Use of IBA techniques at the 3 MV Tandetron of IFIN-HH in environment, materials and life sciences

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Introduction

Ion Beam Analysis (IBA) techniques constitute a cluster of analytical techniques that use an ion beam for study of structures and composition of samples belonging to various classes of materials.
Particle Induced X-Ray Emission (PIXE) is an IBA technique based on the ionization of atomic inner shells of a sample/target by a charged particle beam (protons, in particular) entering the target, followed by emission of the characteristic X-rays [1-3]. **Particle Induced Gamma-ray Emission (PIGE)** is an IBA technique able to determine light elements, such as Li, B, C, F, Na, Mg, Al, P, S, and Cl, besides some heavier elements (e.g. Cr, Mn, Fe, Co, Cu), based on (p,p´γ), (p,γ), (p,αγ) or (p,nγ) nuclear reactions of the projectile particles "p" on target samples [4-7].
PIXE was applied for various applications by our team members using a 3 MeV proton beam, generated by the 9 MV FN Van de Graff Tandem accelerator of the *Horia Hulubei* National Institute of Physics and Nuclear Engineering (IFIN-HH) to determine elemental concentrations in different materials (steels), as well as environmental and biological samples [1-3,5-8].
PIXE proved to be a very useful analytical technique in environmental monitoring and interdisciplinary studies. PIXE was often used as a complementary technique to other multielemental nuclear and atomic techniques, such as instrumental neutron activation analysis (INAA) [1,9,10], PIGE [4-6], Rutherford Backscattering Spectrometry (RBS) [2,7,8] and X-ray fluorescence (XRF) [1, 10-12].

Aim of research

The aim of the present proposal is three-fold: 1) to simultaneously use PIXE and PIGE ion beam analytical techniques for the determination of some major, minor and trace elements in selected environmental samples (animal tissues, aquatic plants, bottom sediments, soils), in order **to complete the atlas of maps of pollution points** and **the database** built in the frame of the Romania-Ukraine-Republic of Moldova cross-border project MIS ETC 1676 (INPOLDE) in the Lower Danube Euroregion and Black Sea area [13]; 2) to apply IBA techniques (PIXE, PIGE, RBS) for bioaccumulation studies of minerals and toxic elements from environment/substrate to related biological tissues in industrial areas in Romania; and 3) to apply IBA techniques (PIXE, PIGE, RBS) for study of impurities in materials with exclusive properties (corrosion resistance, microhardness, chemical resistance, biocompatibility, etc.), such as special steels, biomaterials and polymers.

The samples to be investigated were collected by an international team from polluted (industrial areas) and border natural protected areas in Lower Danube basin, Danube Delta and Black Sea [12-14].

The results obtained by PIXE and PIGE at IFIN-HH in previous experiments for environmental and biological samples were compared with those determined by related nuclear techniques - atomic

absorption spectrometry (AAS), inductively-coupled plasma mass spectrometry (ICP-MS) and energy-dispersive XRF – employed at the collaborating institutions: Dunarea de Jos University of Galati (UDJG), Romania, Institute of Zoology and Institute of Geology and Seismology of Academy of Sciences of Moldova, Chisinau, Ukrainian Scientific Centre of Ecology of the Sea, Odessa, Ukraine, Technological Educational Institute of Kavala, Greece, and Valahia University of Targoviste (UVT), Romania [11,12,14]. PIXE and PIGE results will also permit: a) to complete the studies regarding the regional extent of pollution with heavy metals and toxic elements in Lower Danube and Black Sea areas; b) to identify the trace elements of anthropogenic origin and their bioaccumulation pattern in living organisms in the vicinity of industrial enterprises.

This collaboration will enforce the research partnership of Romanian institutions (UDJG, IFIN-HH, UVT) with research institutes from other countries and will have in view the enlargement of the research network in order to apply to European and international calls of proposals. Furthermore, it is foreseen that, beside the accelerator staff, more scientists (PhD students, young and senior researchers) will get benefit from these analytical tools.

Experiment proposal

Application of PIXE, PIGE and **RBS techniques** using a beam of **3 MeV protons** will be carried out for interdisciplinary studies in order to determine major, minor and trace elemental contents in **biological samples (tissues of fish and molluscs, aquatic plants, cultivated plants, tree leaves and bark), environmental samples (bottom sediments, soils)** and **advanced materials (special steels, biomaterials)** using comparator **standards of similar matrix**, prepared as **thick targets** (IAEA and NIST standards, as well as chemical compounds of elements to be determined). The elements of interest for PIXE are: Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Rb, Sr and Pb. The elements of interest for PIGE are: F, Na, Mg, Al, Si, P, S, Cl, Cr, Mn, Fe, Cr, Co, and Cu. The elements of interest for RBS in biological and environmental samples are: H, O, C, and N.

