

STATUS REPORT ON RAPID, 1.7MV TANDEM ACCELERATOR SYSTEM, THE UNIVERSITY OF TOKYO

S. Ito, H. Matsuzaki, A. Morita, Y. Tsuchiya (Sunohara), C. Nakano, Y. Miyairi

Department of Nuclear Engineering and Management, School of Engineering, the University of Tokyo, Japan.

Abstract

RAPID (Rutherford Backscattering Spectroscopic Analyzer with Particle Induced X-ray Emission and Ion Implantation Devices), The University of Tokyo has been dedicated to various scientific and engineering studies in a wide range of fields by the ion beam analysis availability with 1.7 MV Tandetron accelerator. RBS (Rutherford Backscattering Spectroscopy), ERDA(Elastic Recoil Detection Analysis), NRA (Nuclear Reaction Analysis), PIXE (Particle Induced X-ray Emission) and ion implantation. Total accelerator operation time amounted 10,674 hours since its installation with the highest annual operation time recorded in 2009. RAPID-PIXE analysis system has been contributed to many environmental studies by analyzing elemental composition of water and sediments samples. Recently, the low level ion irradiation system was also developed and applied for the study of CR-39 track detector with proton beam.

INTRODUCTION

RAPID, standing for Rutherford Backscattering Spectroscopic Analyzer with Particle Induced X-ray Emission and Ion Implantation Devices, was installed in 1994 at Research Center for Nuclear Science and Technology (later reorganized to a department of School of Engineering in 2005), The University of Tokyo. The system consists of a 1.7 MV tandem accelerator (Tandetron™, Model 4117-HC, provided by HVEE: High

Voltage Engineering Europe corp., Netherlands), two negative ion sources (a Cs sputter solid ion source and “Duoplasmatron” gas ion source) and three beam lines (Figure 1). The 1.7 MV “Tandetron™” has Cockcroft Walton type charging system. The terminal voltage is monitored and stabilized by a Generating Volt Meter (GVM). Various ion species can be generated by the dual negative ion sources system. Totally 24 ion species, from Hydrogen to Gold, had ever been generated and accelerated so far. Especially it is one of specific features of RAPID that He⁻ ion is available by the “Duoplasmatron” gas ion source. Three beam lines are currently being used on the high energy side, ended by PIXE detector system, RBS&ERDA detector system and Ion implantation chamber, respectively. PIXE detector system at RAPID is conventional vacuum type that Si(Li) semiconductor detector and 3-dimensional position adjustable multiple samples holder are equipped in a PIXE chamber. This versatile elemental analysis system has been applied to various research fields from environmental sciences to archaeology. RBS chamber is mounted with 3-axis goniometer and silicon surface barrier detector. In 2009, we newly started NRA experiment with proton beam. In this experiment, Fluorine and Nitrogen quantification in the surface layer of materials is tested using ¹⁹F(p, αγ)¹⁶O reaction and ¹⁵N(p, αγ)¹²C reaction respectively. BGO (4inch Bismuth Germanate; Bi₄Ge₃O₁₂) scintillation is used as well as Si(Li) for the final detector of NRA. The ion implantation line is tilted by 7 degree to the central axis of the

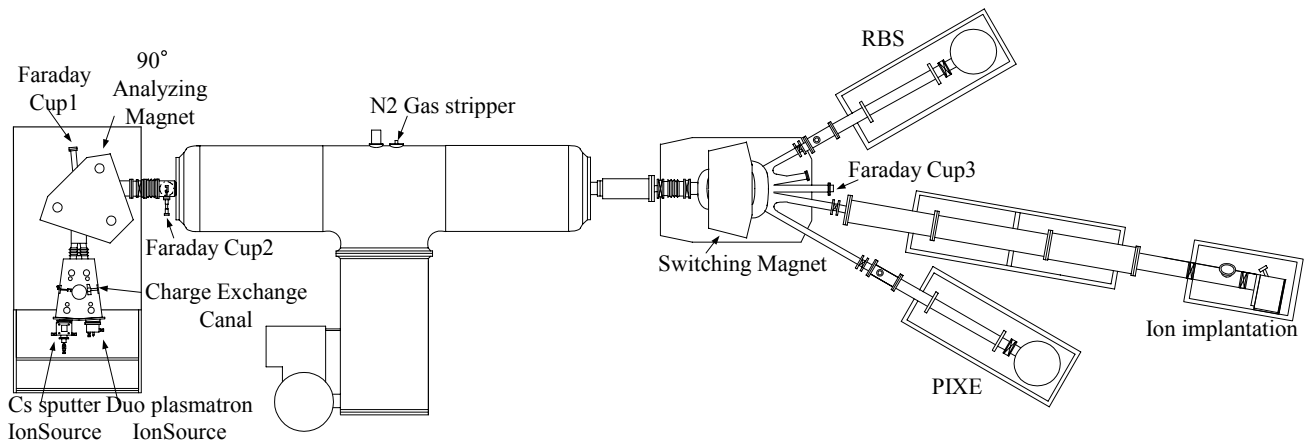


Figure 1: Schematic illustration of the 1.7 MV tandem accelerator system.

accelerator. This apparatus has been widely used for various kind of material processing studies and material evaluation studies for high radiation environmental use.

