ACTIVITY REPORT 2017-2019

2020/08/30

Laboratório de Aceleradores e Tecnologias de Radiação (LATR)

Campus Tecnológico e Nuclear
Instituto Superior Técnico, Pólo de Loures
Estrada Nacional 10, km 139,7, Bobadela LRS, Portugal

Many thanks to researchers and technicians in providing material for this annual report.

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Deputy-Diretor:

Eduardo Alves, ealves@ctn.tecnico.ulisboa.pt

Scientific Output:

Teresa Pires/Ana Faria

Desktop Publishing, Layout and Design:

Teresa Pires, tpires@ctn.tecnico.ulisboa.pt

Cover Photo: Norberto Catarino at Van de Graaff Accelerator, under the JET ILW (ITER Like Wall) Eurofusion project.

Date: August 2020

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ACTIVITY REPORT 2017-2019

LABORATÓRIO DE ACELERADORES E TECNOLOGIAS DE RADIAÇÃO (LATR)

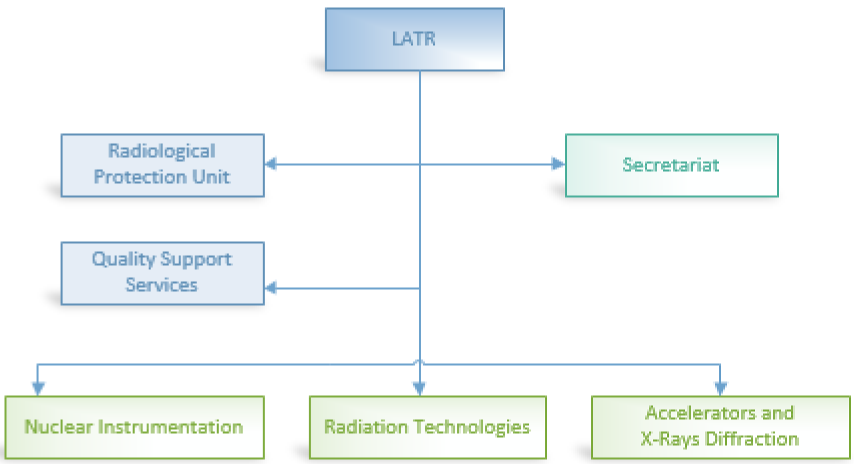
FOREWORD

The *Laboratório de Aceleradores e Tecnologias de Radiação* (LATR, Laboratory of Accelerators and Radiation Technologies), is a laboratory for development and technology (LDT) of *Instituto Superior Técnico* (IST) conducting services and research in the area of charged particle beams and radiation technologies. Among the infrastructures and equipment, it hosts a 2.5 MV Van de Graaff Accelerator and an Ion Microprobe end-station, a 3 MV Tandem Accelerator with a micro-AMS system and a 210 kV High Flux Ion Implanter as well as a semi-industrial ^{60}Co gamma radiation unit.

Around these infrastructures and equipment, different groups of users develop their activities, from research to industrial applications (as it is the case of irradiations services performed at the 60- Co source), focused on areas related with Material Science, Environment, Health and Biomedical Sciences and Conservation and Cultural Heritage. These broad ranges of applications promote and attract strategic collaborations with several institutions and universities, both at national and international levels.

Alongside these activities, strong emphasis has been continually put on postgraduate teaching and training, by actively enrolling graduate students in research activities, leading to masters and doctoral theses.

During 2017-2019, the activities in the Laboratory were focused in two major pillars: advanced services and support to research activities and teaching. Services were mostly provided under radiation technologies and nuclear instrumentation, while the team responsible for the accelerators and X-ray operation supported the research and teaching activities. All these activities were performed under the coordination of the 3 units integrating LATR which is organized according the organigram below.



Radiation Technologies unit explores the *Unidade Tecnológica de Radioesterilização* (UTR, Radioesterilization Technological Unit) using the ^{60}Co source for sterilization, decontamination, disinfection and conservation with applications mostly to medical devices, pharmaceuticals, cosmetics, raw materials, packing, and laboratory equipment. Moreover, the unit provides assistance to institutions in the field of radiation technology transfer under industrial environment and is partner in several International Atomic Energy Agency (IAEA) technical programmes.

Nuclear Instrumentation unit is active in two areas: development of nuclear instrumentation for measurement and control, with applications in productive sectors of the economy and service sectors as well as the sale and supply of equipment and specialized services, including technical assistance and consulting.

