alfa Aesar. Gold foils were purchased from Goodfellow Metals. The tungsten evaporation boats were products of R. D. Mathis Company. Target frames were supplied by the Science Machine Shop at Simon Fraser University, Burnaby, BC, Canada.

Target frame and backing preparation

Gold backings were manufactured from commercial thick Au foils (24 mg/cm^2), lead backings from 27.6 mg/cm^2 Pb foil, produced by rolling of commercially available foils to the desired thickness. Backings were cut to size and glued to the target frames using epoxy adhesive.

Thermal evaporation onto gold backings

The preparation of the calcium targets followed our standard protocol for evaporation of reactive metals. Similar procedures have been described by Kheswa et al. (vacuum deposition of calcium) [2] and Dollinger et al. (calcium targets encapsulated with aluminium layers) [3].

Mounted gold backings were baked at a low enough temperature that the epoxy glue remained unaffected but removal of moisture was still achieved. Specifically, targets were heated in a vacuum oven to 85 °C for 10 min.

The backings were then mounted into the deposition apparatus and heated again in high vacuum for 20 min using the tungsten evaporation boat as a heat source. A gold layer of 100 μg/cm^2 thickness was then evaporated onto the gold backing. The chamber was vented with dry nitrogen and the targets quickly transferred into a sealed container and kept under vacuum.

After installation of a tungsten boat filled with calcium metal the targets were returned to the deposition apparatus, which was evacuated within 1 min. A calcium layer of $\sim$134 μg/cm^2 was evaporated onto the gold backing. The chamber was again vented with dry nitrogen and the targets were removed and stored in the vacuum container. The evaporation source was then changed back to gold. The targets were reinstalled in the evaporator and a final gold layer of 19.3 μg/cm^2 was deposited. Figure 2 shows the gold coated calcium targets.

Preparation of lead backed targets

Lead backed targets were prepared by the same process on unmodified 27.6 mg/cm^2 Pb foils and foils vacuum coated with 100 μg/cm^2 of lead. A calcium layer of 250 μg/cm^2 was deposited as described above and sealed with a lead layer of 20 μg/cm^2.

Results and discussion

Initial attempts to deposit calcium metal directly onto thick commercial gold foils failed as calcium did not adhere to the untreated backing. Good adhesion of the calcium layer was only accomplished on freshly evaporated gold. On lead targets, good results were achieved with plain rolled lead foils as well as backings with freshly deposited lead. The exact reason for this difference in behaviour is not known.

Calcium is not as oxygen sensitive as the alkaline metals and can usually be manipulated in air for short periods without deterioration. Evaporations were initially performed with small calcium granules, which were considered more suitable for rapid loading of the evaporation boat than larger pieces. However, it was noticed that the granules, although handled swiftly, produced a visibly oxidized calcium deposit on the substrates. In some cases, the calcium layer would peel away from the substrate.

In contrast, excellent results were achieved with sources made from calcium ingots. All outer surfaces of the cut calcium chunks were removed manually prior to the

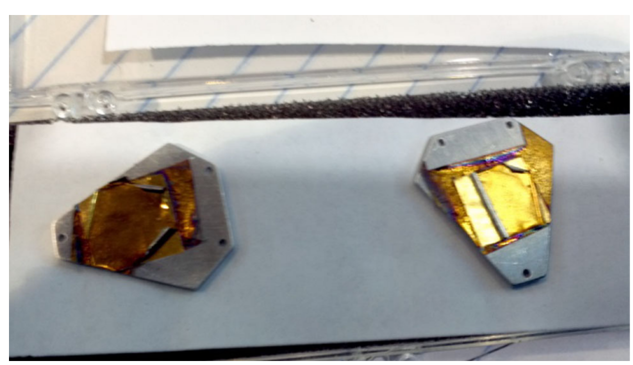

Fig. 2 Calcium targets on gold backing

evaporation. Layers produced from large pieces of the metal adhered well to the backing.

Finally, our experiments showed that the calcium deposits could not remain in the vented evaporator even for the short time required to change the evaporation source as they reacted immediately with moisture and air. All transfers between the evaporator and the vacuum storage vessel had to be performed as swiftly as possible to avoid oxidation of the targets under ambient conditions.

Conclusion

The fabrication of calcium targets is not trivial. Special surface preparation and handling techniques have to be followed in order to achieve high purity, low oxygen targets. Installation of a second evaporation source that permits the production of multilayer targets without breaking vacuum is in progress.

References

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