BEAM ALIGNMENT OF SCANNING MICROBEAM PIXE ANALYSIS SYSTEM IN NIRS ELECTROSTATIC ACCELERATOR FACILITY

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Abstract

The scanning microbeam PIXE (Particle Induced X-ray Emission) analysis allows identifying the several surface elements and taking the high-resolution elemental maps of the specimen at a time, by using the narrow beam downed the size to 1 μ m and the maximum scanning area of 2mm square. We are applying this system to the elements and the structure analysis for bio-cells and environmental specimens. The most important procedure to obtain the high-resolution maps is increasing spatial resolution of the microbeam. We diagnose the resolution by using Scanning Transmission Ion Microscopy (STIM) and PIXE images of the 12.5μm pitch copper mesh. In this workshop, we introduce our experiences of the alignment of the microbeam system.

1 INTRODUCTION

The National Institute of Radiological Science (NIRS) was established in 1957 as a special research institute, attached to the Science and Technology Agency of Japan. NIRS discarded the van de graff accelerator (Model KM3000, High Voltage Engineering) in1997 that had been operated as a device for pre-tumor therapy by neutron and PIXE analysis from 1961. In March 1999, an electrostatic accelerator, of HVEE Tandetron, was installed in the Electrostatic Accelerator Building for PIXE (Particle Induced X-ray Emission) analysis. PIXE analysis is a trace analytical method, which has an advantage of simultaneous determination of elemental concentrations in a small specimen without any chemical separation by measuring characteristic X-rays of elements induced by accelerated charged nuclear particles such as protons.

2 SYSTEM SPECIFICATIONS

2.1 Electrostatic accelerator system

The installed accelerator for PIXE analysis is the Tandetron (Model 4117MC) manufactured by High Voltage Engineering Europe Co. The accelerating voltage is 0.4 to 1.7MV, and the maximum beam current for protons is 5 μ A at 3.4MeV. This system has three beam lines designed for different types of PIXE analysis: conventional, in-He and scanning micro-beam. [1]

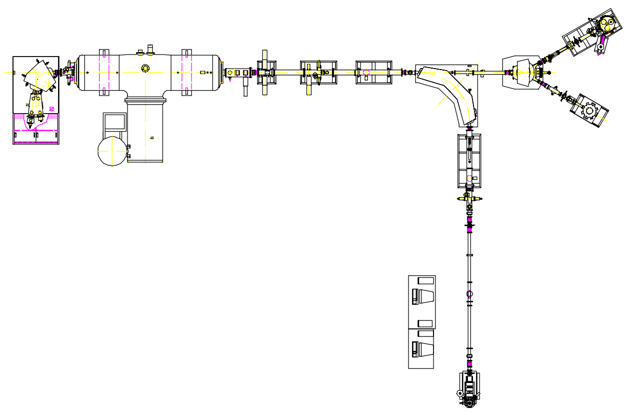

Figure 1

2.2 Conventional PIXE analysis line

The beam port for normal PIXE can supply beams of 0.5 - 2.0 mm square with currents of 10-100 nA. The beam size can be regulated with a set of X-Y slits. Since two types of X-ray detectors, Si (Li) and CdZnTe detectors, are available here, elements from Na (Z=11) to U (Z=92) are detectable. Fifteen samples can mount and analysed semi-automatically using computer control. Each sample is attached to the center of a hole of diameter 20mm on an aluminum plate of 25mm×35mm with appropriate backing film. Detector # 1 is a Si (Li) detector and detector # 2 is a CdZnTe detector, and these are set at 135 degree with respect to the incident ion beam.

2.3 In-He PIXE analysis line

The in-He PIXE analysis system was commissioned in March 2001, and is connected to the second beam port. The in-He beam line is used for irradiation of wet samples using a proton beam of size approximately 2 mm φ. The proton beam, which passes from the vacuum through Kapton film, enters the analysis chamber filled with helium gas at 1 atmosphere.

2.4 Scanning micro-beam PIXE analysis line

The layout of micro-beam scanning system (Model OM2000, Oxford Micro beams, Ltd.) installed at NIRS is illustrated in Figure 1. A proton beam is focused to the micron level by passing the beam through a coarse 0.5 mm diameter object aperture, and two more precise sets of X-Y slits which serve as object and collimator apertures. The beam is focused using a set of quadrupole triplet magnets, and scanned over the sample using a scanning coil positioned before the lens system. This system enables multi-elemental mapping over 2mm × 2mm areas with a spatial resolution of about 1 μ m. Figure 2 shows the chamber for the scanning micro-beam. Characteristics of the system are summarized in Table 1. This apparatus is useful for a research into the elemental and structural analysis of small samples, for example a cell. [2].

