ANL/PHY/CP-103548

Isotopic Germanium Targets for High Beam Current Applications at GAMMASPHERE*

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Abstract. The creation of a specific heavy ion residue via heavy ion fusion can usually be achieved through a number of beam and target combinations. Sometimes it is necessary to choose combinations with rare beams and/or difficult targets in order to achieve the physics goals of an experiment. A case in point was a recent experiment to produce ^{152}Dy at very high spins and low excitation energy with detection of the residue in a recoil mass analyzer. Both to create the nucleus cold and with a small recoil-cone so that the efficiency of the mass analyzer would be high, it was necessary to use the ^{80}Se on ^{76}Ge reaction rather than the standard ^{48}Ca on ^{108}Pd reaction. Because the recoil velocity of the ^{152}Dy residues was very high using this symmetric reaction (5% v/c), it was furthermore necessary to use a stack of two thin targets to reduce the Doppler broadening. Germanium targets are fragile and do not withstand high beam currents, therefore the ^{76}Ge target stacks were mounted on a rotating target wheel. A description of the ^{76}Ge target stack preparation will be presented and the target performance described.

1. Introduction and Motivation

In order to search for hyperdeformation as well as linking transitions from superdeformed bands in the mass 150 region, an investigation of the decay quasi-continuum γ rays in the nuclei ^{151,152}Dy was needed. Sufficient statistics were required to extract and determine the character of the decay out as well as γ rays emitted while the nucleus is potentially hyperdeformed. This was accomplished using the reaction ^{76}Ge(^{80}Se,5n|4n)$^{151|152}$Dy and GAMMA-SPHERE [1] with the Fragment Mass Analyzer (FMA) [2]. The ATLAS accelerator was used to provide as much beam on target as allowed by the counting rates in GAMMASPHERE. Earlier experiments with fixed targets showed severe target damage due to re-crystallization which prompted the use of a rotating ^{76}Ge target wheel. Thin targets were needed to reduce the amount of Doppler broadening observed in the emitted γ rays. The 400 μg/cm^2 thickness of the ^{76}Ge target was chosen to reduce the number of normal decay γ rays in the decay out region in ^{151,152}Dy by taking advantage of isomers in the nuclei. To further optimize the experiment, a double stack of 400 μg/cm^2 ^{76}Ge targets was employed. This stacking of targets is a common experimental technique to reduce Doppler broadening without reducing yield, however it has never before been attempted with target wheels rotating at 600 RPM.

*Work supported by the U.S. Department of Energy, Nuclear Physics Division, contract No. W-31-109-ENG-38.

The crystalline nature of elemental germanium is a challenge for the production of freestanding foils for use in experiments with heavy-ion beams. Many techniques are available including centrifugation, vaporization using electron bombardment, and deposition employing electron beam or focused ion beam sources. A detailed listing of the various methods for the preparation of germanium films has been given by Meens and Ehret [3]. For our purposes, we employed vacuum deposition using a multi-pocket electron beam source of 270° geometry [4].

2. Germanium Targets

The ^{76}Ge separated isotope needed for the targets was obtained as an oxide from Oak Ridge National Laboratory (ORNL) and had an enrichment of 92.82%. The oxide was reduced to the metallic form using a hydrogen furnace [5,6]. The deposition was carried out using an electron beam source onto standard microscope slides, as described by Meens and Ehret [3]. The slides were first coated with NaCl as a parting agent immediately beforehand, using the same source. Although Ramsay [7], recommends BaCl as the optimum substrate for germanium film growth, we experienced difficulty with release of the foils using this salt. The source to substrate distance was 10 cm. The glass slides were heated to approximately 215 °C using a quartz lamp. This temperature was arrived at empirically from previous preparations of Ge targets. The pressure within the evaporator was 2 x 10^{-6} torr, provided by a cryopump. The ^{76}Ge films were then

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floated off and eight quadrant targets were prepared with thicknesses of 300-400 μg/cm^2, enough for one double stacked target wheel.

3. GAMMASPHERE Target Wheel

In order to withstand the high beam currents necessary for the experiment, the targets were prepared as a rotating target wheel. The GAMMASPHERE target wheel was developed for use with volatile or low melting point target materials and has been described previously [8,9]. The targets were mounted on four quadrant frames, each with an open area of 2.62 cm^2. This allows for the higher beam power to be dissipated over a larger area. With the addition of beam wobbling in the vertical direction, so as not to degrade the mass resolution of the FMA, the power per unit area deposited in the target is substantially reduced, thus lowering the temperature within the target. As can be shown from previous calculations [10], the calculated power per unit area deposited in the rotating wheel target for the 314 MeV ^{80}Se beam with a current of 5 pnA was 7.15 mW/cm^2. This translates to a temperature within the target of about 99° C. This is to be compared with a calculated temperature of 488° C for a non-rotating target. In Figure 1, a plot of the time dependence of the heating within the target is given for the first 10 revolutions of the wheel. This heating from the beam would remain well below the melting point of 938.3° C for germanium, thus avoiding loss of target material and increasing the target lifetime.

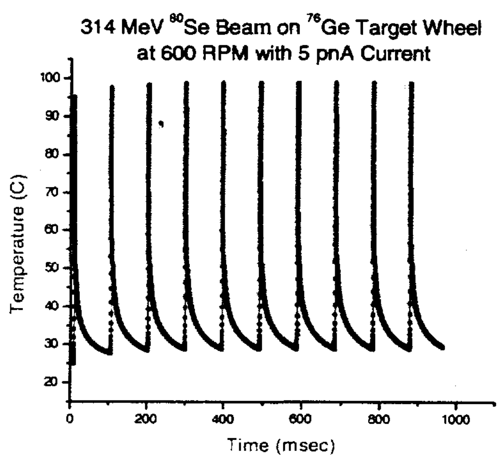

FIGURE 1. Plot of Temperature vs. Time showing the time dependence of the target heating over the first 10 revolutions of the target wheel.

4. Results and Conclusion

In conclusion, the preparation of isotopic germanium target wheels for GAMMASPHERE proved crucial to the success of the experiment. A double stack of 300-400 μg/cm^2 ^{76}Ge foils, prepared for a rotating target wheel, provided sufficient ^{151,152}Dy reactions for the experiment and withstood 314 MeV ^{80}Se beam currents of 5 pnA for six days of running. Examination of the target wheels after irradiation revealed severe damage due to re-crystallization within the foil, particularly for the front foil stack, facing the beam. The re-crystallization temperature for germanium occurs somewhere between 90° and 454° C which would indicate that the target was exposed to a deposited beam power greater than that calculated. This suggests that the focused beam spot may be smaller than expected. A photograph is given in Figure 2 showing target quadrants before and after bombardment by the heavy ion beam.

Figure 2. Photograph of ^{76}Ge target wheel quadrants before and after bombardment by 5 pnA 314 MeV ^{80}Se beam showing damage due to recrystallization in the target.

Acknowledgments

The authors would like to thank Dr. Donald Geesaman, the Physics Division Director, and Dr. Irshad Ahmad, the Target Facility Group Leader, for their continuing encouragement and support of these efforts. This work is supported by the U.S. Department of Energy, Nuclear Physics Division, under Contract No.W-31-109-Eng-38.

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