JSI Tandetron – Modern Interdisciplinary Research Facility


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ABSTRACT

The Tandetron accelerator of the Jožef Stefan Institute has been equipped with four beamlines. Installed spectroscopy methods include PIXE (vacuum, in-air, microbeam), RBS, ERDA, STIM, PIGE and high-resolution X-ray spectroscopy. Broad-beam PIXE is optimized and calibrated for automated aerosol analysis. In-air PIXE has been intensively used and optimized for ink characterization in documents, for studies of metallic objects, paints and glasses. Ion microbeam analysis, combining PIXE, RBS, SE and STIM has been performed on pigments, stalagmites, written documents and aerosols. Recently, the combination of micro-PIXE and forward scattering has been set-up for analysis of microbiological samples. For the analysis of the thin films and surfaces, the RBS spectroscopy and Hydrogen ERDA have been calibrated with Li ion beam, replacing conventionally used He ions. New TOF-ERDA spectrometer enables simultaneous analysis of light elements in thin films. At last, the Proton Beam Writing system (PBW) has been put in operation in 2003.

Keywords: Tandetron accelerator, ion beams, PIXE, dose normalization

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1. INTRODUCTION

Since the installation of the Tandetron accelerator in spring 1997, the accelerator laboratory at the Jožef Stefan Institute could rely on a stable ion beam tailored according to the demands from specific application. Due to the reliability of the computer-controlled accelerator, analytical work has been automated in order to run series of analyses over the night without presence of manpower.

2. HARDWARE SETUP

2 MeV Tandetron is equipped with duoplasmatron and sputtering ion sources. In order to provide proton beam with high brightness for the ion microbeam, the duoplasmatron has been configured for extraction of negative ions. The use of He ions for RBS/Hydrogen ERDA analysis has been adequately replaced by use of $^7$Li beam [1]. Hydrogen ERDA spectra have been evaluated by use of polyimide (kapton) as a thick hydrogen standard.

2.1 Beamlines

Doubly focusing high energy magnet is equipped with five exit ports, mounted at -30°, -10°, 0°, 10° and 30° with respect to the accelerator axis. Zero degree exit port is equipped with a Faraday cup to optimize the beam transmission. Four beamlines are installed at the exit ports of the switching magnet:

-beamline with external beam at -30°,
-ion microbeam at -10˚,
-beamline for broad beam analysis with PIXE chamber and RBS/ERDA/TOF-ERDA chamber at +10˚,
-beamline with high resolution X-ray spectrometer at +30˚.

2.2 Automation

Several automation projects have been completed in the LABVIEW® programming language. External beam measurements of manuscripts performed in the frame of the project “INKCOR” within the 6th Framework Project of the EU required large number of point and line scans by PIXE. The measuring point definition, object positioning, remote object distance recognition and spectrum accumulation have been integrated for a complete automated measurements in the preset points at the manuscripts.

For the PIXE measurements of series of aerosol samples, the sample positioning, dose control and spectra acquisition were integrated into a remote system.

The Proton Beam Writing system replaces the beam positioning available in the Omdaq system of Oxford Microbeams Ltd., which is running at our ion microbeam. The PBW system transforms B&W bitmap drawings into beam scanning pattern, providing fast (i.e. 10 ns) switching of the beam and pixel normalization by external counts.

2.3 Dose normalization

Several types of dose normalization have been applied at the Ljubljana tandem:
-external proton beam: the yield in the Ar K X-ray line is based on the fixed geometry of the exit nozzle, object and the detector.
-ion microbeam: the propeller is rotating in the beam after the collimating slits. The propeller is made of graphite layered with thick Au (4 micrometers). The RBS spectrum of protons scattered from the propeller at the angle of 135˚ is recorded simultaneously with the measured spectra.
-RBS/ERDA chamber: mesh charge integrator [2] is positioned in the beam. It is consisted of fine tungsten mesh encapsulated by two negatively biased apertures in order to suppress the escape of secondary electrons.
-PIXE chamber: chamber including all adjacent components is insulated from the surrounding and earthed via charge integrator.

In the later two cases, the digitized output of charge integrator is fed into the beamline controlling system in order to define the length of the each measurement. Beam stopping device could be either quartz window or inserted Faraday cup.

3. APPLICATIONS

Ion beam analytical methods have been applied to various types of samples, including aerosols, thin and thick layers and coatings, manuscripts, paintings, effect pigments, geological samples, metallic objects, plant and human tissues. Most recently, we put into operation the Proton Beam Writing (PBW) system at ion microbeam for micromachining of micromechanical objects.
3.1 Ion microbeam

Ion microbeam based on magnetic quadrupole triplet made by Oxford Microbeams Ltd. has been installed in 2000 [3] and is undergoing continuous upgrading. Most recently, the beam chopper has been installed after the collimating slit for dose normalization. RBS spectrum accumulated from the gold-coated graphite chopper is measured simultaneously with the PIXE, RBS, secondary electron and STIM spectra obtained from the target to define the impact dose of protons in the high current operational mode (currents typically above 10 pA). An independent beam control system for Proton Beam Writing has been put into operation, including fast beam deflection unit for fast ON-OFF switching of the beam. For the elemental analysis of thin tissue sections (thickness bellow 100 micrometers), STIM detector has been calibrated to determine the “thickness” map of the object.

The three-dimensional tomography of metallic pigments, consisting of Al flakes dispersed in synthetic resin, has been performed by the combination of RBS and PIXE method [4]. The pearlescent pigments, consisted of mica flakes coated by TiO$_2$, have been analyzed using the enhanced backscattering of protons from carbon.

3. CONCLUSIONS

Wide range of applications of ion beams at Ljubljana tandetron includes analysis of aerosols, archaeological objects, written documents, microbiology, thin films, effect pigments and micromachining by Proton Beam Writing.

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REFERENCES

2. M. El Bouanani, private communication, University of North Texas, Denton, unpublished.