2.5 Scanning Transmission Ion Microscopy (STIM)

The STIM system was attached to the micro-beam scanning line in March 2001. The function of this apparatus is illustrated in Figure 2.

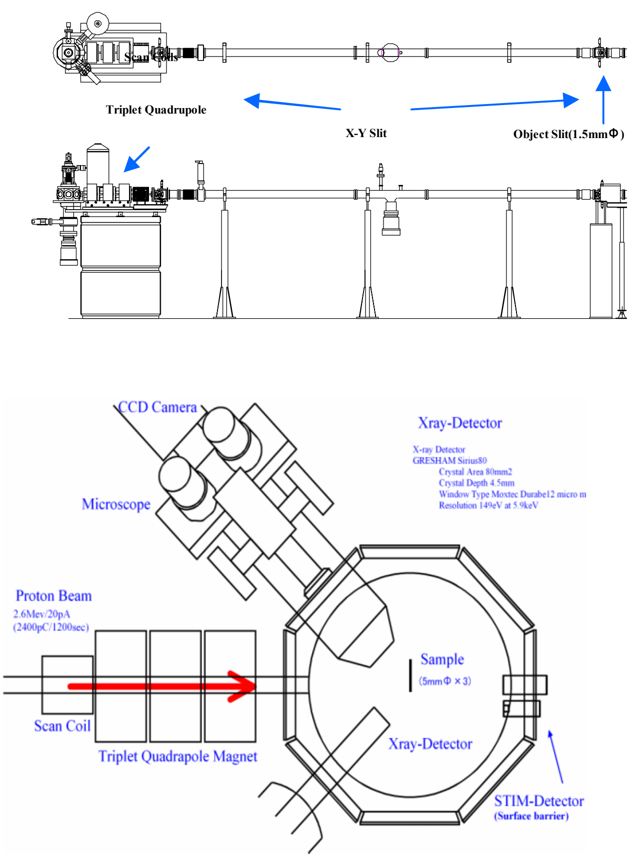

Figure 2
Schematic diagram of Scanning micro-PIXE line and Micro-PIXE chamber

An energy-loss spectrum of transmitted proton can be obtained using a surface barrier Si detector behind the sample. Since the energy-loss of transmitted protons depends on thickness and density of the sample, by scanning the sample surface with proton beams, we can get the energy-loss map to image the structure of a thin sample (up to 30 μ m meters) with this system. Thus, we can observe simultaneously the structure of samples in the scanning area during PIXE analysis.

3 THE RESULTS OF BEAM RESOLUTION TESTS

3.1 First step in the year of 2000

Figure 3 indicates the result of beam resolution tests carried out in February 2000 during the system installation. The beam size was estimated to be 0.4 × 0.6μ m with 12.7 μ m meters repeat distance gold grid for 3MeV proton. The beam current was 50pA, the scan size was 5μ m square and the irradiation time was 20min.

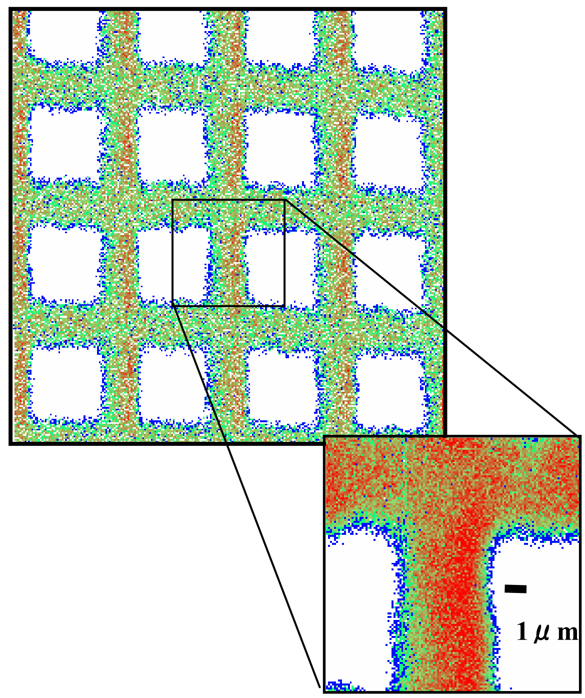

Figure 3
Result of beam resolution test

3.2 Second step in the year of 2001: The installation of Scanning Transmission Ion Microscopy (STIM)

Figure 4 indicates the result in December 2001. The estimated beam resolution is 100 × 200 nm, measured using a 2.6 MeV proton beam scanned over a 12.5μ m repeat distance copper grid.

