Preparation and Characterization of a ^{22}Ne implanted target

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Introduction

Studies of nuclear reactions relevant to astrophysical scenario often require measurement of crosssection in picobarn to nano-barn range (1 barn = 10^{-24} cm^2) [1]. So we need targets that are extremely pure isotopically and can withstand high beam load over a long time. Even the backings used should contain no or very low concentration of impurities. Implantation technique has been found to be one of the most effective methods to produce such targets [2].

The ^{22}Ne(p,γ)^{23}Na is one of the important reactions in NeNa cycle. This cycle is not so important for the energy generation of the stars, because the Coulomb barrier is relatively higher in this reaction. However this cycle along with MgAl cycle has some role in the synthesis of elements between ^{20}Ne and ^{27}Al. It is known [3] that ^{22}Ne(α,n) ^{25}Mg is the most favored neutron source of the s-process. In natural Neon, ^{20}Ne and ^{22}Ne have 90.28% & 9.25% abundances, respectively. So implantation may be a suitable technique to produce isotopically pure ^{22}Ne target to pursue relevant measurements.

The isotopic purity of an implanted target depends on the mass resolution of ion beam delivered by the implanter. We have already reported characterisation of a ^{14}N-implanted target [4], where we could not quantitative estimate the amount of ^{15}N (natural abundance 0.364%) impurity implanted with ^{14}N ion.

In the present work, we shall discuss the preparation and characterisation of the surface properties of ^{22}Ne implanted target and estimate the mass resolution of the mass separator.

Requirements

Backing material, energy and charge state of the ions should be chosen judiciously for preparation of an isotopically pure implanted target that will be able to bear high beam load. The choice of the backing material should satisfy a few requirements. It should make stable compound with the implanted ions at room temperature. The material should have a high saturation value and a low sputtering yield for the implanted ions. It must have low β^+ activity for proton-induced reaction.

We have selected few backing materials and calculated their sputtering yields as a function of implanted ^{22}Ne ion energy using SRIM-2008 code [5]. The saturation values of ^{22}Ne ion implantation into these materials have been taken from Ref. [6]. The variations of sputter yield for different elements are shown in Fig. 1.

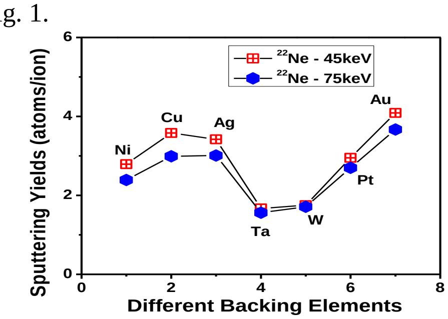

Fig. 1 Variation of sputter yields of Ne ion implanted in different backing materials.

Tantalum (Ta) was chosen to be the backing material in the present work as it has small sputter yields and high saturation value for Ne implantation. Comparing the ion distribution curves generated by TRIM calculation [5] at different ion energies, the energy of the implanted ions has been chosen.

Target preparation

The target was implanted at Tata Institute of Fundamental Research, Mumbai, using an ECR based 400 kV small accelerator. A 0.05 mm thick Tantalum foil was used as a backing. No special treatment was undertaken to reduce contaminants in the foil. High purity Ne gas was used in ECR ion source to produce high intensity Ne ion beam. ^{22}Ne ions have to be separated from the incoming ions to prepare an isotopically enriched ^{22}Ne implanted target. A 0.3 Tesla dipole magnet was used to separate the incoming Ne ions according to m/q ratio. The abundances of ^{20}Ne and ^{22}Ne with different charge states were plotted as function of their m/q ratios (Fig. 2) by scanning the ion beams through wide range of magnetic field. The calculated value of mass resolution (m/Δm) of the separator, where m and Δm are the centroid and FWHM of ^{20}Ne-2^{+} peak, comes out be ~60 (Fig. 2). The mass resolution of the mass separator is very important because this is useful to estimate the amount of other isotopes in along with the implanted isotope of interest.

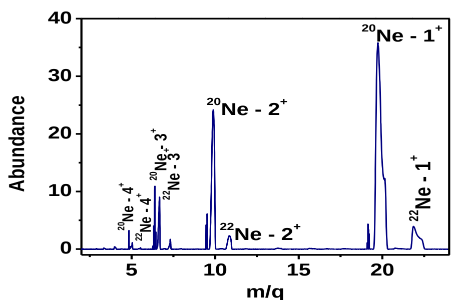

Fig. 2 Abundances of different isotopes of Ne after 90^{o} dipole magnet as a function of m/q.

The beam current of ^{22}Ne for each charge state was estimated by changing the magnetic field. Finally 75 keV ^{22}Ne ions with 2^{+} charge state have been selected for the implantation. Implanted dose was 1×10^{17} atoms/ cm^{2}. The beam was scanned on the target to ensure a uniform circular implantation area of diameter of around 1.5 cm.

Target Characterization

The projected range of 75 keV ^{22}Ne in Ta is 57.6 nm. To start with, we have utilized X-ray photoelectron spectroscopy (XPS) to detect presence of elements as low as Boron (B) from the few nm (≤ 10nm) depth of the material surface. XPS is a quantitative spectroscopic technique to measure the elemental composition of the material surface. In this technique, electron spectra providing the numbers of electrons as a function of their kinetic energy are obtained by irradiating a material with a beam of X-rays. The experimental XPS spectrum with incident 1253.7 eV (Mg - K_{α}) X-ray is shown in Fig. 3. In the figure, the electron kinetic energy is converted to the binding energy of the electron orbital from which it is liberated. Although, oxygen and carbon impurities are observed, unlike in ^{14}N implanted target [4], absence of fluorine and sodium was noticeable.

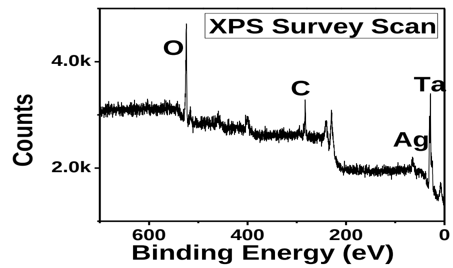

Fig. 3 XPS spectrum for ^{22}Ne-implanted target indicates the presence of impurity on target surface.

Conclusion

A ^{22}Ne-implanted target has been prepared. The mass resolution of the dipole magnet in the implanter has been estimated. XPS analysis helped us to estimate the amount of the impurities present on the target surface. In future we plan to investigate ^{22}Ne distribution in the bulk of the material by using Rutherford Back Scattering spectroscopy or resonance reactions.

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