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Construction and Evaluation of X-ray Detection and Analysis System for the External PIXE at KOMAC

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1. Introduction

Particle induced X-ray emission or proton induced X-ray emission (PIXE) is an analytical method which is the measurement of characteristic X-rays emitted from a target sample due to the irradiation of a high energy ion beam (typically 1-2 MeV of H or He) [1]. PIXE can identify various constituents up to ppm (parts per million) composition in the target sample non-destructively, precisely, and quantitatively [2]. Micro-element analysis based on a PIXE system has a detection limit orders of magnitude lower than can be attainable by X-ray spectrometry techniques using electron excitation such as X-ray fluorescence (detection limit of XRF: ~200 ppm). Under favorable conditions, a detection limit ~1 ppm for thin foils and ~10 ppm for thick samples can be achieved [3]. Therefore, the PIXE analysis system has been successfully applied to solving problems in various fields, including corrosion and oxidation, semi-conductors, metallurgy, thin films, geoscience, air pollution and atmospheric science, biology, medicine, art, archaeology, water analysis, and forensic science [4-6]. However, since the measurement of characteristic X-rays of the target samples through the conventional PIXE system was carried out under vacuum conditions, the replacement time of target samples was long and the analysis of specific samples such as liquid, powder, and bulky one like cultural properties was difficult, and furthermore, it is possible to damage the target samples by the irradiation heat of particle beam because the cooling system was hard to install in a narrow vacuum chamber [7]. On the other hand, an external PIXE system using an extracted particle or proton beam into air can easily solve the problems of conventional PIXE due to its features, and therefore, recently, various types of external PIXE analysis systems have been actively developed [8].

Here, we present construction and evaluation of X-ray detection and analysis system for the external PIXE of the 1.7 MV tandem accelerate at Korea Multi-purpose Accelerator Complex (KOMAC).

2. Methods and Results

In this section, the detailed procedures of construction and evaluation of X-ray detection and analysis system for the external PIXE at KOMAC are described.

2.1 1.7 MV Tandem Accelerator

The 1.7 MV tandem accelerator (S5DH-1, NEC) at KOMAC is schematically and optically displayed in Figure 1. The accelerator voltage is 0.1 ~ 1.7 MV (voltage stability: < 1 kV) and maximum energy and beam current of proton beam are 3.4 MeV and 10 μA, respectively. The low energy part of 1.7 MV tandem accelerator was composed of ion source (source of negative ions by cesium sputtering; SNICS), buncher, and tandem accelerator tank as shown in Fig. 1a. There are 4 beamlines such as implantation for ion insertion into materials (-30 degree of main beam line of tandem accelerator), Rutherford back-scattering (RBS)/elastic recoil detection (ERD) for composition and depth profile for samples (-15 degree), neutron for standard mono-energy neutron source (0 degree), and PIXE for analysis of microelements (+15 degree).

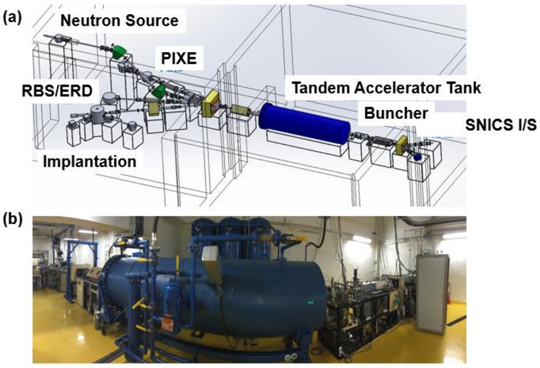

Fig. 1. (a) Schematic and (b) optical image of the 1.7 MV tandem accelerator at KOMAC.

2.2 X-ray Detectors for External PIXE Analysis System

Among the 4 beamlines of 1.7 MV tandem accelerator, the PIXE beamline was newly designed and upgraded for development of external PIXE system. Two X-ray detectors were used for the external PIXE analysis system. One is a Si(Li) detector produced by Canberra, and another is a SDD(Silicon Drift Detector) from Amptek. The Si(Li) detector was applied to collecting the normal and high energy X-rays, and the

SDD was used for analyzing the X-rays of light elements.

