Verification Experiment of Cultural Properties Analysis Using External Beam PIXE on the 1.7 MV Tandem Accelerator of KOMAC

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1. Introduction

An external beam PIXE (Proton Induced X-ray Emission) is very effective tool for the cultural heritage analysis. The external beam PIXE has the possibility of analyzing objects in air without the need to place samples under vacuum conditions. This in-air option upgrade the PIXE' rating as a non-destructive technique inasmuch as; (a) the presence of air reduces the possibility of sample overheating under the ion beam; (b) vacuum related damages (such as dehydration processes in paper manuscripts) are avoided; (c) objects larger than the required size to fit vacuum chambers can be analyzed avoiding risks of damage related to sampling and/or transport procedures. [1]

We established an external beam PIXE system on the 1.7 MV tandem accelerator of KOMAC (Korea Multi-purpose Accelerator Complex) for the analysis of cultural heritage. To verify the availability of the application to cultural heritage analysis, we conducted some experiments using cultural heritage objects, such as bottle, bowl, paper which are assumed to be made in Chosun and Goryeo Dynasty. The results of the verification experiment of cultural heritage analysis using this external beam PIXE are reported in this paper.

2. Methods and Results

2.1 External Beam PIXE System

The external beam PIXE system installed at the end of the PIXE beam line on 1.7 MV tandem accelerator is shown in Fig. 1.

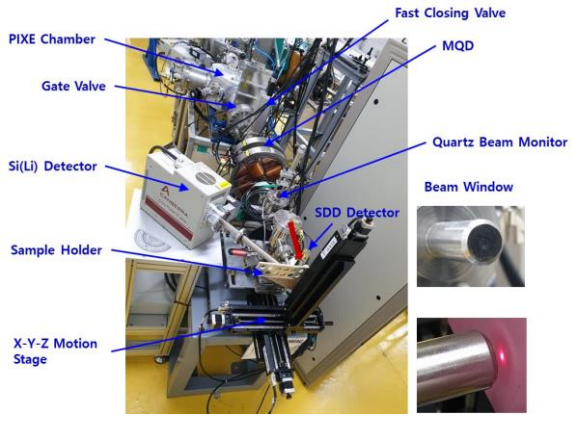


Fig. 1. External beam PIXE system installed at the end of the 1.7 MV tandem accelerator.

The system is composed of gate valve to isolate from the PIXE chamber, fast closing valve to protect the vacuum system of the whole accelerator, MQD (Magnetic Quadrupole Doublet) to control the beam optics, viewer made of quartz plate to monitoring the beam profile, beam window made of kapton film to extract proton beam from vacuum to air, two detectors to measure the x-ray emitted from the sample, and X-Y-Z stage to control the sample position. Beam size can be minimized to 1 mm in diameter.

2.2 Cultural Heritage Object

To verify the availability of the application to cultural heritage analysis, we conducted some experiments using cultural heritage objects, such as bottle, bowl, paper which are assumed to be made in Chosun and Goryeo Dynastey. The objects are shown in Fig. 2.

Fig. 2. Cultural heritage to be used for the verification experiments; Gyoji from Chosun Dynasty (left), Octagonal celadon white porcelain bottle from Chosun Dynasty (middle), Goryeo celadon octagonal bowl (right).

2.3 X-ray Spectrum Measurement

The spectrums were measured by two X-ray detectors and the objects is very close to the beam window to minimize the x-ray peak from Ar in the air as shown in Fig 3. A SDD (Silicon Drift Detector) and a Si(Li) detector are installed at angles of -45 and +45 degree to the beam axis. The fast SDD detector has 25 mm^2 active area, 500 um thickness, and energy resolution less than 125 eV for 5.9 keV x-ray. The super Si(Li) detector has 12.5 mm^2 active area, 2 mm thickness, energy resolution (FWHM) less than 135 eV for 5.9 keV x-ray and electric cryostat.

2.4 Analysis Using GUPIXWIN

In the Fig. 4, the analysis results of gyoji and bowl samples are shown. As shown in the Fig. 4, the spectrums and elements in the samples are different. Especially, Pb (lead) is included in the gyoji sample

different from bowl sample. It seems to be caused by the contamination with dust for a long time.

