Characterization of ^{22}Ne implanted target by ^{22}Ne(p,γ)^{23}Na resonance reaction

Abhijit Bisoi[1], M. Saha Sarkar[1*], C.A. Desai[2], L.C. Tribedi[2], H. S. Jung[3], K. Setoodehnia[3], S. Lyons[3], J. Görres[3], Ed Stech[3], D. Robertson[3] and M. Wiescher[3]
[1]*Saha Institute of Nuclear Physics, Kolkata - 700064, INDIA*
[2]*Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*
[3]*Joint Institute for Nuclear Astrophysics, University of Notre Dame, Notre Dame, Indiana 46556, USA*
* *email: maitrayee.sahasarkar@saha.ac.in*

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 isotopically pure 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 depth profile of implanted ions into the backing depends on the type of implanted ion, the backing material, the implantation energy and the implantation dose. It is important to know the implanted ion distribution profile and the number of implanted ions inside the backing for its usage in an experiment where quantitative estimation of target thickness is needed.

The ^{22}Ne(p,γ)^{23}Na is an important reaction in NeNa cycle. This cycle is not so important for the energy generation of the star due to its relatively high Coulomb barrier. However, both NeNa and MgAl cycles are important for the nucleosynthesis of elements in between ^{20}Ne and ^{27}Al. Moreover, ^{22}Ne targets are also needed to study the ^{22}Ne(α,n)^{25}Mg reaction, which is the most favored neutron source of the s-process [3]. Thus preparation of a pure, enriched ^{22}Ne target is essential to study these reactions.

A ^{22}Ne implanted target (Target-1) has been prepared by using 75 keV ions from an ECR ion source at Tata Institute of Fundamental Research, Mumbai. Surface characterization of this target has been done using the XPS facility at Saha Institute of Nuclear Physics, Kolkata. We have already reported the preparation and surface characterization of this implanted target [4]. In the present work, we shall discuss about the bulk characterization of the same ^{22}Ne implanted target by resonance reaction.

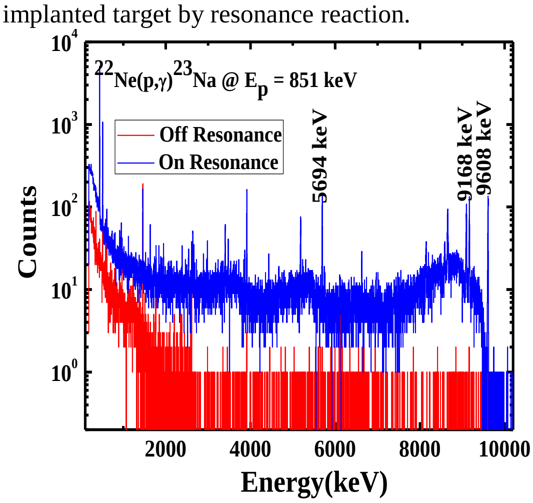

Fig.1 γ-ray spectra from ^{22}Ne(p,γ)^{23}Na reaction for two different proton energies. The red and blue spectra corresponds to E_p = 849.8 keV (off-resonance) and 852.7 keV (on-resonance) respectively. Transitions (branching > 10%) from the resonance state (9608 keV) are marked.

Experiment, Results and Discussion

Nuclear Resonance Analysis (NRA) using a narrow and well-separated resonance is an excellent tool to determine the thickness and uniformity of an implantation 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 no of implanted ions inside the backing.

The bulk characterization of this implanted target has been done using ^{22}Ne(p,γ)^{23}Na resonance reaction at 851 keV. The proton beam was delivered from a 5MV new accelerator at University of Notre Dame, USA. The energy calibration of the accelerator have been done using ^{27}Al(p, γ)^{28}Si resonance reaction for four different proton energies (E_P = 633, 992, 1317 and 1797 keV). The estimated energy spread of the ion beam was ~ ±150 eV. One large volume HPGe detector was placed at 0^{o} with respect to beam line to measure the gamma rays emitted from resonance state (Fig. 1). The detector was calibrated by using the γ-ray energies from ^{27}Al(p,γ)^{28}Si resonance reaction.

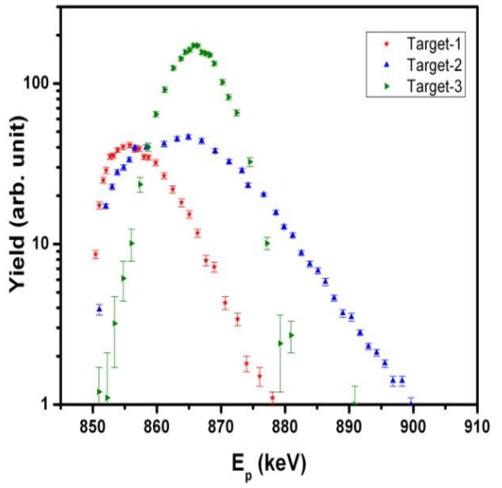

Fig.2 The distribution profiles of implanted Ne ions in three different targets.

The experiment was performed for two different distances between target and detector (0.2 cm and 25 cm) to see the summing effect as well as the effects due to the roughness of target surface. During the experiment, beam intensities were between 10 and 15 μA. To get the depth profile of the implanted target, the energy of the proton beam has been changed in a step of ~ 1 keV. The yield of gamma ray connecting the resonance state to ground state of ^{23}Na (Eγ = 9.608 MeV) was analyzed for this measurement. The thickness of this target was estimated by measuring the FWHM of the ion distribution. The amount of implanted ions present inside the backing have been estimated by comparing our results with other two ^{22}Ne implanted targets prepared at Germany. They had the same implantation energy (150 keV). However, the ions were implanted into two different backing materials, Tantalum (Target-2) and Beryllium (Target-3) respectively. The ion distributions of these targets have also been measured in this experiment. The distribution profiles of Ne ions in these three targets have been shown in Fig.2. For the Beryllium backing target, the exact amount of implanted ions was already known from RBS measurement. So the comparison of yields distributions of these targets helped us to estimate the number of implanted ions in our target. The results of these measurements have been shown in Table 1.

Table 1: Comparison between three different ^{22}Ne implanted targets.

Target	Backing material	Ion energy (keV)	Target thickness (keV)	Implanted dose 10^{17} ion/cm^2
1	Ta	75	11.65(15)	0.86(4)
2	Ta	150	21.66(28)	1.74(9)
3	Be	150	10.15(9)	3.28(16)

The target thickness in terms of μg/cm^2 unit has been obtained from the FWHM of the distribution profile (Fig. 2) by considering the stoichiometry of the implanted ions in the backing and the stopping power of these ions inside the target material. The ion distribution of ^{22}Ne inside Ta backing has also been compared with results of TRIM simulation [5].

Acknowledgments

One of the authors (A.B.) acknowledges CSIR and JINA for financial support.

References

[1] C. Rolfs and W S Rodney, Cauldrons in the Cosmos (University of Chicago Press) 1988.
[2] S. Seuthe et. al, Nucl. Instr. and Meth. A **260**, 33 (1987); H.Y. Lee et. al, Nucl. Instr. andMeth. B **267**, 3539 (2009); J. Cruz et. al, Nucl. Instr. and Meth. B **267**, 478 (2009); T.A.D. Brown et. al, Nucl. Instr. and Meth. B **267**, 3302 (2009).
[3] C Rolfs, H.P Trautvetter and W.S. Rodney, Rep. Progr. Phys . **50**, 233 (1987).
[4]Abhijit Bisoi et. al., DAE Symp. Nucl. Phys. **57**, 902(2012).
[5] James F. Ziegler,http://www.srim.org