DESIGN AND SIMULATION OF THE PIXE/PIGE FACILITY AT THE 2-MV KIST TANDEM ION ACCELERATOR

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The PIXE/PIGE system has been designed and evaluated the performance and characteristic by using the CAD program and Monte Carlo simulation packages (MCNP6, PHITS, and TRIM). The components of systems as a target vacuum chamber dimension, beam's collimator and beam's nozzle and Si(Li) and HPGe detectors were considered in the design. The design of the PIXE/PIGE will be turned to appropriate with the requirements of the purpose based on the simulated results before installation at the KIST Tandem Ion Accelerator (Republic of KOREA).

I. INTRODUCTION AND METHOD

I.A. Introduction

Particle Induced X-ray Emission (PIXE) is a method in which X-ray emission is used for analysis. The high energetic proton beam excites, due to inner-shell ionization, the emission of characteristic X-rays from the sample target atoms (Ref. 1). Besides, PIGE (Proton Induced Gamma Emission) is based on the detection of prompt gamma rays emitted from nuclei that are excited state following the nuclear reactions (p, γ), (p, p'γ), (p, aγ) in the sample (Ref. 2). Gamma rays and X-rays emit simultaneously when the samples are bombarded with high energetic protons. The PIGE is utilized in the analysis of light elements as lithium, boron, and fluorine, which are often difficult to determine by other analytical methods. In addition, The PIGE complements to PIXE that is a powerful yet non-destructive elemental analysis technique.

The Korea Institute of Science and Technology has a Tandem Ion Accelerator, which has been installed in 2011, consisting of mainly four ion accelerators as 6-MV, 2-MV, 0.5-MV, and 400-keV (Ref. 3). This study has carried out the design and simulations of a PIXE/PIGE system at the reserved location of the 2-MV output port where is available for standard analysis.

I.B. Method

A target vacuum chamber that will be installed at the end of the 2-MV beam line was designed for a high throughput of samples, ensured by a tight geometry of its components. The appropriate materials for chamber walls, components and especially collimators were carefully chosen for rendering a low intrinsic chamber background. The schematic diagram of the vacuum chamber, as well as collimators, detectors and standing table, is shown in Figure I.

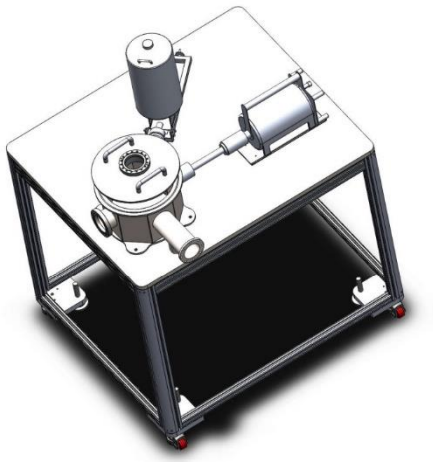

Fig. I. Schematic view of the vacuum chamber, collimator, and detectors will be install at KIST Tandem Ion Accelerator.

The entire chamber is made of stainless steel (0.5 cm thickness) of 30 cm inner diameter and 30 cm height. At 0.9 cm height, the chamber has five ports that were designed meets all requirements of a purposed PIXE/PIGE system. It consists of Si(Li) and HPGe detectors, a sample holder, a Faraday cup, etc. In addition, vacuum feedthroughs are provided to supply to the electron gun, current suppressor, etc. The chamber also attached vacuum pump and beam drum. There are two kinds of the detector were intended to setup in the system as Si(Li) and HPGe detectors with the serial numbers as CANBERRA SI12170 and ORTEC 51-N42257A, respectively. In addition, the beam's collimator and beam's nozzle were designed and optimized in order to deliver protons to the target with minimal losses, therefore reducing secondary radiation. The design of the PIXE/PIGE systems has been done using the CAD program and can be easy to export to the simulation packages.

The physics that needs to be considered for the simulation of PIXE/PIGE include the energy loss and scattering of the incident charged particle, atomic shell ionization cross sections, and atomic transition probabilities and energies. On top of these physical features, consistency should be ensured, when modeling PIXE/PIGE system, with the particle transport schemes governing the Monte Carlo simulation.

The simulation of PIXE/PIGE in the context of MCNP6/PHITS/TRIM (Ref. 4, Ref. 5, Ref. 6) must deal with the constraints imposed by the condensed-random-walk schemes adopted for charged particle transport, as well as with the limitations of the theoretical calculations which are currently available in this problem domain.

An example of simulation is a calculation of the Si(Li) detector efficiency. The characteristics of the Si(Li) crystal and the representation of the detector structure given by the manufacturer are presented in Figure II.

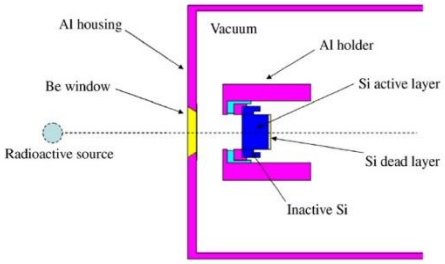

Fig. II. Schematic representation of the configuration used to model the response of the Si(Li) detector

II. CONCLUSIONS

The PIXE/PIGE system has been designed and predicted the performance by using the CAD program and Mote Carlo simulation codes. Based on the simulated results, the PIXE/PIGE systems will be turned compatibly with the proposed requirements before manufacturing and installing at the available position of the KIST Tandem Ion Accelerator.

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