Bulk characterization of ^{14}N implanted target using Resonance reaction and SIMS measurements

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Introduction

Implantation technique has been found to be one of the most effective methods to produce targets which are isotopically pure and can withstand high beam load over a long time [1,2]. To use these targets in Nuclear Physics or Nuclear Astrophysics experiments, the distribution profile of implanted ions in the backing should be known precisely. This profile depends on the type of implanted ion, the backing material, the implantation energy and the implantation dose. It is also important to identify the impurities present at different depths of backing material and quantify them accordingly.

The ^{14}N(p,γ)^{15}O, being the slowest reaction in the hydrogen burning CNO cycle [1], controls the energy generation in it. But measurement of the cross-section of this reaction is hampered by the ^{15}N(p,α)^{12}C background reaction with ^{15}N impurity in the target. It was found that the ^{14}N implanted targets have a ^{15}N depletion of about two orders of magnitude [2].

A ^{14}N implanted target with Ta backing has been prepared by using 75 keV ^{14}N^{3+} ions from an ECR ion source at Tata Institute of Fundamental Research (TIFR), Mumbai. Surface characterization of this target has been done using the existing facilities at Saha Institute of Nuclear Physics, Kolkata We have already reported the preparation and surface characterization of this implanted target [3]. In the present work, we shall discuss about the bulk characterization of the ^{14}N implanted target by nuclear resonance reaction and Secondary ion mass spectrometry (SIMS) measurement.

Experiment, Results and Discussions

(a) **Nuclear resonance reaction:** Nuclear Resonance Analysis (NRA) using a narrow and well-separated resonance is an excellent tool to determine the thickness and uniformity of an implanted target. Apart from that if the level energy, the resonance width and its strength are well known, then it also allows us to determine the total number of implanted ions inside the backing.
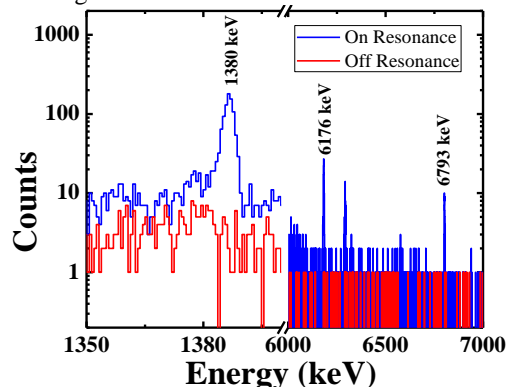

Fig.1 γ-ray spectra from ^{14}N(p,γ)^{15}O reaction for two different proton energies. The red and blue spectra correspond to E_p = 277 keV (off-resonance) and 280 keV (on-resonance) respectively. Transitions from ^{15}O are marked.

The bulk characterization of this implanted target has been done using ^{14}N(p,γ)^{15}O resonance reaction (Γ_{lab} = 1.115 keV [4]) at 278 keV. The proton beam was delivered from an ECR based 400 KV accelerator [5] at TIFR, Mumbai. The energy calibration of the accelerator has been done using ^{27}Al(p,γ)^{28}Si resonance reaction with 293 keV proton energy. The estimated energy spread of the ion beam was ~ 1 keV. One HPGe detector (30%) was placed at 0° with respect to beam line to measure the gamma rays emitted from excited ^{15}O (Fig-1). Two radioactive sources ^{152}Eu and ^{60}Co have been used to calibrate our detector. The distance between the

detector and the target chamber was 5 cm. The data have been taken in a 4 Channel 14 bit 100 MS/s Digitizer (N6724) developed by CEAN. During the experiment, beam intensities were between 7 and 15 μA.
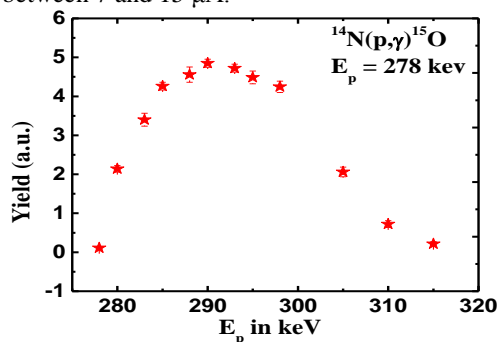

Fig-2: The distribution profile of ^{14}N ions in the Ta backing.

To get the depth profile of the implanted target, the energy of the proton beam (E_P) has been changed in steps of ~ 3-5 keV. The yields of gamma ray connecting the resonance state (7556 keV) to 6167 keV state in ^{15}O ($E\gamma$ = 1.380 MeV) for different E_P, were analyzed for this measurement. In this experiment, the target chamber itself was used as a Faraday cup and the yields have been normalized with total charge deposited in it. It gives us the yield distribution of implanted ions which is independent of beam intensities. The thickness of this target (23 ± 4 keV) was estimated by measuring the FWHM of the ion distribution. The ion distribution of ^{14}N inside Ta backing has also been compared with the results of TRIM simulation [6]. The implanted dose will be calculated from the yield distribution of the implanted ions.

(b) **Secondary ion mass spectrometry (SIMS) measurement:** Secondary ion mass spectrometry (SIMS) is a technique, used to analyze the composition of solid surfaces by sputtering the surface of the specimen with a focused primary ion beam. In our case, The SIMS measurement has been done specially to identify the impurities present inside the backing material and their yield distributions inside the backing material. From our earlier measurements [3], it was found that we have impurities like C, O, F and Na on the target surface. So in the present experiment, we mainly focused on these impurities. Fig. 3 shows the yield distributions of

these impurities with sputtering time which is basically proportional to the target depth. A 5 keV Cs ion was used to sputter the target surface. The beam current was 40 nA.
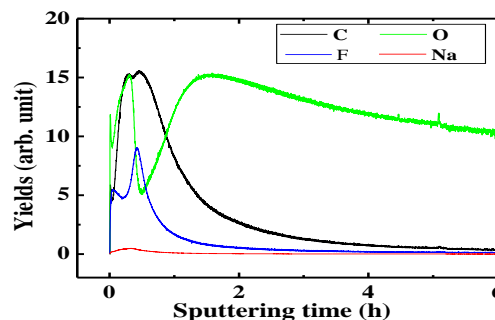

Fig. 3 Yields distributions of different impurities inside the backing material.

The result shows that the amount (proportional to the yield) of C, F and Na sharply decreased with time (i.e. depth). However, even after 6 hours of sputtering, large amount of Oxygen has been found inside the target. So before doing ion implantation, effort will be made to remove the Oxygen impurity from the backing material.

Acknowledgments

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