Irradiation with ion beams

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).

In the last period, a new beam line was installed in the laboratory dedicated to irradiation procedures. The new setup allows the irradiation of single samples using 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:

In first years we have performed measurements 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.
- New technology for tiristors construction - defects generation in a given piece of device induced by proton irradiation.
- 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.

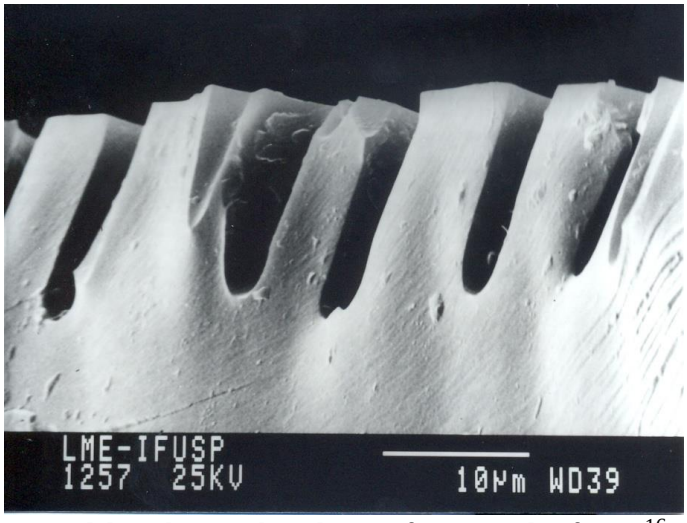

Figure 1: Pores generated by chemical etching of ion tracks from ^{16}O (24 MeV) ion beam in CR39

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. Results show a clear difference in the trace elements composition in these species.

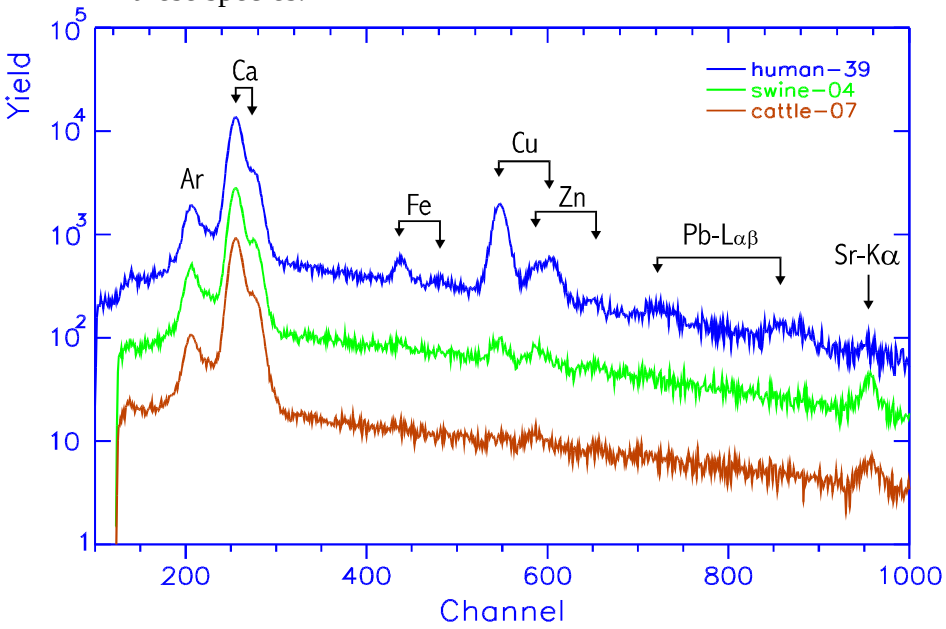

Figura 2: X ray spectra obtained using the external beam setup at Pelletron Laboratory

Future measurements were based in the following lines:

Irradiation of polymers: In future works our group intends to study the relationship between tracks created by radiation damage of each single projectile and characteristics of pores that can be generated by chemical etching. For that we will irradiate several samples varying the ion/energy configuration trying to generate different types of damage in the ion tracks.

1) M.E. Brandan, I. Gamboa-de-Buen, M. Rodriguez Villafuerte - Private communication
2) B. Jayant Baliga, E. Sun - IEEE Transactions on electron devices ED-24 (1977)

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.

1) J. Räisänen, A. Antilla **NIM196** (1982) 489
2) E.T. Williams **NIM B3** (1984) 211
3) J. Räisänen **NIM B17** (1986) 344

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.

1. MEUDERS, J.P., LELEUX, P., MACQ, P.C., PIRART, C., Fast neutron yields and spectra from targets of varying atomic number bombarded with deuterons from 16 to 50 MeV (for radiobiology and radiotherapy), Phys. Med. Biol. 20 (1975) 235–243
2. WREAN, P.R., BRUNE, C.R., KAVANAGH, K.W., Total cross sections and thermonuclear reaction rates for 9 Be(α,n)12C, Phys. Rev. 49 (1994) 1205–1213.

We estimate in next year we will need about 4 days for analyzing samples.

PAC 2018

Proposal	N° 43 (cont)
Title: **Irradiation with ion beams**	
Responsable: **Nemitala Added**	e-mail: **nemitala@if.usp.br**
Participants **N. Added, M.A. Rizzuto, M.H. Tabacniks, bolsistas IC**	
Spokeperson: **Nemitala Added**	e-mail: **nemitala@if.usp.br**
Telephone: 3091-6824	Skype:
Number of days for experiment:	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
D	TiD2	500 nA	6,5	7,5	n	0	several

Other relevant/needed information:

New beam line setup

One day each two or three months

Previous Information on Project

Proposal approved	
Period of beam time (date)	
Results or problems: Problems: Installation of a new setup in the 0 degree beamline.	
Proposal approved	N
Period of beam time (date)	
Results or problems:	