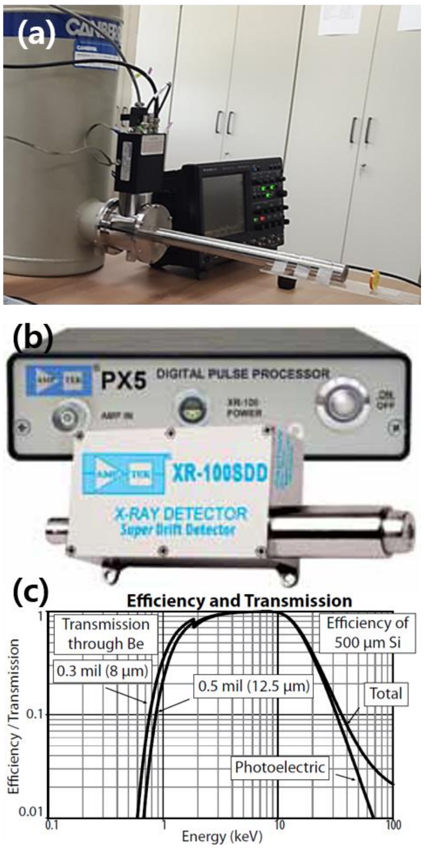

Fig. 2. (a) Si(Li) and (b) SDD detectors for the external PIXE analysis system. (c) Detection efficiency of SDD as a function of X-ray energy.

Before installation at the external PIXE beamline, energy calibrations for two detectors were carried out using standard isotope samples (Mn-54, Co-57, and Fe-55) produced by Eckert&Ziegler. Fig. 3 shows the evaluation results for Si(Li) and SDD detectors, respectively. The FWHM(full width at half maximum) values for principal peaks(at 5.4 keV of Mn-54 and at 5.9 keV of Fe-55) was lower than 140 eV. It means that detection resolution of two detectors is excellent.

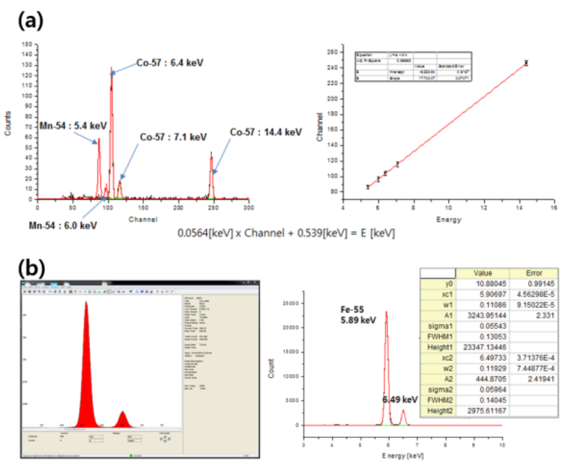

Fig. 3. The evaluation results on detection performance for (a) Si(Li) and (b) SDD detectors.

2.3 Installation of X-ray Detectors at External PIXE Beamline

Fig. 3 shows the installation of Si(Li) and SDD detectors at the external PIXE beamline. Two detectors were installed in 45° and 135° for the beamline, respectively, because background noises were minimized at these positions by avoiding secondary electron, bremsstrahlung X-rays, and so on.

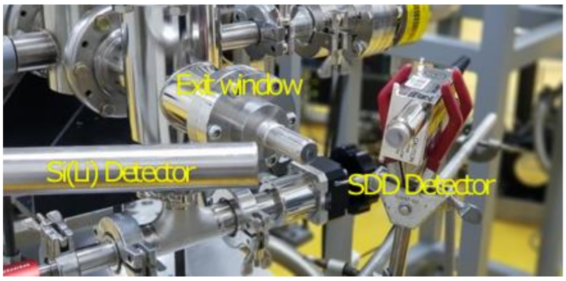

Fig. 4. Installation of two X-ray detectors at the external PIXE beamline.

3. Conclusions

The X-ray Detectors, Si(Li) and SDD, were evaluated and installed at the external PIXE beamlines. Energy calibration was carried out and detection performance was also evaluated for two detectors. For minimizing the background noises, two X-ray detectors were installed in specific positions, respectively. At a next step, we will analyze simple and standard samples using the external PIXE system, and the external system will be evaluated.

4. Acknowledgement

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