Fabrication of ^{178}Hf using ultra-high vacuum evaporation technique

Kavita[1], Abhilash S. R[2], K. S. Golda[2], D. Kabiraj[2], Rakesh Kumar[1], Rakesh Dubey[2], Neeraj Kumar[3], and Hardev Singh[1]*

[1]*Department of Physics, Kurukshetra University, Kurukshetra, Haryana-136119, INDIA*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
[3]*Department of Physics & Astrophysics, University of Delhi, Delhi-110007, INDIA*
**email:hsinghphy@kuk.ac.in*

Introduction

For the synthesis of super heavy elements, a complete understanding of the reaction mechanism of heavy ion induced fusion-fission reactions is the necessary requirement in the context of nuclear physics experiments. The very first step is the preparation of target(s) as per the experimental requirements. During fabrication, one needs to be careful about the uniformity of the thickness distribution across the deposition area of the target material as well as the chemical purity of the deposited films [1]. For one of our experiment, we needed isotopically enriched ^{178}Hf as target in the thickness range of 150-200 μg/cm^2. To the best of our knowledge, a few reports are available on HfO_2 deposition by atomic layer method [2] and chemical vapor deposition [3]. Maier et al. [4], applied bomb reduction technique to prepare self-supporting Hf targets in the thickness range of 100-300 μg/cm^2 from HfF_4 by high vacuum sputter deposition.

In the present work, the isotopic Hf targets were successfully fabricated in the target development laboratory of Inter University Accelerator Centre (IUAC), New Delhi, using the turbo pump based coating unit with a vacuum of the order of 10^{-7} Torr. In this paper, we describe the various steps followed to fabricate good quality ^{178}Hf targets on carbon backing.

Fabrication details

It is very difficult to prepare the thin self-supporting targets and most often backing material is needed to support such thin targets. Here in the beginning, we used thin foil of carbon (~20 μg/cm^2) as backing and $BaCl_2$ as the parting reagent. Carbon foils were made by electron beam deposition using diffusion pump based coating unit [5]. Glass slides used as a substrate were kept at 19.5 cm and 18.5 cm away from the resistive heating arrangement and the electron gun assembly, respectively. Carbon was deposited on the glass slides after the successful deposition of releasing agent. These carbon coated glass slides were annealed in a tubular furnace at 325°C for 1 hour in nitrogen atmosphere to remove any internal stress on the deposited films.

Keeping in mind the high cost and limited availability of enriched isotopic materials, several trials were first made with natural hafnium to optimize different parameters of the deposition process. Initial attempt of Hf fabrication was done by 2 KW electron gun deposition arrangement using diffusion pump based coating unit. A Tungsten crucible was used for the deposition of the source material. After the deposition & floating of the target films, in order to check the purity of the deposited films, X-ray fluorescence (XRF) measurements were carried out at Department of Physics, Panjab University, Chandigarh. The XRF data showed the presence of high percentage of Tungsten contamination in the deposited films. Thereafter, we switched to the turbo pump based coating unit having 6 KW electron gun arrangement. This system is also equipped with a quartz crystal thickness monitor for controlling the thickness as well as the rate of deposition. Fig. 1 shows the inside view of turbo based evaporation assembly. The overall schematic of turbo based coating unit is shown in Fig. 2. A few trials were first carried out using natural Hf for the reasons discussed earlier. After the first attempt of Hf deposition, the films got damaged during floating probably due to the low thickness of carbon backing.

Fig. 1: Inside view of turbo based evaporation assembly.

In order to overcome this problem, before the next deposition, the thickness of carbon backing was increased from existing 20 µg/cm^2 to 35 µg/cm^2. In the final deposition with enriched material, the carbon coated glass slides were kept at 24 cm and 8 cm away from quartz crystal and electron gun arrangement respectively.

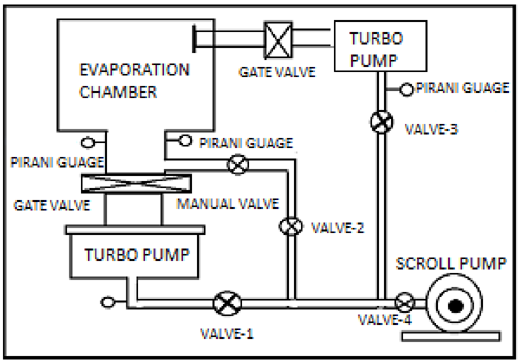

Fig. 2: The schematic diagram of turbo based coating unit at IUAC.

The Hf deposited glass slides were annealed in nitrogen environment at 325°C for 1 hour to relieve any internal stress on the deposited films. Finally, these films were floated in hot deionized water and were successfully mounted on the target frames.

Conclusion

Following the procedure described above, we could successfully fabricate five ^{178}Hf targets of thicknesses ~ 200 µg/cm^2 on the carbon backing having a thickness of 35 µg/cm^2. The prepared targets have already been used for the fission fragment mass distribution measurements in medium mass region.

Acknowledgements

The authors would like to acknowledge Prof. D. Mehta for XRF measurements at Department of Physics, Panjab University, Chandigarh. One of authors (Kavita) acknowledges IUAC, New Delhi & UGC-BSR, New Delhi, for the financial support through fellowship in carrying out this research work.

References

[1] Kavita et al., Vacuum **145,** 11-13 (2017).

[2] Y. Wang et al., Chem. Mater. **19**, 3127 (2007).

[3] T. S. Yang et al., Chem. Mater. **17**, 6713 (2005).

[4] H. J. Maier et al., Nucl. Instr. And Meth. A **334**, 113-115 (1993).

[5] P. D. Shidling et al., Nucl. Instr. And Meth. A **590**, 79-82 (2008).