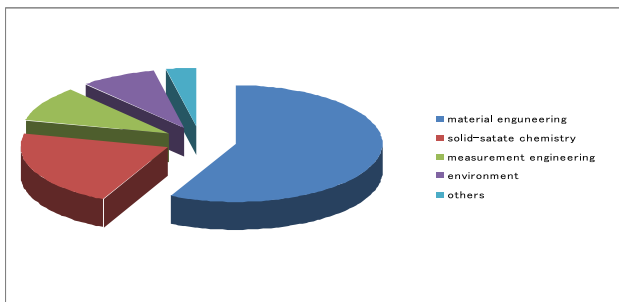


Figure 2: The percentage of research fields in 2009.

Figure 2 shows the percentage by which each application field occupies the RAPID machine time. Figure 3 shows the yearly accelerator operation time of RAPID. The total operation time has reached to 10,674 hour

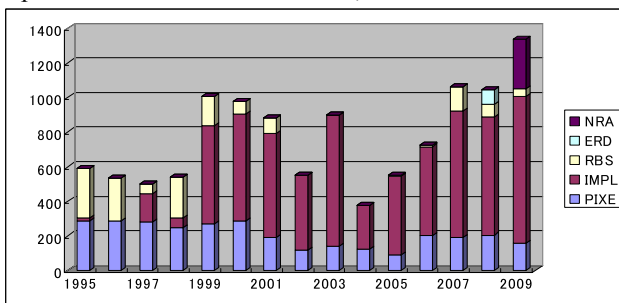


Figure 3: Yearly operation time for each beam lines.

APPLICATIONS

PIXE Analysis of Pond Sediments and Air Dust

PIXE is a good example for understanding the basics of the IBA technique and is easily applied for the environmental study. Hence, a student experimental program was designed with PIXE analysis of environmental samples. Main subject of the program is simply the PIXE analysis of the pond sediments collected from the bottom of a “Sanshiro-ike” in the University of Tokyo which various plants and creatures are living. However it contains from the field work, sampling, pre-treatment for the IBA, PIXE analysis itself and detailed analysis of the data. Students are expected to recognize the relation between human and natural bio system as well as the acquisition of the PIXE technique through this program. Figure 4 shows an example of the PIXE analysis spectrum. Fortunately, pollutant metal such as Cd, As, Hg has not been observed so far. In 2009, newly designed student experiment program was started which

treats SPM (Suspended Particulate Matter) in the atmosphere. Atmospheric dust particles larger than 0.45

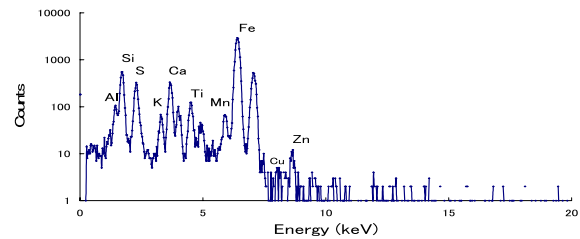


Figure 4: PIXE spectrum of pond sediment. This is that of “Sanshiro-ike” pond in the University of Tokyo.

micro-m size were collected by a hand-made dust collector at the rooftop of the accelerator building. The main component of the dust around Tokyo area is 1) natural soil, 2) volcanic ash, 3) artificial origin dust due to such as the exhausted gas from the automobiles or industrial factories, 4) Sea salt and 5) Yellow sand from Chinese continent. The amount and the portion of these

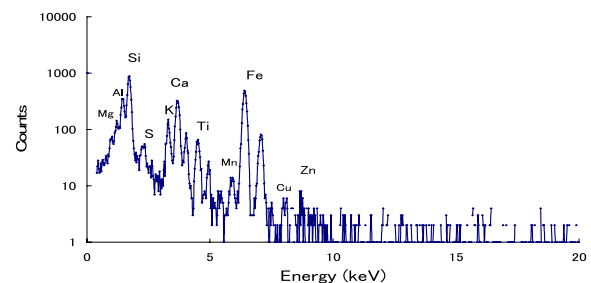


Figure 5: PIXE spectrum of SPM corrected in the campus of University of Tokyo.

components vary with seasons and weather. For example, amount of the yellow sand arriving Japan is greatly enhanced during the term from February to May. The PIXE spectrum of SPM collected at March 21st, 2010 is shown in Figure 5.

