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Exit Window for External PIXE of the 1.7 MV Tandem Accelerator at KOMAC

Jun Mok Ha*, Seoung Ho Lee, Kye-Ryung Kim, Jae Kwon Suk, Min Young Kim, and Yong Sub Cho
Korea Multi-purpose Accelerator Complex (KOMAC), Korea Atomic Energy Research Institute (KAERI),
181 Mirae-ro, Geonchon-eup, Gyeongju, Gyeongbuk, 38180, Korea
Corresponding author: jmha@kaeri.re.kr

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]. Exit window is an important part of external PIXE for extracting proton beam from vacuum to air. The exit window is a thin foil which separates the vacuum from the atmosphere, and therefore, it has to be strong enough to withstand the pressure difference and thin enough so that the beam does not lose much energy through it [9].

Here, we present design, fabrication, and vacuum test of exit window for external PIXE of the 1.7 MV tandem accelerate at Korea Multi-purpose Accelerator Complex (KOMAC). The PIXE beamline of the 1.7 MV tandem accelerator at KOMAC will be modified into external PIXE for applying to restoration and preservation treatment of cultural properties. For the reason, an exit window has to be designed and developed. The fabricated exit window using havar foils exhibited a stable operation under vacuum conditions for the external PIXE analysis system at KOMAC.

2. Methods

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 Figure 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).

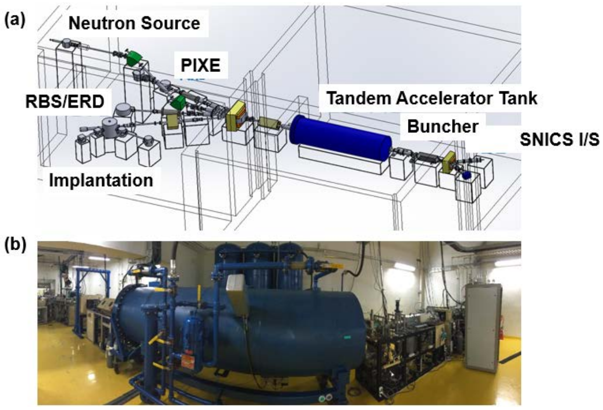

Figure 1. (a) Schematic and (b) optical image of the 1.7 MV tandem accelerator at KOMAC.

Exit window was fabricated using havar foil (Goodfellow). The size and thickness of foil are 10 x 10 mm^2 and 4 µm, respectively. Figure 2 shows the exit window components for installation and operation of havar foil. Since the foil with a very thin thickness could be easily torn, all components of exit window were carefully fabricated and the roughness of components was minimized. The hole edges of adaptor (Figure 2c) were roundly treated because the part was strongly contacted with the havar foil under vacuum conditions.

Figure 2. An optical image of the exit window components.

The havar foil (10 x 10 mm^2) was attached between support and adaptor (Figure 2b and c, respectively) using epoxy glue which is surrounding the support, and then, enoughly dryed at room temperature during 3 ~ 6 hr to block the movement of expoxy glue under vacuum conditions.

3. Results and discussion

In this work, the epoxy glue can play two important roles: strongly attachment of havar foil with adaptor and holding of the havar foil against pressure difference for a vacuum stability of external PIXE system. However, the glue will be impurities if it was irradiated by the proton beam. Figure 3 exhibited the fabricated exit window. There was no epoxy glue on the havar foil (center part of Figure 3) after fabrication. It means that a suitable amount of epoxy glue was used for attachment between havar foil and adaptor, and well surrounded at the edges of adaptor and support.

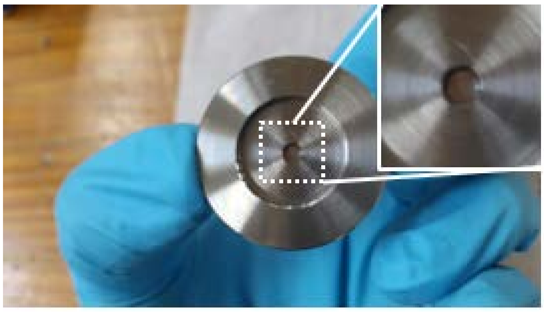

Figure 3. An optical image of fabricated exit window (backside view). No epoxy glue existed at the center of window.

Kapton foils and films have been widely used for exit windows for an external PIXE due to less noise and moderate thickness (tens or hundreds μm). However, because Kapton foils had a little weak resistance to beam damage and pressure, and also beam energy loss is big through it, we selected a havar foil for the exit window. It is metal material which is much stronger than polymer foils, and furthermore it is much thinner than polymer one. Total diameter of the fabricated exit window system was 30 mm and the hole diameter (for extracting external beam into air) of exit window was 1.5 mm.

Figure 4. Vacuum stability test of the exit window using havar foil.

Vacuum stability test of the fabricated exit window using a havar foil with the thickness of 4 μm was carried out as shown in Figure 4. The stability tests were conducted under low vacuum conditions because the pressure difference against air atmosphere is almost same for both low (~10^{-3} torr) and high vacuum coditions (~10^{-7} torr). The exit window was well withstand from the pressure difference between air and vacuum atmospheres. The vacuum degree of exit window system was easily reach at ~ 10^{-3} torr after the test of 30 min and maximum vacuum degree was 2.52 x 10^{-3} torr.

4. Conclusions

Exit windows using havar foils were fabricated for external PIXE analysis system at KOMAC. Epoxy glue was strongly holding the havar foil against vacuum pressure, as a result, the fabricated exit window exhibited stable operation under vacuum conditions and good vacuum performance. At a next step, we will carry out the experiment of proton beam extraction into air through the exit window, and furthermore, will reduce the diameter of total exit window system and the thickness of exit window (or change of materials) for the enhanced performance of external PIXE at KOMAC.

5. Acknowledgement

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