THE USE OF PROTON INDUCED X-RAY EMISSION (PIXE) SPECTROSCOPY AT THE TANDEM VAN DE GRAAFF ACCELERATOR IN ZAGREB

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ABSTRACT

Elemental analysis by proton induced x-ray emission spectroscopy has been developed at the tandem Van de Graaff accelerator in Zagreb. Construction of multipurpose scattering chamber for routine PIXE analysis and chamber with proton beam collimated down to 100 μm is explained.

1. INTRODUCTION

Since 1970, when Johansson [1] first reported that combination of proton beam excitation of characteristic x-rays and their detection by a semiconductor detector results in a powerful multielemental analytical technique (PIXE), many groups demonstrated various applications of this method. Different experimental configurations, studied by many authors, resulted in the PIXE use for routine multielement analysis [2], measurements of element distributions with focused beams (proton microprobe) [3],

external beam analysis [4] and measurements with low energy protons and windowless Si(Li) detectors. Combination of the PIXE technique with some other nuclear analytical methods provide possibility to analyze all elements in sample, from hydrogen to uranium.

When the proton beam defined by collimator slits, hits the target sample, x-rays, γ-rays, scattered protons, nuclear reaction products, secondary electrons, bremmstrahlung, etc. are produced in the sample. For the PIXE spectroscopy, important is detection of characteristic x-rays. They are detected by a Si(Li) semiconductor detector. Main source of background is bremmstrahlung radiation produced by secondary electrons. Characteristic line intensities are the measure of the corresponding element amount in the sample. Minimum detectable concentration of particular element depends on the proton energy, element atomic number and the sample matrix. All elements whose characteristic x-rays are detected can be analyzed simultaneously. Quantitative measurements are possible for both thin and infinitely thick samples [5]. With chemical pretreatment of sample, detection limits can be improved for a few orders of magnitude.

2. EXPERIMENTAL

EN tandem Van de Graaff accelerator at the Ruder Boškovic Institute in Zagreb is in operation since 1987. In experimental area, four beam lines are used. In figure 1. layout of the accelerator is given.

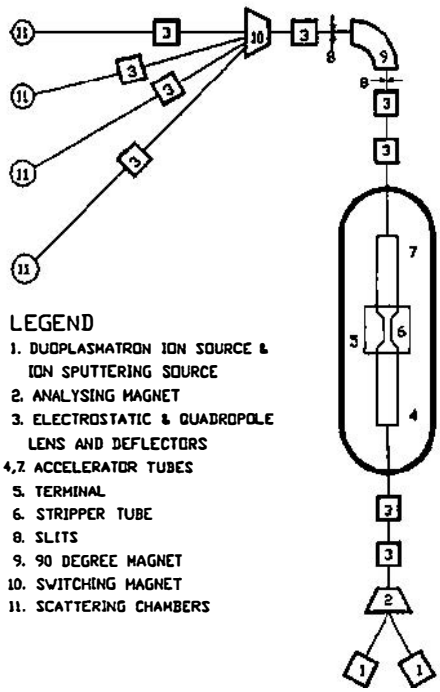
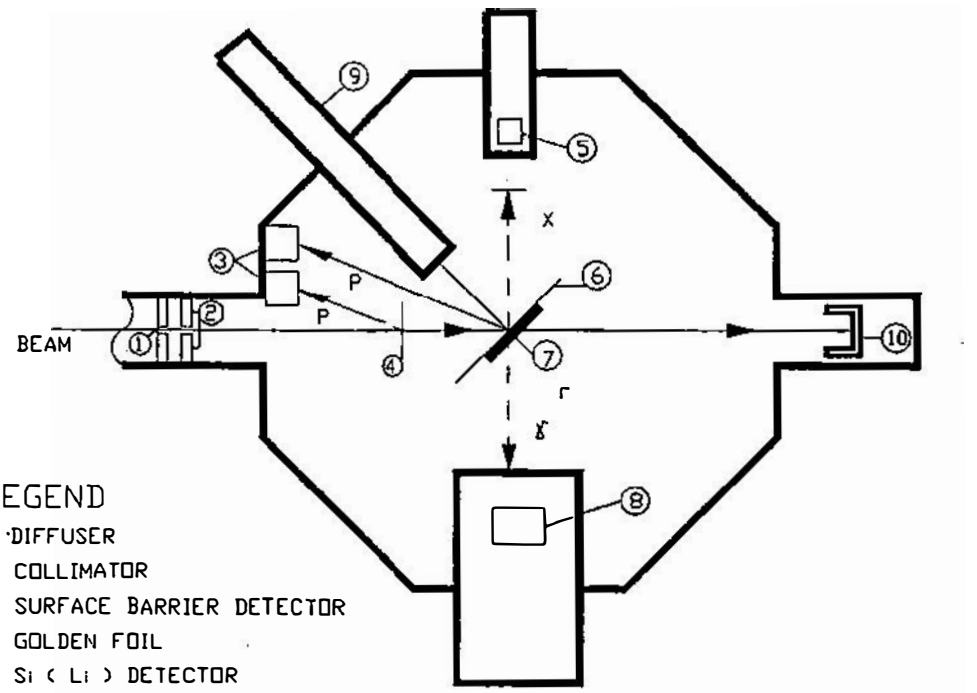


Figure 1. Shematic layout of the Tandem Van de Graaff accelerator in Zagreb.

