LABORATÓRIO ABERTO DE FÍSICA NUCLEAR

PAC 2023

Proposal	N° 43 (cont) + 15 (cont)
Title: **Irradiation with ion beams: modification and characterization of materials**	
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Number of days for experiment:	1 + 1+ 1 + 1+ 1
Period planned for the experiment (are the setup ready for beam time?): Experiment can be used in next month	

Technical information

Ion source			Accelerator			Experimental Area	
Beam	Cathode	$I_{mínima}$	V_{min}	V_{max}	Bunched beam?	Beam line	Target
Several		300 nA	6,5	7,5	n	0	several
H	TiH2	500 nA	6,5	7,5	n	0	several
Cl		300 nA	6,5	7,5	n	0	several

Other relevant/needed information:

New beam line setup (0 beam line)

One or two days each two or three months

Irradiation with ion beams: modification and characterization of materials

The interaction between charged particles with matter can be used for produce new materials, radioactive materials or also to destroy some cancerous cells in radiotherapy. The main goal of this project is to provide experimental setups that attend specifications of each irradiation. In particular, to attend the irradiation of samples that can´t be mounted in a low-pressure chamber, we have developed an external beam setup. One of the characteristics of that setup was to allow the simultaneous irradiation of several small samples (5 x 5 mm^2) with the same dose. The total dose in samples was evaluated by a surface barrier detector used as a monitor facing the Al foil exit window.

One of the most used techniques to identify elements in a sample is PIXE (Particle Induced X-ray Emission) technique. The identification of characteristic X-ray leads to a very precise identification especially for high Z elements. It is well known that PIXE has a better efficiency to identify high Z elements. A complementary technique to identify low Z elements is PIGE technique, which discriminate the elements analyzing the particle induced gamma-ray emissions. By applying both PIXE and PIGE methods, a very good overall picture of the elemental composition of a sample may be obtained. The important additional advantage of an external beam combined with these techniques is that heat dissipation from the surface of sample is effective and samples may be cooled easily. Another characteristic of this combination is related with the possibility of analyzing samples that cannot fit or be under low pressure. This is the case of some archaeological artifacts (porosity) or biological samples (liquid solutions).

Another option is to use ERDA technique that is very efficient to identify and quantify implanted (or evaporated) substances on surfaces of large samples. This technique is specially indicated for samples consisted of thin films of light Z elements (mainly under Ne) on substrates of heavy Z elements, a mass region where other techniques (like RBS - Rutherford BackScattering) have a low efficiency. Our setup uses an ionization chamber to perform measurements using a ΔE-E technique to identify the elements, identifying the ejectiles by their Z number. Data are taken using an ionization chamber mounted at 45^o in relation of beam direction. Samples are mounted with a 60^o in relation of beam direction. Analysis of the two-dimensional spectrum shows a clear identification of the isotopes, specially for the Z under 17.

In order to show the quality of data obtained with our experimental configuration we present below a two-dimensional spectrum ΔE-E from our participation in a “robin round” experiment to analyze Al N O films on Si substrate with width ranging from 10 to 1000 A. Samples were generated by Dr Nuno Barradas in Sacavem (Portugal). Statistical analysis comparing results of several laboratories showed that our results were consistent with most of other laboratories and that we were part of the few able to distinguish the N contribution in the thinner films.

These options are available in a new beam line installed in the laboratory dedicated to irradiation procedures. The new setup allows the irradiation of single samples using a focused beam of some nA or a broad homogeneous beam (areas up to 2 x 2 cm^2) with intensities ranging from 10^2 to 10^7 particles/s/cm^2. Other feature of the new setup is a 4D goniometer controlled target holder allowing the variation in the position and the incidence angle of the irradiated area. In new period our group (GFAA) intends to use our irradiation setups to probe several materials, some in collaboration with other groups.

