Production and characterisation of ^{14}N implanted target

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Introduction

Studies of nuclear reactions relevant to astrophysical scenario, often require measurement of cross section in picobarn to nano-barn range (1 barn = 10^{-24} cm^2) [1]. So we need targets which 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. Implanation technique has been found to be one of the most effective methods to produce such targets [2].

The $^{14}N(p,\gamma)^{15}O$, being the slowest reaction in the hydrogen burning CNO cycle [1], controls energy generation in it. But measurement of the cross-section of this reaction is hampered by the $^{15}N(p,\alpha\gamma)^{12}C$ background reaction with ^{15}N impurity in the target. The ^{14}N implanted targets have a ^{15}N depletion of about two orders of magnitude [2]. In the present work, we shall discuss the preparation and characterisation of primarily the surface properties of a ^{14}N implanted target.

Experiments, Results and Discussion

The stability of the implanted targets depend on the backing element. If the atoms of the backing material sputter out during implantation, it reduces target stability. We have calculated the sputtering yields of Au and Ta as a function of implanted ^{14}N ion energy using SRIM-2008 code [3]. This simulation shows (Fig.1) that the sputter yield for Au backing is much higher (almost three
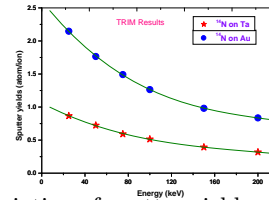
FIG. 1: Variation of sputter yields with energy for two different backing (Au & Ta).

times) than Ta backing for the same implanted dose and energy of ^{14}N ions. The implantation energy has been chosen from the ion distribution curves generated by TRIM calculation at different ion energies.

A 0.3mm thick Tantalum foil was used as a backing. No special treatment of the foil was undertaken to reduce contaminants in the foil. 75 keV ^{14}N ions with 3^+ charge state from an ECR ion source at Tata Institute of Fundamental Research, Mumbai was implanted on it. Implanted dose was 2.2×10^{16} atoms/ cm^2. The beam was scanned on the target to ensure a uniform circular implantation area of diameter of around 2 cm. The projected range of 75 keV ^{14}N in Ta is 57 nm. But to start with we have utilised X-ray photoelectron spectroscopy (XPS), Raman spectroscopy and scanning electron microscopy (SEM) along with energy dispersive X-ray spectrometry (EDX) to detect presence of elements as low as Boron (B) from the few nm ($\leq 10nm$) 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 number 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
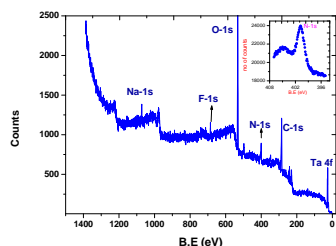
FIG. 2: XPS spectrum for ^{14}N implanted target. The peak corresponding to nitrogen is shown in the inset.

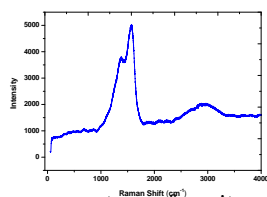

FIG. 3: Raman spectrum for nitrogen implanted target (Ta backing) with 75 keV implantation energy.

incident 1486.6 eV (Al K_α) X-ray is shown in Fig. 2. In the figure, the electron kinetic energy is converted to the binding energy of the electron orbital from which it is liberated. After comparing the observed peaks in the spectrum with the reference values compiled by NIST database [4] concentrations of C (40%), O (37%), N (6%), Na (7%), F (6%) and Ta (4%) have been obtained. These elements are present in pure forms or as compounds. We found that 15.53% Ta is present as metallic Ta and remaining 84.47% Ta is existing as Ta_2O_5. So it is apparent that special efforts should be taken to produce oxygen and carbon -reduced implanted targets [2].

The experimental spectrum of Raman shift for the implanted metallic target with incident 488 nm monochromatic polarized laser light is shown in Fig. 3. For this laser source, the skin depth of metallic Ta is 7.45 nm. The spectrum clearly indicates the presence of nitrogen in this depth region. We have also measured the photo luminance (PL) yields at different positions on the target to find the nitrogen concentration distribution.

In order to investigate the effect of implantation on the surface of the target, a pure Ta sheet, and an irradiated Ta sheet were charac-terized using the scanning electron microscope (SEM). As expected, the pure sheet showed smoother surface. Implantation of energetic nitrogen resulted in unevenness in the surface. Unfortunately, the EDX studies showed no evidence of nitrogen. This was due to the fact that the nitrogen in the present sample was with atomic fraction of 0.04%, but EDX is sensitive to atomic fraction $\geq$ 0.1%.

Conclusion

An implanted target has been prepared and its surface morphology has been characterized. Investigations with SEM and EDX are being done and the results will be compared and combined with XPS and Raman data for a firm conclusion. Results obtained so far indicate presence of low Z impurities like carbon and oxygen. So special efforts are needed to reduce them. By these measurements, we could study only the surface (target depth $\simeq$ 1 to 10 nm) of the target. So in future we plan to investigate nitrogen distribution in the bulk of the material by using Rutherford Back Scattering spectroscopy or resonance reactions. Effort will be made to extract quantitative estimation of ^{15}N impurity present in these targets.

Acknowledgments

References

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