Irradiation with ion beams

A) Modifying 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 particular 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 this setup is to allow the simultaneous irradiation of several small samples (5 x 5 mm^2) with the same dose. The total dose in samples can be evaluated by a surface barrier detector used as a monitor facing the Al foil exit window.

In the last years we have performed measurements in collaboration with different groups:

- 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.

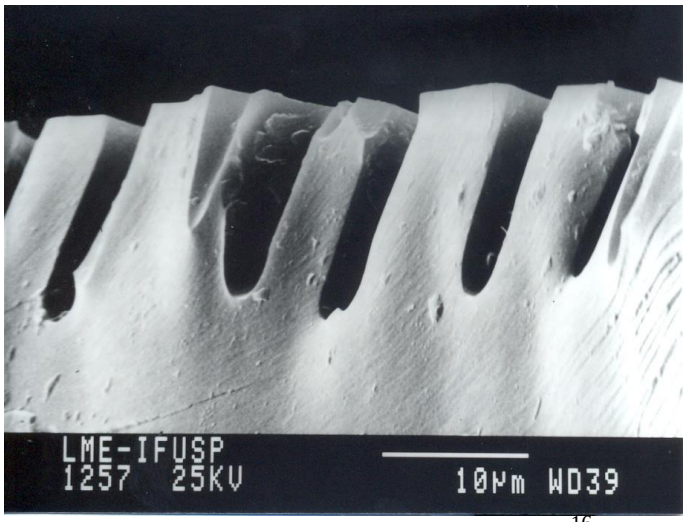

Figure 1: Pores generated by chemical etching of ion tracks from ^{16}O (24 MeV) ion beam in CR39

For this new period our group (GFAA) intends to use our irradiation setups to probe several materials, some in collaboration with other groups:

Irradiation of polymers: In these 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)

B) Identifying composition

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).

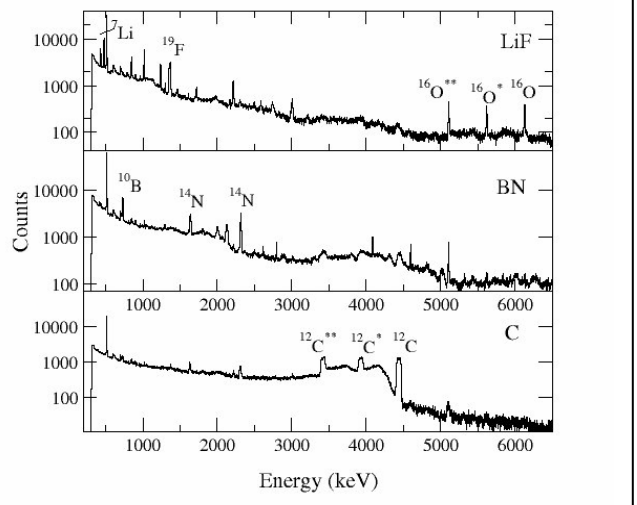

Figure 1. Energy spectra obtained for some of the simple compounds analyzed in the experiment. Peaks used for identification of elements are pointed out in figure. Stars on C and O indicate single and double escape processes for these energies.

The experimental setup used for measurements uses a 0.5 mm Al exit window after a 3mm Tantalum collimator. Detection system consists of a HPGe detector (from gamma group) for gamma rays and a Si(Li) detector for X rays. This setup was used to perform 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.

An experimental setup can be mounted in 30B beam line. First measurements indicated that will be easier to control a low intensity beam in this setup, a necessary condition for these experiments to minimize dead time in the acquisition system. We have also improved our experimental setup in order to be

possible the simultaneous PIXE and PIGE measurements. Results indicated we must reduce and control the contribution from the interaction of beam particles with collimators and exit window.

In the future we plan to adapt our setup to use the zero degrees beam line, that it was built to reduce the intensity of the probing beam without losing intensity in the control area of accelerator.