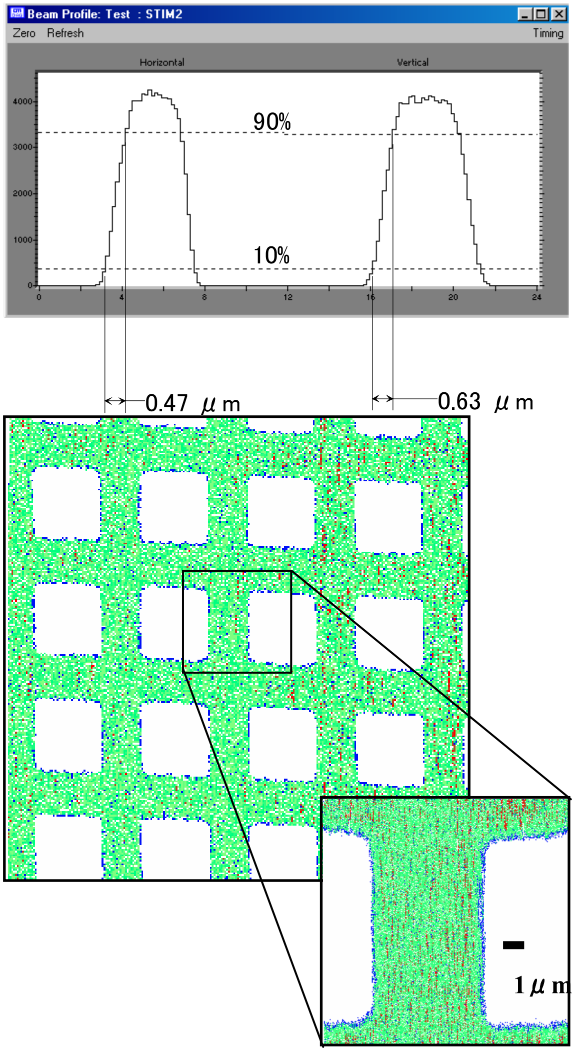

Figure 4
Highest resolution of this apparatus is estimated as 100 × 200 nm

3.3 Measuring objects and system condition

Table 1 shows the analyzed samples and the system condition. Mainly we analyze biological and environmental samples.

4 FUTURE RESEARCH PLAN: MICRO-BEAM IRRADIATION OF CELLS

The use of high-energy ion Microbeams is a new avenue of radiation research especially in radiation biology and radiation protection. For this purpose, we have started the construction of a new microbeam irradiation facility (named as SPICE) which will be connected to our Tandem accelerator (3.4 MeV $^{2}H^{1+}$ and 5.1 MeV $^{4}He^{2+}$). For our primary goal, “irradiation of cell organelles by a single high energy ion within a position resolution of 2μ m in a reasonable irradiation time", special features must be considered. Using a 90 degree magnet, a vertical beam line will be branched from the present the micro-beam PIXE beam line. The focusing system will be installed in a cradle which is hung on a rigid frame structure. At the end of the vertical beam line will be mounted a focusing triplet quadrupole -magnet system (Oxford Microbeams, Ltd.), an automated x-y stage for cell dishes and a video microscope will be mounted.

6 REFERENCES

[1] M. Yukawa, H. Imaseki: *International Journal of PIXE*, **10**[1-2], 2000, P71-75.
[2] H. Imaseki, M. Yukawa: *International Journal of PIXE*, **10**[3-4], 2000, P77-90.

Table 1

Sample	Beam Line	Species	Energy	Intensity	Beam Size	Comment
Chestnuts of mouse	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	
Ear stone of fish	Microbeam	Proton	2.6MeV	30pA	Raster scan: 10um-2mm	Need to use absorber Ratio of Ca is high
Paste include Hg and AS	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	
Fossilized wood	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	
Blood of mouse	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	Need to use absorber
Hair	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	
Yellow sand	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	Difficult to select a fixative
Cells of organ	Microbeam	Proton	2.6MeV	20-100pA	Raster scan: 50um-2mm	
CR-39 film (track detector)	Microbeam	Proton	2.6MeV	< 1pA	Resolution: 0.5-1um Raster scan: 50um-2mm	Less than 100cps
Ear stone of fish	Conventional	Proton	2.6MeV	13nA	0.5mm x 0.5mm	Need to use absorber Ratio of Ca is high
Paste include Hg and AS	Conventional	Proton	2.6MeV	10nA	0.5mm x 0.5mm	
Plankton	Conventional	Proton	2.6MeV	12nA	0.5mm x 0.5mm	
Blood of mouse	Conventional	Proton	2.6MeV	13nA	0.5mm x 0.5mm	Need to use absorber
Seawater filter	Conventional	Proton	2.6MeV	11-14nA	0.5mm x 0.5mm	
Paste of organ	Conventional	Proton	2.6MeV	13nA	0.5mm x 0.5mm	