For the development of PIXE technique, proton beam with energies from 1.5 to 4.0 MeV is used. In order to make use PIXE analitical capabilities as wide as possible, three scatering chambers were constructed.

The first target chamber (figure 2.) is designed to provide routine work, and it is mounted at the first beam line (0^{o}). Up to eighteen samples can be mounted on the sample changer. Samples are positioned at the 45^{o} angle to the beam direction. The semiconductor Si(Li) x-ray detector

(30 mm^2) is mounted at the right angle to the beam direction. In the same chamber the γ-ray detector as well as the backscaterring particle detector are mounted. In order to indirectly measure the total charge accumalated on the target, collimated beam (3 mm diameter) is transmitted through a thin golden foil before hitting the sample. This is important when direct measurement of charge collected in Faradey cup is not possible (thick target samples).



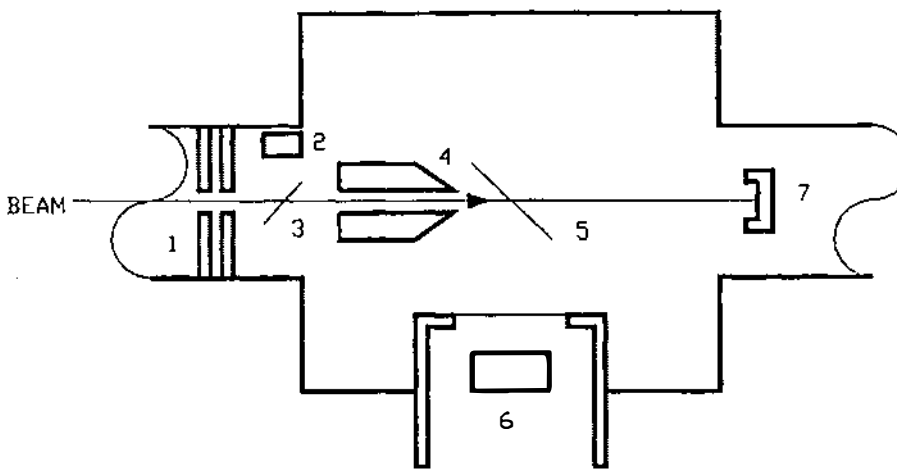
LEGEND

1. DIFFUSER
2. COLLIMATOR
3. SURFACE BARRIER DETECTOR
4. GOLDEN FOIL
5. Si (Li) DETECTOR
6. SAMPLE HOLDER
7. SAMPLE
8. Na I DETECTOR
9. SAMPLE CHANGER
10. FARADEY CUP

Figure 2. Scaterring chamber for routine PIXE analysis.

In order to optimize the system to the problem involved there is a possibility of placing various absorber foils between the sample and the x-ray detector. All functions. including the cnangeing of the samples. are remotely operated from the control room.

On the second experimental line (15°), the target chamber with the graphite collimator that reduces the beam diameter down to 100 μm (milliprobe) is mounted. Possibility of the transversal target displacement, provide option for the PIXE element distribution measurements. Shematic wiev of the chamber is given in figure 3.



LEGEND :

1. COLLIMATOR
2. SURFACE BARRIER DETECTOR
3. GOLDEN FOIL
4. GRAPHITE COLLIMATOR
5. SAMPLE
6. SI (Li) DETECTOR
7. FARADEY CUP

Figure 3. Scaterring chamber for the PIXE analysis with collimated beam (milliprobe).

Distance between target and detector can be easily changed in both chambers. This option is very important when small specimens are analyzed and therefore the best sensitivity is desired.

The third chamber where PIXE measurements will be made, is planned to be installed at the fourth beam line (45^{o}), where now a focusing system (microprobe) is under construction. A system consists of object (defining) slits, beam scanning coils and magnetic quadropole dublet with a possibility of focusing the beam down to the 1 μm diameter.

3. DATA ANALYSIS AND STORAGE

After amplification, pulses from the x-ray, γ-ray or particle detectors are transformed by the ADC (analog to digital converter) into digital values, and stored in multichannel analyzer. When spectrum collection is finished, data are stored in a PDP 11/34 computer. The analysis of the PIXE spectra is performed by AXIL [6], nonlinear least squares fitting program. Result of the analysis are the intensities of the caracteristic lines.

For the thin target samples, quantification of data is rather simple. The PIXE system is calibrated by using thin film standard samples.

Quantification of data for the thick target samples is not straightforward because of the x-ray absorption effects and change in the x-ray production cross section when protons are stopped in the sample. Two basically different

approaches are usually performed. The use of doped standards of the same matrix is the most accurate, but involves a rather great number of chemically prepared standard samples. The other possibility is to compute the specific x-ray yield of the element of interest for the given experimental conditions (accumulated charge, proton energy, detector used, sample matrix). In our case the THICK programme [7] for the computation of x-ray yields use proton stopping power data of Andersen and Ziegler [8], proton cross section provided by Cohen and Harrigan [9] and attenuation coefficients by Thiesen and Vollath [10].

4. DISCUSSION

With the PIXE systems explained, especially when combined with the RBS (Rutherford backscaterring) and PIGE (proton induced γ emission), it is possible to obtain a complete picture of the sample constituents. By using of collimated (milliprobe) and focussed (microprobe) beams, measurements of elements concentration distributions are possible too.

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