Characterization of X-ray detection system and its application in the search of contaminations in nuclear astrophysics targets

Arkabrata Gupta[1], Gourav Saha[1], S. Sarkar[1] and Abhijit Bisoi[1*]
[1]*Indian Institute of Engineering Science and Technology, Shibpur, Howrah - 711103, INDIA*
* *Email:* abijitbisoi@gmail.com

Introduction

Nuclear processes take a major role in stellar evolution. Thus nuclear reaction rates and nuclear properties are essential ingredients to look for most of the important questions in astrophysics. To extract these information, direct measurement of astrophysical important reactions with high accuracy and precision is required [1]. However at low energies relevant for astrophysical situations, these measurements are very difficult to perform due to their low reaction cross section. It is of the order of nano-barn to pico-barn. Thus we need background radiation free environment to perform these experiments. These backgrounds may be coming from the environment or from the target i.e reaction induced background. With proper shielding we can reduce only the environmental background [2] but in order to reduce the reaction induced background, proper characterization of target is needed. Therefore, preparation and characterization of target is very important for nuclear astrophysics experiment. We have already prepared two implanted targets (^{14}N and ^{22}Ne) and characterized them (both surface and bulk) using X-ray photo electron spectroscopy (XPS), Scanning electron microscope (SEM), Rutherford backscattering Spectroscopy (RBS) and nuclear resonance reaction [3]. It can also be possible to characterize the target surface by detecting the characteristic X-ray emitted from the excited target atom. These atoms can be excited by bombarding charge particles, X-rays or gamma rays. In our laboratory we have procured an X ray source and a X-ray detection system from Moxtek, USA. Our primary motivation is to use this set up to characterize our targets to be used in nuclear astrophysics experiments. In this present work, we have tested the performance of the detector for different shaping time, system dead time. We have also performed some elemental analysis using known sample to validate our system.

Experimental set-up

Our experimental set up consists of a 4 W MAGNUM X ray source, a Si-pin diode detector and a digital pulse processor (DPP). A schematic representation of our set up is shown in Fig-1. The X-ray tube has Silver (Ag) anode and the tube window is made of 0.25 mm Berulliym. The maximum tube current is 200 µA and the tube voltage can be increased from 4 kV to 50kV. The Si pin diode detector has 25 µm thick DuraBeryllium window. The thickness and the active area of the diode is 625µm and 6 mm^2 respectively. There is a two stage of thermo electric cooling system to operate the detector at a temperature of -25^{o}C. The data has been taken using MXDPP50 digital pulse processor. It includes an integrated 4k channel MCA, detector temperature controller and detector power supply. It can acquire data from 1 ms to 49 days. All the parameters in the digitizer, the detector and the x-ray tube are controlled by SinerX software.

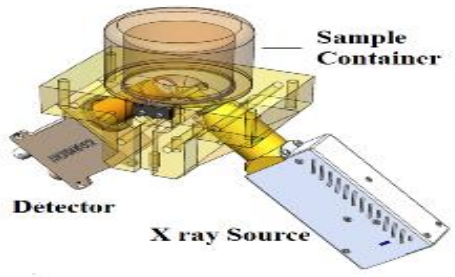

Fig-1: **Schematic diagram of the detection system**.

Results and Discussion

The quality of the spectrum recorded by the detector depends on several parameters but mostly on shaping time and dead time of the detection system which depends on the tube current (Fig-2). In the present work, we have measured the detector resolution for different

shaping time and system dead time. We have used a silver coin as our target and measured the resolution of 22.16 keV K_α line of Ag (Fig-3).

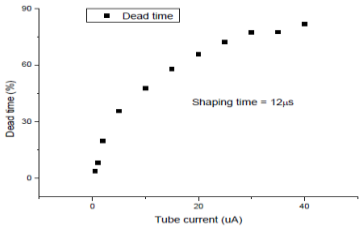

Fig-2: Variation of dead time with tube current.

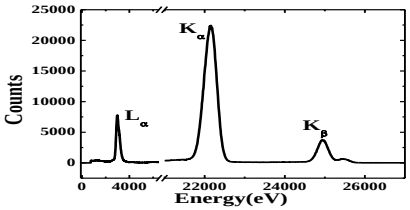

Fig-3: **Spectrum of Ag target.**

The data have been taken in SinerX and analyzed them using the analyzing program NSCTSK. In order to find out the dependency of shaping time and dead time on detector resolution, we have taken two set of data. In the first case, keeping the shaping time constant, we vary the tube current and measured the resolution of 22.16 keV for each tube current. Then we have repeated the experiment for five different shaping time. The results are shown in Fig-4.

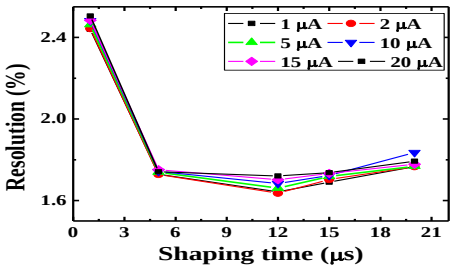

Fig4: Variation of resolution with shaping time.

It shows that the resolution improves for higher shaping time up to 12 μs but after that it increases due to the higher system dead time. It has the minimum value at 12 μs shaping time and 2 μA tube current. We have also investigated the peak to total ratio for these variations.

Finally, we have estimated the elemental concentration of a few known samples (SS316, Brass-385 etc.) using 12 μs shaping time and 2 μA tube current (Fig-5). The detector has been calibrated using Cu and Ag targets.

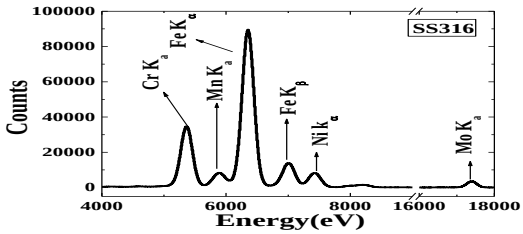

Fig-5: **Spectrum of SS316**.

The analysis has been carried out using SinerX. Elemental concentrations of these samples are then compared with the reference values [4] as shown in Table-1 to validate our measurement. The results show good agreement with the reference values. Some disagreements may be due to sample impurities.

Table-1: **Concentration of SS316 and Brass-385.**

Concentration in % [ref. values are shown in bracket]	
SS316	Brass-385
Mo -8(3), Ni-9(12), Fe-64 (65), Cr-16 (17), Mn-2 (2)	Cu-55 (58), Pb-4 (4), Zn-41 (38)

We are now planning to characterize some targets which will be used for low energy proton induced reaction study. These targets will be prepared by ion implantation or evaporation method.

The authors acknowledge Prof. M. Saha Sarkar, SINP, Kolkata for her fruitful suggestions and encouragement. One of the authors (A. Gupta) thanks DST-INSPIRE for financial support (Reg.No.IF160297).

References

[1] A. E. Champagne et.al. ; AIP Advances 4, 041006(2014).
[2] M. Saha Sarkar et al., Proceedings of the DAE symposium on Nucl. Phys. 61,1022(2016).
[3] A. Bisoi et al., Proceedings of the DAE symposium on Nucl. Phys. 55, 732(2010); A. Bisoi et al., ibid 57, 902(2012); A. Bisoi et al., ibid 58, 934(2013).
[4] http://www.espimetal.com; https://www.azom.com