Dissimilarity in the behavior of natural and isotopic Zirconium targets

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Introduction

The study of fusion and transfer reactions around the Coulomb barrier have been of immense interest for last many years. In the energy region near the Coulomb barrier, various reaction channels open up and have a great influence over each other. In order to have a complete study on fusion and transfer reaction dynamics, an experiment was proposed with nuclear reactions ^{28}Si+^{92,96}Zr using recoil mass separator, Heavy Ion Reaction Analyzer (HIRA) at Inter University Accelerator Centre (IUAC).

For success of any nuclear physics experiment, isotopic enriched targets of appropriate thickness is an absolute necessity. To perform the above experiment, self supporting Zr targets of thickness around 250 μg/cm^2 are required. Zirconium has low vapour pressure and is difficult to evaporate apparently due to the presence of tightly adhering films over its surface which makes preparation of Zr target a challenging task.

In our previous work on target fabrication, ^{92}Zr and $^{96}ZrO_2$ targets were prepared on 20 μg/cm^2 carbon backing [1]. These targets were used for measurement of fusion cross-sections [2]. During experiment, targets of ^{92}Zr were ruptured while bombarding with ^{28}Si beam. Therefore, a fresh attempt has been carried out to fabricate ^{92}Zr targets for the study of transfer reaction. In addition, we have investigated the behavior of natural as well as isotopically enriched Zr targets. These targets were fabricated in the target laboratory of IUAC using electron beam evaporation method under vacuum in the order of 10^{-8}-10^{-9}Torr.

Target fabrication set up

A diffusion pump based coating unit and cryo pump based coating unit was used for preparation of targets [3]. The enriched material for the isotopes ^{92}Zr and $^{96}ZrO_2$ was available in the form of metal and powder, respectively. A particular isotope was available in 100 mg amount only. Thus, to avoid wastage of enriched material during trial runs, evaporation was first carried out with natural material. Since, fabrication of self supporting zirconium targets attempted by S. Kalkal *et al.* [4] was unsuccessful. Therefore, we opted for preparing the targets with carbon backing.

Carbon films of various thickness in the range 20-75 μg/cm^2 were prepared in diffusion pump based coating unit. Silver paste was applied around the edges of carbon films to avoid furling of films and for better conduction of heat during zirconium evaporation. Finally, these films were transferred in cryo pump based coating unit in which deposition of natural as well as enriched zirconium material was carried out. This technique could not give successful results with natural Zr (metal) and ZrO_2 (powder).

Direct evaporation of natural Zr and ZrO_2 was carried out on 20 μg/cm^2 annealed carbon slides respectively which has given better and consistent results. Hence, enriched ^{92}Zr and $^{96}ZrO_2$ was deposited directly over carbon slides [1]. After deposition, these slides were kept for annealing at 325^{0}C for 1 hr in Ar/N$_2$ atmosphere and then floated and mounted on target frames. It was observed that most of the targets started furling and ruptured after few seconds of mounting. Silver paste was also

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used to prevent furling, but rupture of targets could not be avoided. Moreover, it was observed that targets of ^{92}Zr which were left intact could not sustain the intense ^{28}Si beam and ruptured during experiment. The behavior of isotopically enriched Zr was found completely different from natural.

To protect the targets, it was decided to increase the thickness of backing film and provide a thin layer of carbon capping. Keeping similar settings, deposition of natural Zr was successfully achieved on 35 μg/cm^2 carbon backing and with 4 μg/cm^2 carbon capping. However, during evaporation of enriched material of ^{92}Zr, carbon started peeling off from the glass slides, hence zirconium evaporation had to be stopped midway and slides were covered with a 4 μg/cm^2 layer of carbon without disturbing the vacuum. When these films were floated and mounted on frames, it was observed that targets had again ruptured. Therefore, some of the targets were mounted on frames of smaller area (5 mm diameter). After several attempts, targets of thickness around 160 μg/cm^2 were prepared.

Characterization

In order to check the impurities of other elements present in the targets, Rutherford backscattering (RBS) measurements were carried out. Results are shown in FIG. 1. In the spectrum of natural Zr, small peaks of carbon, oxygen and barium were present along with zirconium. The carbon peak was observed due to the carbon backing and capping films. Barium peak may appear due to the parting agent $BaCl_2$ and oxygen peak is present as a result of oxidation of films. Thickness measurement was performed with Alpha energy loss method as well as Stylus profilometer [5]. Since deposition was stopped midway, thickness of Zr was found to be slightly less ($\sim$160 μg/cm^2).

Conclusion

Behavior of natural Zr was found to be entirely different from the isotopic enriched ^{92}Zr and $^{96}ZrO_2$. Thicker carbon backing (35 μg/cm^2) could not sustain the deposition of isotopic ^{92}Zr till the end. Moreover, no significant improvement was observed due to carbon capping. Thickness of prepared targets was found to be around 160 μg/cm^2.

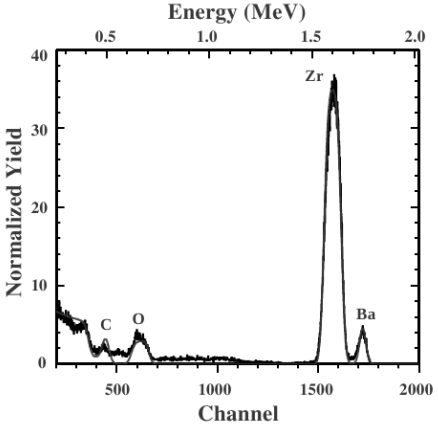

FIG. 1: RBS spectrum of natural Zr target.

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