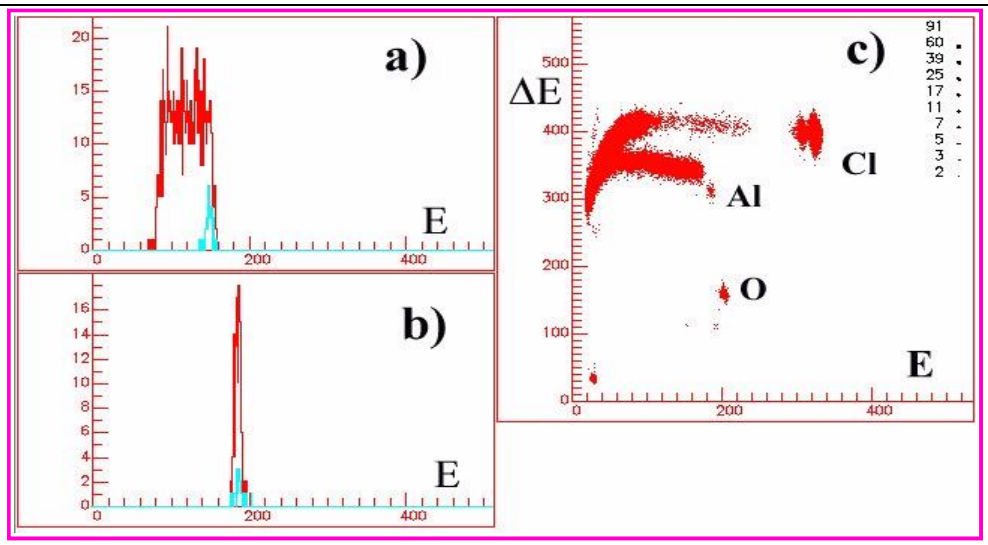

Figura 1: a) Energy spectrum obtained for Al recoils from samples (ITN - Portugal), nominally 1000 and 10 A; b) Energy spectrum obtained for Al recoils from samples (ITN - Portugal), nominally 10 and 100 A; c) Two Dimensional spectrum DE x E obtained for sample S3.

We present below some measurements performed previously in collaboration with different groups:

A) Modifying materials

- **Irradiation of proton in DNA samples** - evaluation of number and size of fragments (Collaboration with Depto Física Experimental - IFUSP, IPEN, Universidade de Havana) Tese de Mestrado.
- **Proton dosimetry** - investigation of new materials for proton dosimetry motivated by its use in radiotherapy (Collaboration with Emico Okuno's group - DFN-IFUSP). Amostras de Eduardo.
- **Irradiation of plastic foils (polymers) to create ion tracks**. These irradiations were used in pos-graduation works in our group (GFAA), studying the characteristics of these ion tracks for several configurations of ion/energies and using these ions tracks for generating micropores eventually used to build micro structured devices.

B) Identifying composition

- **Measurements to evaluate the traces elements composition in three different species:** human, bovine and suine teeth. This work was a collaboration between our group and the Faculdade de Odontologia da USP.
- **Thickness and composition of CN films:** In collaboration with LACIFID group (J.F. Chubaci, M. Matsuoka). In order to investigate hardness of CN films, samples are produced using different methods. Recently, the group has implemented the IBAD technique that allow the production of thin films with a high purity. Results of measurements combined with mechanical properties of the films indicate which method is the most efficient to achieve the expected behavior.

- **Measurement of B in Si samples:** In collaboration with IPT researchers (J.B. Ferreira Neto). One of the problems in the development of silicon technology for solar cells is to evaluate the contamination of impurities in the metallurgical process. Several methods can be used, but none is as efficient as ERDA to measure the depth profile of boron in Si, especially if this contribution is in the ppm region.
- **Influence of nitrogen content on the surface in the ductility of ancient swords:** In collaboration with Diogo Emiliano. The project aims to correlate ductility of ancient swords obtained measuring mechanical properties with the nitrogen contribution on the steel surface. As it is well known, the nitriding of metallic pieces change their mechanical properties. Using $^{15}N(p,\alpha\gamma)^{12}C$ reaction, it is possible to evaluate the nitrogen content as well as its depth profile for the swords. This information can be analyzed together with crystalline structure of these compounds to understand their correlation with ductility.
- **Study of the Sr/Ca relation in bones as a temperature sensor**: That is an ongoing project of our group. Bones are basically formed by Ca compounds, highlighting hidroxyapatite. In biological systems, Ca atoms are replaced by Sr atoms, depending on the offer of Sr and the temperature of environment. In this project, we will measure Sr/Ca relation in bones from several species to investigate the correlation with body temperature. As the most of biological samples, these measurements should be done using external beam setup

Future measurements:

- **Analysis of corrosion in metallic surfaces:** That is an ongoing project of our group in collaboration with several groups, highlighting the MAE group. As in the case of ceramics, sometimes the thickness of corrosion films on metallic surfaces demands a more energetic beam in order to investigate the internal region of metallic sample. The information of the composition of the internal region is fundamental to understand the corrosion processes and help indicating the best way to treat the problem.
- **Production of neutron beam using specific nuclear reactions**: The idea is develop a procedure to generate neutrons beams with specific energies to be used in irradiation processes (mainly investigating SEE processes). We intend to check the energy and angular distribution of these neutrons in the new beam line setup using known nuclear reactions mechanisms.
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- **Measurement of hydrogen in steel samples:** In collaboration with Centro Tecnológico da Marinha researchers (D.Y. Kobayashi). The stress failure of steel (350 type) has been related to hydrogen contamination during the fast oxidation process. ΔE-E ERDA technique it will be used to identify H contribution in the oxidized film. Samples prepared in controlled environment will be probed to evaluate the sensitivity of measurements.