Plan for Ion Beam Analysis Systems Based on 3-MV Tandem Accelerator

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1. Introduction

The IBA (Ion Beam Analysis) techniques have been used for the material sciences and the needs and importance are continuously increased during last several tens of years from 1960's. The PIXE (Proton Induced X-ray Emission), ERDA (Elastic Recoil Detection Analysis), RBS (Rutherford Backscattering Spectroscopy), PIGE (Proton Induced Gamma-ray Emission), and NRA (Nuclear Reaction Analysis) are generally used IBA systems. For these IBA systems, usually MeV tandem accelerators are used and many worldwide accelerator laboratories which have these kinds of electrostatic accelerators are put their efforts to establish the IBA systems and performance improvements. [1-2] The KOMAC (Korea Multi-purpose Accelerator Complex) has two kinds of tandem accelerators, a 1.7-MV tandem accelerator (NEC; National Electrostatics Corp., USA) and a 3-MV tandem accelerator (HVEE; High Voltage Engineering Europa, Netherlands). Many kinds of IBA systems, a PIXE, an external beam PIXE, a RBS, and an ERD systems were established at the 1.7-MV tandem accelerator and has been operated from 2018. On the other hand, the 3-MV tandem accelerator had been used for the C-14 AMS (Accelerator Mass Spectrometry) before the movement to KOMAC. Reflecting the needs for the IBA, we make a plan to add three new beam lines, for ion implantations, ion beam analysis such as PIGE (Proton Induced Gamma Emission) and NRA, and beam irradiations for nuclear material test. And some material scientists want to know the composition of the thin film including contents of light elements such as hydrogen. So, we decided to make a plan to develop and install the combined IBA system, combination of RBS, PIXE, ERD, PIGE, and so on at the one beam line of the 3-MV tandem accelerator. Figure 1 shows the layout of the 3-MV tandem accelerator installed at the KOMAC.[3]

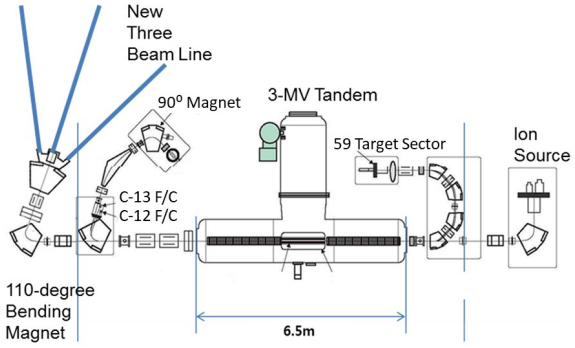

Fig. 1. The layout of the 3-MV tandem accelerator at KOMAC with new 3 beam lines.

The specification of the 3 MV tandem accelerator are shown in Table. 1.

Table 1. Specification of the 3-MV tandem accelerator

Company	HVEE
Model No.	4130
Terminal Voltage [MV]	0.2~3.0
Ion Source	SNICS, Duoplasmatron
Beam Currents [eμA]	
Proton (1+)	25
He (2+)	2

2. Combination of IBA Systems

The PIXE is very suitable to element identification and its quantification of bulk sample. But for the heavy element analysis of thin film in light element matrices, it is not easy to identify the heavy elements because the L-line x-ray energy peaks from heavy elements are overlapped to the K-line X-ray peaks from light elements. So it will be very useful to use the RBS in combination. In addition, a combination of another different IBA skills may be the solution. The NRA and PIGE are very powerful tools for the analysis of the light elements in heavy ion matrices. And it can be possible to analyze depth profile also. When we analyze the composition of the thin film using RBS, it is not also easy to identify the light elements contained in the sample such as oxygen and carbon. Nevertheless it is possible to analyze using nuclear resonance scattering reaction, $^{16}O(\alpha,\alpha)^{16}O$ and $^{12}O(\alpha,\alpha)^{12}O$, there are some limits and it is not easy to obtain the resonance peaks by controlling the incident ion energy. So, it may be very useful if we can use it in combination with PIXE, NRA, PIGE or/and ERDA. Actually, we already have some IBA systems based on the 1.7-MV tandem accelerator, they are installed at the different beam lines and are operated separately. So, it is not effective and very time-consuming to compare the analysis results from different IBA systems. Reflecting the experiences of utilization of the 1.7-MV tandem based IBA systems, we are trying to develop a combined IBA system based on the 3-MV tandem accelerator for the effective analysis of various kinds of materials.

