Preparation and Characterization of Implanted Targets of ^{16}O and ^{24}Mg for Nuclear Astrophysics experiments

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Introduction

Most nuclear reactions relevant to astrophysical scenario have very low cross sections (~pico barn). The precision of their measurements requires isotopically pure targets and contamination free backing, which can stand high beam-current for long period without deterioration. Ion implantation technique offers the potential to produce such targets.

Earlier studies for hydrogen burning of ^{24}Mg at low stellar temperatures suggest that the total widths of the low energy resonances have a significant influence on the reaction rates [1]. These widths are related to the lifetimes of the states, mostly suitable to be measured through Doppler shift attenuation (DSA) method with implanted targets [2]. It is quite difficult to produce a Mg target without Oxygen impurity. Thus, to delineate the effect of this impurity, similar study of an oxygen only target may be useful.

In this work, we have discussed preparation of ^{24}Mg as well as ^{16}O implanted targets. Both high and low Z backings were utilized. Low Z backing targets were prepared to have advantages in Rutherford backscattering measurements.

Simulations

In order to make isotopically pure implanted targets with reasonable thickness, we need to choose backing material and implantation energy properly.

The backing materials should satisfy the following criteria; a) it should make stable compound with the implanted ions at room temperature, b) the materials should have a high saturation value and low sputtering yield for the implanted ions and c) it must have low β^+ activity for proton induced reactions [2].

We have selected some backing materials and have calculated the saturation and sputtering yields due to implantation of ^{16}O and ^{24}Mg ions using SRIM-2008 code [3]. The variations of sputter yields for different backing elements are shown in Fig 1. We have found Ta as well as Carbon show low sputtering yields resulting in a stable configuration for both the ion species. We have chosen Ta backing (thickness ~ 0.3 mm) to implant ^{16}O. On the other hand, ^{24}Mg ions are implanted on a thin (< 0.1 mm) C backing.

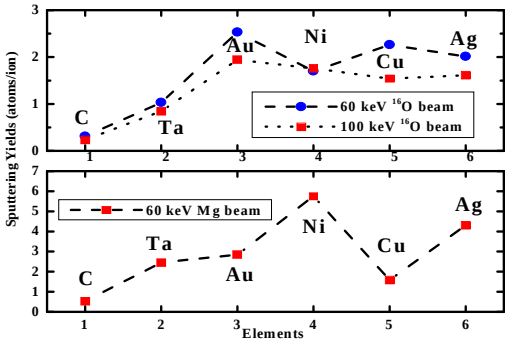

Fig 1 Variation of sputter yields of Mg and O ion implanted in different backing materials.

Target Preparation

The targets were prepared using a low energy negative ion implanter facility at IUAC, New Delhi. The facility is equipped with a sputter based negative ion source, namely, MC-SNICS (Multi Cathode Source of Negative Ion by Cesium Sputtering) placed on a high voltage platform (200 kV) for generating negative ion beams [4].

Dual energy implantations were done with ^{16}O ions of 60 and 100 keV energies. At first ^{16}O

ions with lower energy were implanted, which was followed by high energy one. The implantation doses (0.87×10^{15} atoms/cm^2 for 60 keV ions and 1.07×10^{15} atoms/cm^2 for 100 keV ions) were selected so that the target thickness becomes nearly uniform [5].

On the other hand, single energy (60 keV) implantation has been done to prepare ^{24}Mg target. The Mg ion source contained Magnesium in oxide form, thus we have chosen 100 keV implantation energy so that according to mass ratio the ^{24}Mg ions were implanted with 60 keV energy.

Characterization

• Backing

Any contamination in the backing material needs to be identified. Thus, elemental analysis of the backing materials has been done using energy dispersive X-ray fluorescence (XRF) technique using a 4 W MAGNUM X-ray source and X-ray detection system. The Ta backing before and after implantation of ^{16}O has been tested to ensure the absence of any other high Z elements as impurity.

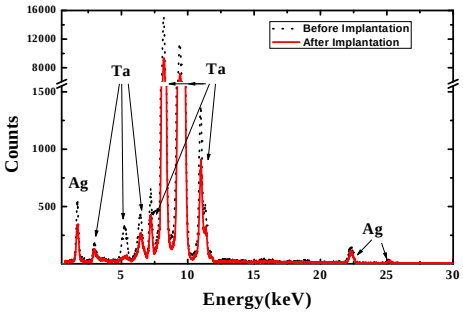

Fig 2 XRF spectra of Ta backing.

Fig 2 clearly shows that there is no high Z contamination in the backing (the Ag lines in the XRF spectra are coming from the X-ray source).

• Target

To get accurate information about the elemental composition of the implanted targets we have utilized Rutherford Backscattering Spectroscopy (RBS) technique, an ion beam based analytical technique, using 5SDH-1.7MV Tandem accelerator at Pelletron Accelerator for RBS-AMS System (PARAS) at IUAC, New Delhi [6]. He^{++} beam at 3056 keV was bombarded on the targets and backscattered ions were detected at 166^o by silicon surface barrier detector subtending a solid angle of ~3.6 msr. For the ^{24}Mg (carbon backed) and ^{16}O (Ta backed) targets, 12 µC and 5 µC charges, respectively, were collected. Fig 3 shows the RBS spectra for the two targets. This result provides us information about the stoichiometry of the targets.

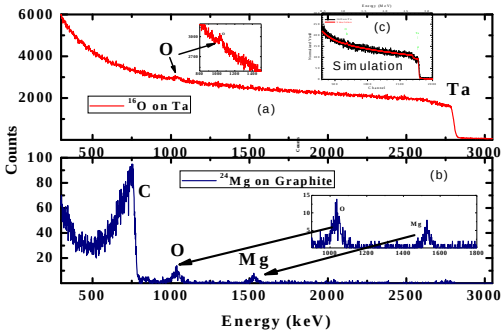

Fig 3 RBS spectra of targets of (a)^{16}O, (b)^{24}Mg and (c) comparison with simulation.

Conclusions

Isotopically pure ^{16}O and ^{24}Mg targets have been prepared using implantation technique. The stoichiometry of the targets is determined from RBS analysis. RBS spectrum also indicated the presence of oxygen in the ^{24}Mg target, which is due to the oxidized ion source. XRF analysis confirms that no other higher Z elements are present in the Ta substrate.

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