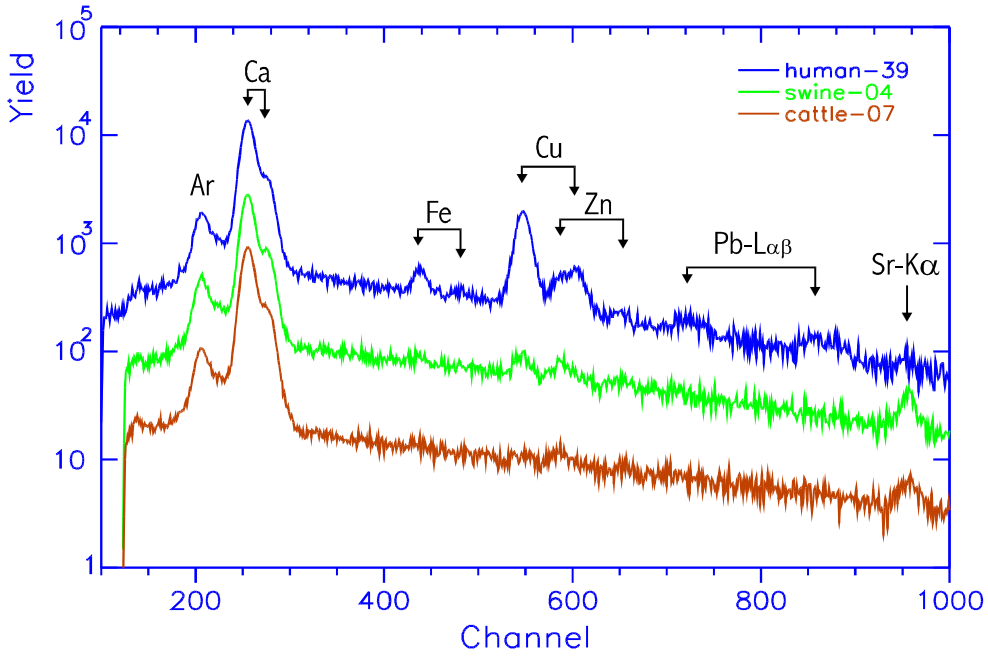

Figura 1: X ray spectra obtained using the external beam setup at Pelletron Laboratory

Future measurements were based in the following lines:

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.

Analysis of ceramic samples: in collaboration with UEL researchers (Carlos Appoloni). Ceramic samples can be classified in relation to several properties: clay used, treatment of external or internal surface or functionality. Many times it is necessary to use energetic

proton beams (or heavier) to be able to pass the external surface to excited the atoms in the clay region. The range of a 15 MeV proton beam is around 1,4 mm in a Si piece, allowing the analysis of the internal region of ceramic pieces.

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.

We estimate in next year we will need about 1 days for optimazing the new setup and another 3 days for analyzing samples. So we request a total of 4 days for next year.

Bibliography

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

Previous Information on Project

Proposal approved	N 43d
Period of beam time (date)	09 a 13 /12 /2013

Results or problems:
Measurement of SEE cross section for 3n163 transistor + study of waveform of the related electrical pulse

Data used in the Vitor Aguiar´s master dissertation

Experimental setup for Single Event Effects at the São Paulo 8UD Pelletron Accelerator
VAP Aguiar, N Added, NH Medina, ELA Macchione, MH Tabacniks, ...
Nuclear Instruments and Methods in Physics Research Section B: Beam ..

Brazilian facilities to study radiation effects in electronic devices
NH Medina, MAG Silveira, N Added, VAP Aguiar, F Aguirre, R Giacomini, ...
Radiation and Its Effects on Components and Systems (RADECS), 2013 14th

Medina, N.H., et al., "First Successful SEE Measurements in Brazil", IEEE Radiation Effects Data Workshop (REDW), 2014, Paris, France.