Development of Low Level Irradiation Chamber

To evaluate the response of CR-39 track detector to low level irradiation, specially designed irradiation chamber system was developed and set at the ion implantation line of RAPID. If we receive accelerated proton beam directly, it is difficult to reduce the flux to less than 1×10^8 [ions/cm²]. Newly developed system uses the backscatter proton and enables to reduce proton dose significantly. The backscatter angle is 45 degrees. The proton flux can be reduced to the degree of the backscattering cross section and the actual solid angle of the irradiation area. The geometry of the system is shown

in Figure 6. As a result, the dose was restricted to less than 10^7 [ions/cm²]. Initial proton flux is monitored by the faraday cup placed co-axially. The distance between the scattering target and the irradiated sample is 160 mm and the inner diameter of the aperture in front of the irradiated sample is 8 mm. Hence the actual solid angle for the scattered ion particles is as small as 0.063sr so that the irradiation can be considered as uniform. By the Silicon Surface Barrier detector placed behind the irradiated sample the energy spectrum of the back scattered ion particles is measured. The energy distribution of the scattered ion particles can be changed by changing the thickness and the materials of the scattered target film. Using this system the response of CR-39 to low level irradiation was investigated. Figure 7 (a) is the result of direct irradiation of the initial proton beam to the CR-39 and Figure 7 (b) is the result of the irradiation by the scattered ion particles. Obviously an appropriate dose rate to identify each ion track is the case

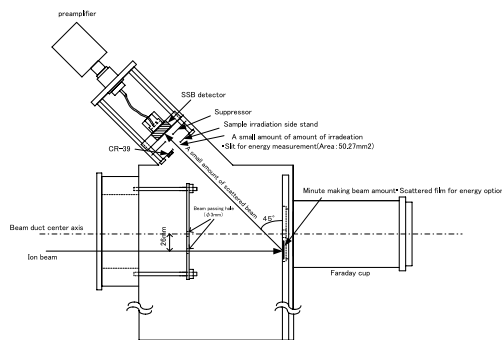


Figure 6: Schematic drawing of new irradiation system.

of the scattered ion particle irradiation (Figure 7 (b)). Each spot on the Figure 7 (b) corresponds a track. Concentrated spot means the concentrated energy deposit by the ion, a large energy loss near the end of the track. Track Spot A is more concentrated than track Spot B in Figure 7 (b). Energy deposit for track Spot B is smaller which means that the ion had have higher energy and the energy loss had been smaller. Figure 7 (c) shows the energy spectrum of the irradiated ion particles generated by the backscattering which was measured by a solid state detector.

SUMMARY

RAPID, the University of Tokyo is a beam analysis and ion implantation system being used for various application studies. Total accelerator operation time amounted 10,674 hours since its installation (1995) with the highest annual operation time recorded in 2009. At the fall of 2009, RAPID started new NRA experiment with proton beam. Environmental analysis (pond sediments and atmospheric dust) using PIXE is performed as a student experiment. A special irradiation chamber system was developed which enabled low level irradiation (less than 10^3 ions/cm²) by means of back scattering. The

energy distribution of the back scattering beam is also variable by changing the thickness and materials of the scattered target. Using this system the response of CR-39 track detector to low level irradiation was investigated

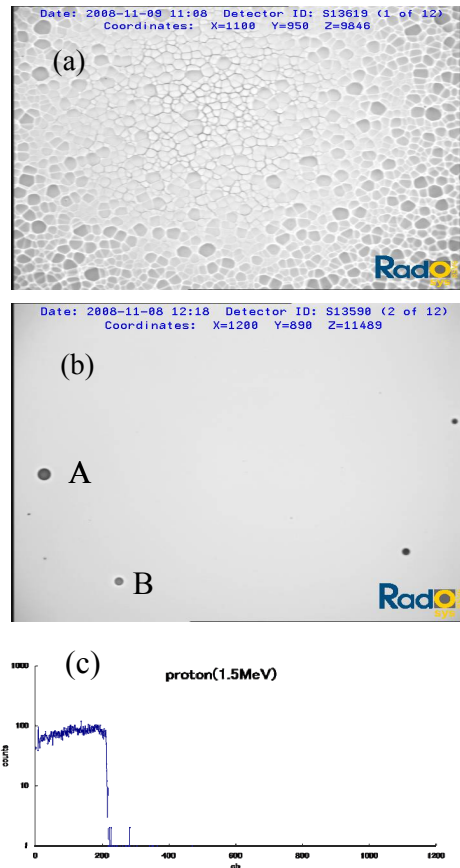


Figure 7: Photograph of the irradiated CR-39 by proton beam; (a) Direct irradiation (b) Backscattered irradiation (c) Energy spectrum of backscattered proton beam transmitting CR-39, which was obtained simultaneously with Figure 7 (b). (Scatter target = 12.5mm thick Al foil).

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