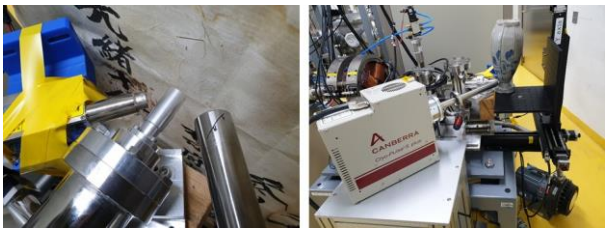
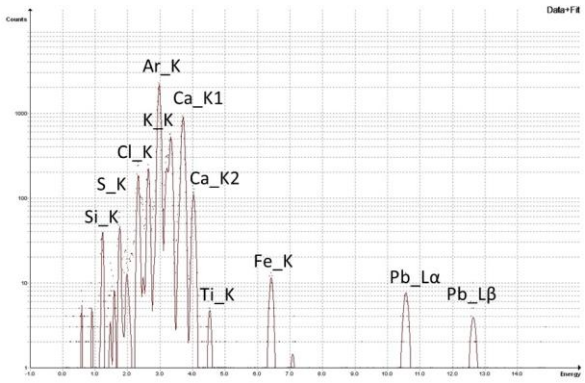
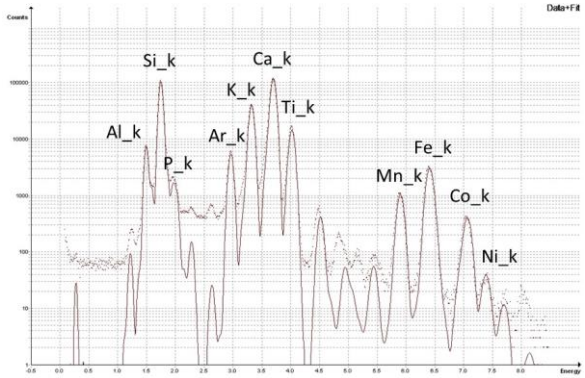


Fig. 3. X-ray spectrum measurement using the external beam PIXE; gyoji (left) and bottle (right).



(a) Gyoji sample



(b) Bowl sample

Fig. 4. Analysis results using GUPIXWIN.

2.5 Identification of the Fake Part

By using PIXE analysis technique, we can identify the difference among the whole parts of the samples. For example, the octagonal celadon white porcelain bottle from Chosun Dynasty has a repaired part as shown in the Fig. 5. If the broken parts are the parts of the same bottle, there's no big difference between the x-ray spectrums and analysis results. But as shown in Fig. 5, some difference are detected. It means that the neck part was not the original one of the bottle. From this results, we can recognize that we can identify the fake part of the cultural heritage. On the other hands, there's no big difference between the spectrums from inner and outer wall of the Goryeo celadon octagonal bowl as shown in Fig.6.

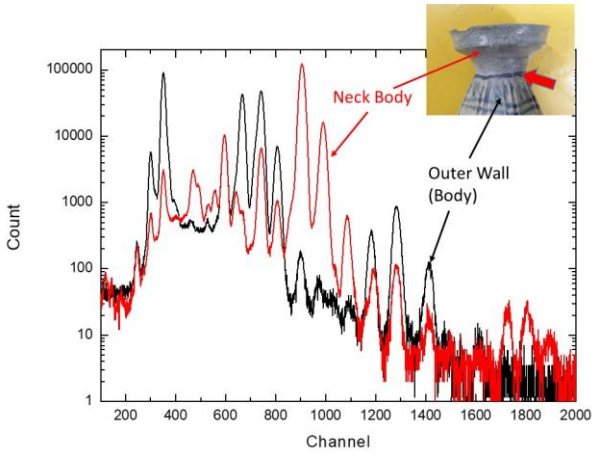


Fig. 5. Comparison of x-ray spectrums obtained at the different part of the octagonal celadon white porcelain bottle from Chosun Dynasty.

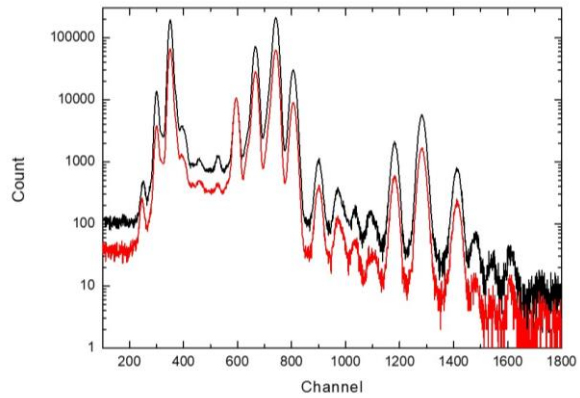


Fig. 6. Comparison of two x-ray spectrums obtained at the different part of the Goryeo celadon octagonal bowl.

3. Conclusions

The external beam PIXE system was installed on the 1.7 MV tandem accelerator of KOMAC. The verification experiments for the application to the cultural heritage analysis were performed. From the experiment results, we can recognize that the external beam PIXE can be utilized for the element analysis of the cultural heritage and for the identification of the fake parts.

ACKNOWLEDGEMENT

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REFERENCES

[1] E. A. Varella, "Conservation Science for the Cultural Heritage: Applications of Instrumental Analysis" (2013).