Proposal approved	N 43 d
Period of beam time (date)	02 a 06 / 06/ 2014

Results or problems:

Analyzing waveform for SEE with a PXI based configuration. Two transistors were irradiated: 3n163 + bipolar (Collaboration FEI)

Data used for definition of experimental setup with PXI

A Commercial off-the-shelf pMOS Transistor as X-ray and Heavy Ion Detector
MAG Silveira, MAA Melo, VAP Aguiar, A Rallo, RBB Santos, NH Medina, ...
Journal of Physics: Conference Series 630 (1), 01201

A New Test Environment Approach to SEE Detection in MOSFETs.
LE Seixas Jr, MAG Silveira, NH Medina, VAP Aguiar, N Added, ...
Advanced Materials Research 1083

Proposal approved	N 43d
Period of beam time (date)	13 a 15 /10/2014

Results or problems:

Measurements of SEE curves for:

1) Spartan3 (collaboration with PUC-RS) – varying Gate voltage and X-ray doses
2) Zynq (collaboration with UFRGS)

X-Ray-Induced Upsets in a Xilinx Spartan 3E FPGA
MAG da Silveira, RBB Santos, FGH Leite, NE Araujo, NH Medina, ...
Radiation and Its Effects on Components and Systems (RADECS), 2015 15th ..

Proposal approved	N 43d
Period of beam time (date)	28/04 a 01/05/2015

Results or problems:

Investigation of mitigation techniques (collaboration with UFRGS) for reducing SEE for:

1) Zynq using ARM for communication
2) Artix direct communication

Proposal approved	N 43 d
Period of beam time (date)	27 a 31 /07/2015

Results or problems:

Measurement of SEE curves and investigation of imprint effects in Spartan3 varying X-ray doses

Analysis of SRAM-Based FPGA SEU Sensitivity to Combined Effects of Conducted EMI and TID
J Benfica, B Green, BC Porcher, LB Poehls, F Vargas, NH Medina, ...
Radiation and Its Effects on Components and Systems (RADECS), 2015 15th

X-Ray-Induced Upsets in a Xilinx Spartan 3E FPGA
MAG da Silveira, RBB Santos, FGH Leite, NE Araujo, NH Medina, ...
Radiation and Its Effects on Components and Systems (RADECS), 2015 15th .

Proposal approved	N 43 d
Period of beam time (date)	09 a 11/nov/ 2015

Results or problems:

Checking new beamline alignment with beam.
Problems: no slits control

Data will be used in Vitor Aguiar's Thesis

Proposal approved	N 43d
Period of beam time (date)	14 a 18 /12/2015

Results or problems:

Investigation of Multiple Bit Upsets varying Linear Energy Transfer (collaboration with UFRGS) + measurement of SEE curve for Zynq

Heavy Ions Induced Single Event Upsets Testing of the 28 nm Xilinx Zynq-7000 All Programmable SoC

LA Tambara, FL Kastensmidt, NH Medina, N Added, VAP Aguiar, ...

Radiation Effects Data Workshop (REDW), 2015 IEEE, 1-6

Proposal approved	N 43d
Period of beam time (date)	26 a 29 / jan/2016

Results or problems:

Measurements of SEE for ProAsic3

1) Citar Collaboration – influence of different mitigation techniques in the SEE measured in the flash memory of device
2) Curve SEE + imprint effects (collaboration with PUC-RS)

Analysis of single event upsets in a Microsemi ProAsic3C FPGA
PRC Villa, RC Goerl. F Vargas, et al
RADECS 16

Proposal approved	N 43 d
Period of beam time (date)	24 a 26 /fev / 2016
Results or problems: Investigation of SEE in ARM and PIN diodes (collaboration with FEI): Waveform and cross section Ionizing radiation effects on a COTS Low-cost RISC microcontroller FFH Leite, RBB Santos, MAG Silveira et al. Radecs 16	

Proposal approved	N 43 d
Period of beam time (date)	29/2 a 02/03/2016
Results or problems: CITAR collaboration – investigation of SEE cross section for different mitigation techniques using a SpaceWire interface	

Proposal approved	N 43 d
Period of beam time (date)	21 a 24 /03/2016
Results or problems: Investigation of Multiple Bit Upsets varying Linear Energy Transfer (collaboration with UFRGS) in two ways: changing projectile or changing the incidence angle	
Proposal approved	N
Period of beam time (date)	
Results or problems:	

LABORATÓRIO ABERTO DE FÍSICA NUCLEAR
PAC 2016

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, P.H.O.V. Campos, 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, 30B	several
H	TiH2	500 nA	6,5	7,5	n	0, 30B	several
D	TiD2	500 nA	6,5	7,5	n	0, 30B	several

Other relevant/needed information:
One day each two or three months