The detectors used in experiments are of High Purity Germanium (HPGe) type: a) for PIXE (X-ray detection) – SDD Amptek with Be window of 0.00762 mm, placed inside the reaction chamber (140 eV resolution at 5.9 keV); b) for PIGE (γ-ray detection) - GEM10P4-70 High Purity Germanium (1.75 keV FWHM at 1.33 MeV of ^{60}Co), placed at 15 cm outside the reaction chamber. For RBS, a passivated ion implanted silicon detector with energy resolution of 16 keV was used.

Examples of PIXE and PIGE spectra measured at IFIN-HH by our team for a thick target biological sample are given in Fig. 1 [to be published]. RBS spectrum for a tree leaves environmental sample is given in Fig. 2 [7]. The samples were dried, ground, and then pressed as pellets (~ 1 mm thickness, diameter 1 cm) using a hydraulic press.

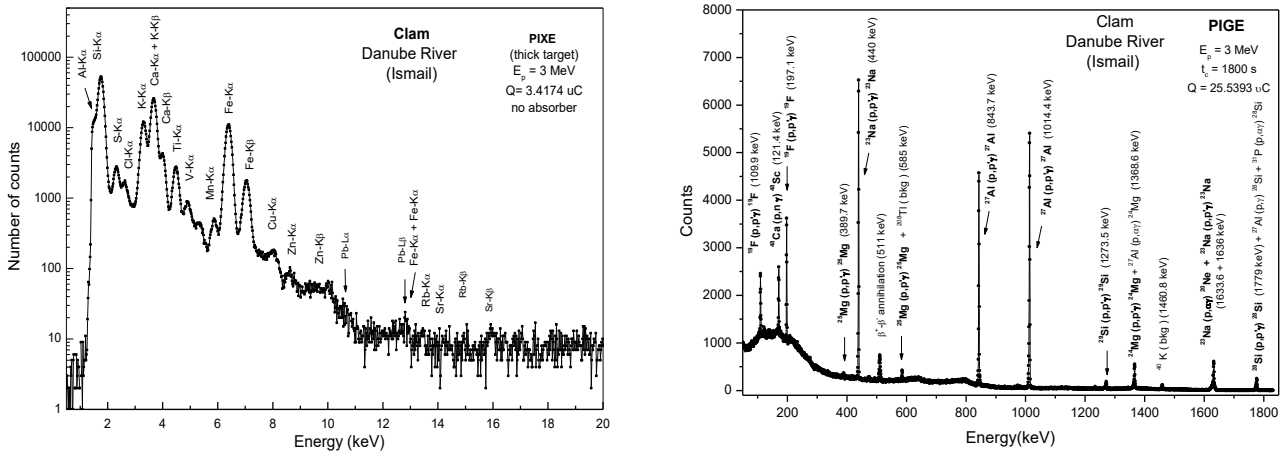

Fig.1. PIXE and PIGE spectra at IFIN-HH for a Danube River clam sample (thick target)

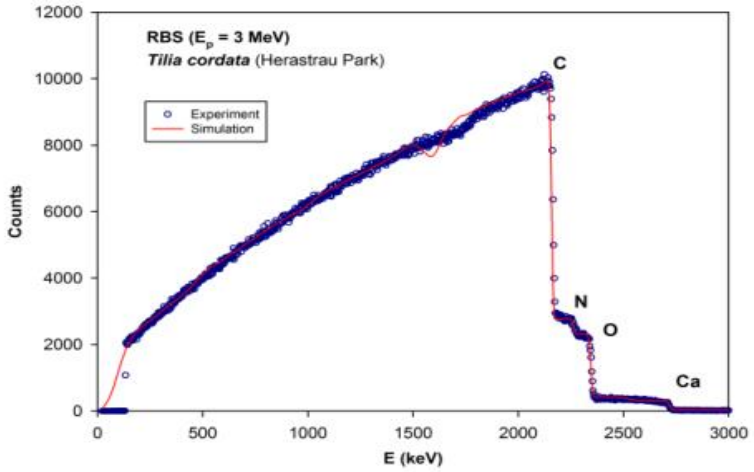

Fig.2. RBS spectrum at IFIN-HH of a tree leaves sample (thick target).

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BEAM REQUEST at Bucharest 3 MV TANDETRON

Experiment Title: Use of IBA techniques at the 3 MV Tandetron of IFIN-HH in environment, materials and life sciences.

Experiment Responsible

Name*: Prof. Dr. habil. Antoaneta Ene; E-mail address*: aene@ugal.ro; Phone: 0745164178

Short presentation of the scientific project (maximum four pages): see above

Beam time request (unit=8 hours)*: 30 shifts; Desired Period*: 2 periods in 2nd and 3rd trimesters

Desired beam properties

Type*: protons; Energy (MeV)* 3; Intensity*(p/nA): ~ 5-10 nA

Vacuum Requests*: 10^{-6} torr

Special requirements for detectors, electronics, acquisition system:

Experimental set-up belonging to the IBA reaction chamber

Minimal information needed for the radiological risk evaluation:

a) Source activity:* -

b) Use of open sources*: -

c) Estimate of the residual activity as a result of irradiation*: -

d) Means of storage/transportation for irradiated targets*: -