Target Development of High Melting Point Metals

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Introduction

Target development of W, Re, Ta, Mo, Nb, Ir and Hf poses lots of challenges by virtue of its physical properties like high melting point and comparatively poor malleability. Targets of high melting point metals are more often considered as the choice for many accelerator based nuclear physics experiments. Contrary to the low melting point metals, the involvement of huge amount of heat brings in multiple complexities in target development by evaporation. According to the experimental need, both thick and thin targets in the form of either a self-supporting or with backing are used for experiments. In experiments like fusion evaporation study, the presence of backing material may lead to an increased energy loss and undesirable results. The self-supporting targets are preferred for such studies. In addition, highly enriched isotopic materials are the ideal choice for many nuclear physics experiments with ion beam. Most of the isotopes are highly expensive and rarely available. So, the target development of isotopes of high melting point metals with limited amount becomes more complicated. Over the last few years, an extensive amount of work has been done in Inter-University Accelerator Centre (IUAC) in the target development using high melting point metals. The challenges and solutions involved in the target development of high melting metals will be discussed in the report.

Experimental procedure

1. Development of W, Ir and Re targets

It is well known that tungsten is one of the metals having the highest melting point and brittleness. Target fabrication of W by cold rolling technique is not a preferable choice owing to its poor malleability. Despite the fact that e-beam evaporation causes more material consumption and wastage, it is considered as one of the preferable choices for W target fabrication. Intrinsic stress developed in the target film, degradation of the substrate and releasing agent due to the enormous heat developed at the e-beam source are the major constraints in W evaporation.

Target Development Laboratory (TDL) of IUAC has developed a standard procedure for fabricating stress relieved W targets. The procedure also ensures contaminant-free targets with minimum material consumption [1]. TDL is successful in delivering several targets of ^{182}W, ^{184}W and ^{186}W of 100-700μg/cm^2 with C backing of 10-100 μg/cm^2 and the targets have been successfully used in experiments in various accelerator labs in India. The targets of Re (3,182 °C) and Ir (2,446 °C), the high melting point metals, are also fabricated using the same methodology.

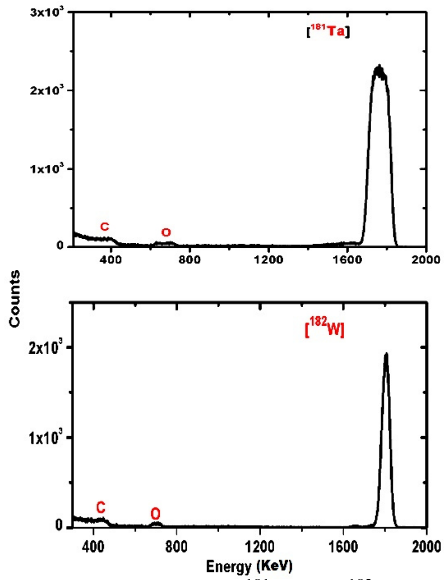

Figure.1: RBS spectra for ^{181}Ta and ^{182}W targets

2. Development of Ta targets

Ta is also one of the metals having high melting point. As a consequence, high power e-beam source is essentially required for the fabrication of Ta target by vacuum evaporation. TDL has fabricated and delivered many Ta targets of 100-300μg/cm^2 with thin C backing of 10-100μg/cm^2.

Optimization of a suitable releasing agent which can withstand the high temperature from the electron beam source is the major constraint in the fabrication of self-supporting Ta targets by evaporation. To overcome this issue, rolled thin Cu foil is used as the substrate and the Ta is deposited over the Cu foil. Finally, the Cu foil is removed by selective etching. In order to minimize the stress that develops during thin film growth, the Cu foil is kept at 300^{0}C during the film growth. TDL is successful in fabricating several self-supporting targets of Ta by evaporation method followed by etching. The targets with thickness range of 400-800μg/cm^2 are prepared by this method and the targets are free from major contaminations.

Ta is a comparatively malleable metal and cold rolling technique is the simplest method of fabrication for targets of thickness above 1mg/cm^2. Contrary to the evaporation method, targets prepared by rolling contribute no material loss.

3. Development of Mo targets

Mo has a melting point of 2,623°C, close to only a few naturally occurring elements like tantalum, osmium, rhenium, and tungsten having higher melting points. Consequently, e-beam evaporation technique and rolling technique are preferably used for the fabrication of Mo target. Generally, the Mo isotopes are supplied in the form of fine powder with a limited quantity (in few milligrams). Fabrication of targets from the powder constitutes lots of challenges. Vacuum evaporation is not a preferable method for the fabrication of comparatively thick targets of >1mg/cm^2 owing to huge wastage of material. In such cases, the Mo power is consolidated into a metal shot by melting using e-gun under high vacuum condition. The metal shots are then rolled into thin foils. Targets of Mo isotopes of 1-4mg/cm^2 have been fabricated by this method using limited amount of material in powder form [2]. In addition, targets of Mo isotopes of 100-400μg/cm^2 with thin backing of C and thick backing of Ta and Au are also frequently fabricated at IUAC by evaporation techniques.

4. Development of Hf targets

In addition to the problems associated with the high melting point, the tendency of Hf to react in air is also a major constraint during the target fabrication. The oxidization attributes porous texture over the metal surface and eventually pin holes are formed in the self-supporting targets. TDL is putting enormous amount of effort to develop the procedure for fabricating stable self-supporting targets of such kind of metals. The cleaning of the surface by appropriate etching solution followed by storing the foil in neutral environment minimizes the oxygen contamination and porosity of the target surface. The annealing of Hf foil at 600^{0}C in high vacuum environment improves its ductility, which helps the foil to thin down to 1mg/cm^2 by cold rolling.

Furthermore, the evaporation technique by using 6kW e-beam source is frequently used for the fabrication of thin targets of Hf isotopes. TDL has delivered targets of ^{178}Hf and ^{179}Hf of 100-600μg/cm^2 with different backing to various nuclear physics groups from across the country for their experiment in IUAC Pelletron.

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