3. Conceptual Design of Combined IBA System

The conceptual design is shown in the Figure 2. The combined IBA system is composed of X-ray detectors,

gamma-ray detector, particle detectors, goniometer, Faraday cup, camera, filter etc.

3.1 PIXE

Two X-ray detectors will be installed at the angle of 45 degree to the beam axis. The first one is a Fast SDD (Silicon Drift Detector, AMPTEK) and its active area is 70 mm^2 and Be or C1 window for the measurement of low-energy X-ray (<~10 keV). The other is a Si(Li) detector for the measurement of the high energy X-ray. For the high efficiency, the detector will be installed at the position to the sample as close as possible.

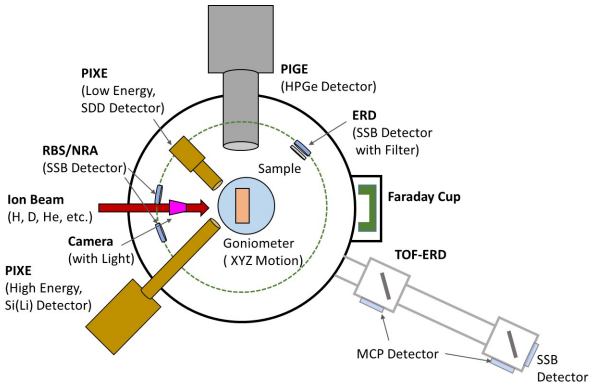

Fig. 2. Conceptual drawing of the combined IBA system.

3.2 RBS

For the RBS, two SSB (Silicon Surface Barrier) detectors will be installed. The detectors are used for the detection of ions backscattered from the sample after colliding with the atoms in the sample. The main detector is fixed at the 10º vertically off-axis to the angle of beam entrance. The positions of the other detector can be changed in the range of 30~170º for the simultaneous measurement with combination of the other IBA, for example, ERDA. For the RBS the beam incident angle to the target have to be able to be change if necessary. For this reason, goniometer will be mounted to the target stage for the XYZ motion of the sample. The RBS-Channeling also can be possible to be used.

3.3 ERDA

For the ERDA, SSB detector will be installed at the appropriate angle with a filter such as Mylar film. The thickness of the Mylar film will be determined by the experimental conditions. The recoil and backscatter incident ions must stop at the filter, and other light ion which we want to measure can reach the detector passing through the filter.

3.4 PIGE

HPGe detector will be installed for the gamma-ray detection for the PIGE at the angle of 90° to the beam axis to avoid or minimize the Doppler broadening Effect. The HPGe detector can be replaced by the NaI(Tl) detector.

3.5 Data Acquisition System and S/W

A DAQ (Data Acquisition System) must also be combined for effective operation. It would be the best way to take advantage of the commercial programs we're already using. The main analysis programs for the RBS/ERD and PIXE are SIMNRA and GUPIXWIN we are familiar with.

3.6 Accessories

Inside the chamber of the combined IBA system, a Faraday cup for the beam current measurement, illuminated camera, and phosphorous screen will be installed, allowing us to image and control the beam position and size. And vacuum pumping system, gate valve will be added for the vacuum pumping and a load-lock chamber will be installed for shortening the sample replacement time.

4. Summary

We made a plan for the development of a combined IBA system based on the 3-MV tandem accelerator reflecting users' requirements and recent trends of IBA techniques for the advanced material science. The combined IBA system will improve the ability of the IBA and will be developed and installed at the 3-MV tandem accelerator in near future.

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