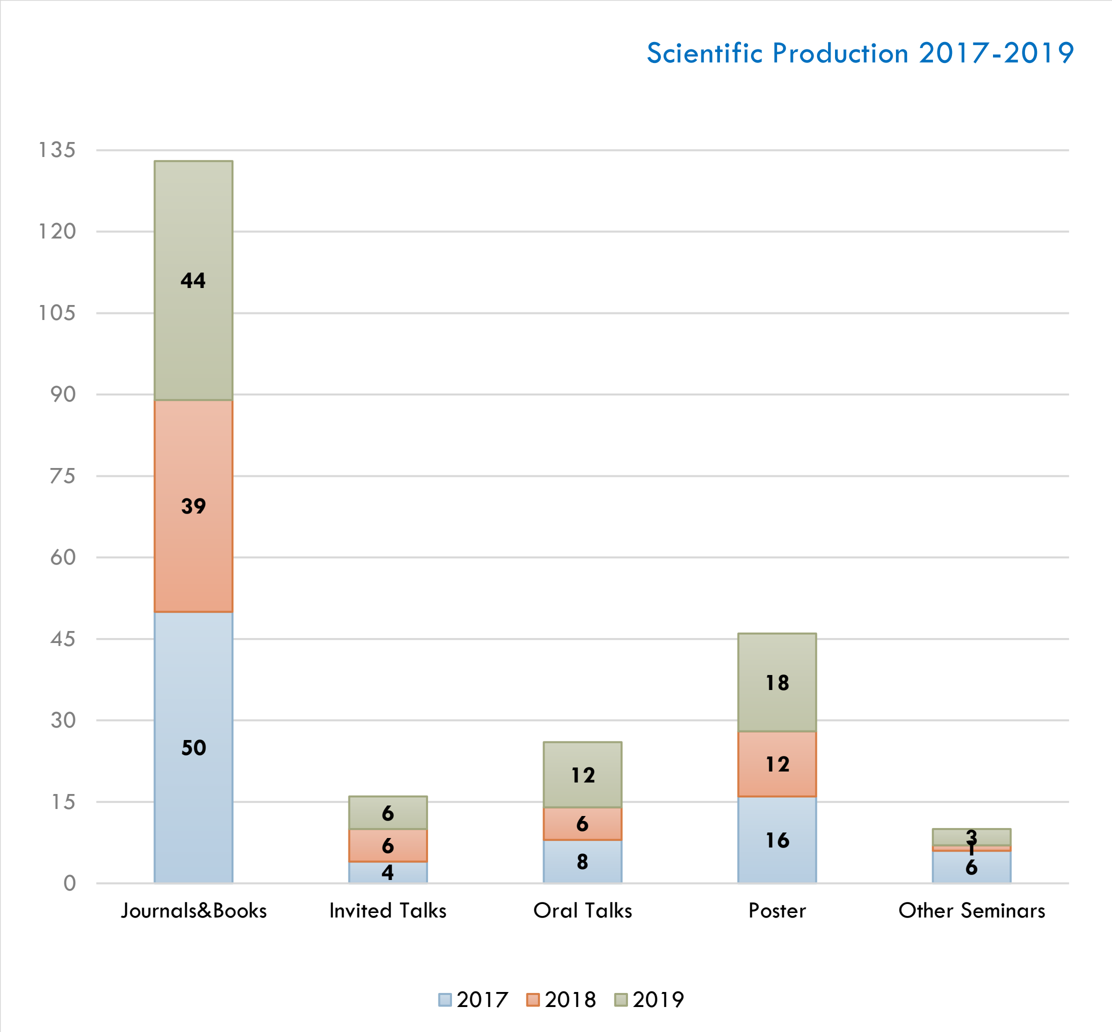
Accelerators and X-ray Diffraction unit has a long standing research activity on charge particle interactions with solids leading research projects and collaborating in several research programmes both National and European. Currently the unit is partner in the project *INFRAIA-01-2018-2019 (H2020): Research and Development with Ion Beams – Advancing Technology in Europe (RADIATE)* and very active in the European Fusion Programme, EUROfusion.

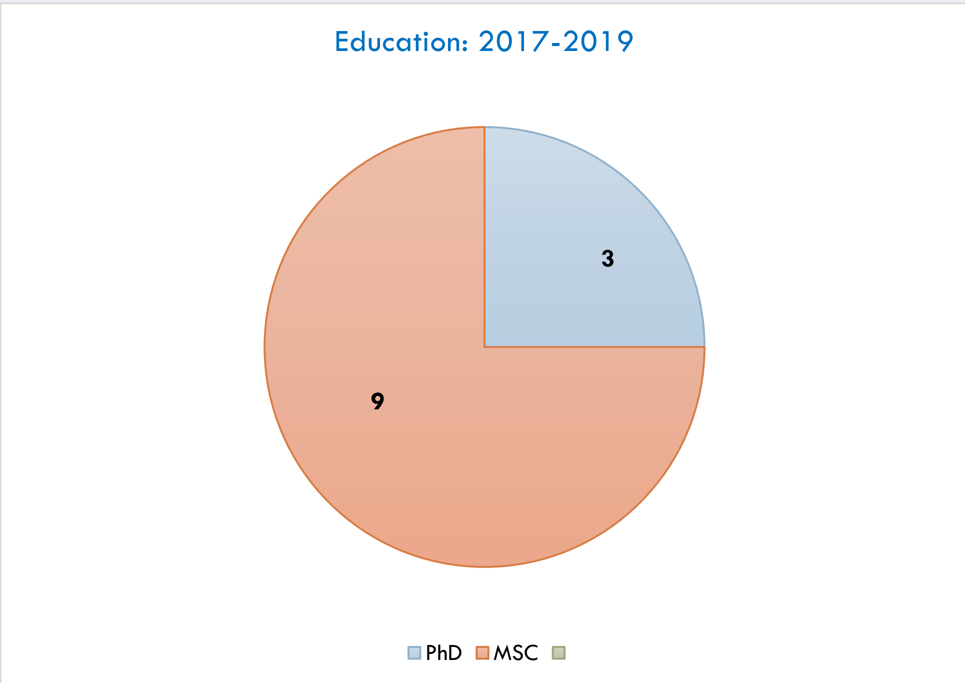
All the LATR Members belong to the *Departamento de Engenharia de Ciências Nucleares* (DECN, Department of Engineering and Nuclear Sciences) and during 2017-2019 contributed for the outputs on R&D and services highlighted in the next pages.

The Deputy-Director

Eduardo Jorge da Costa Alves

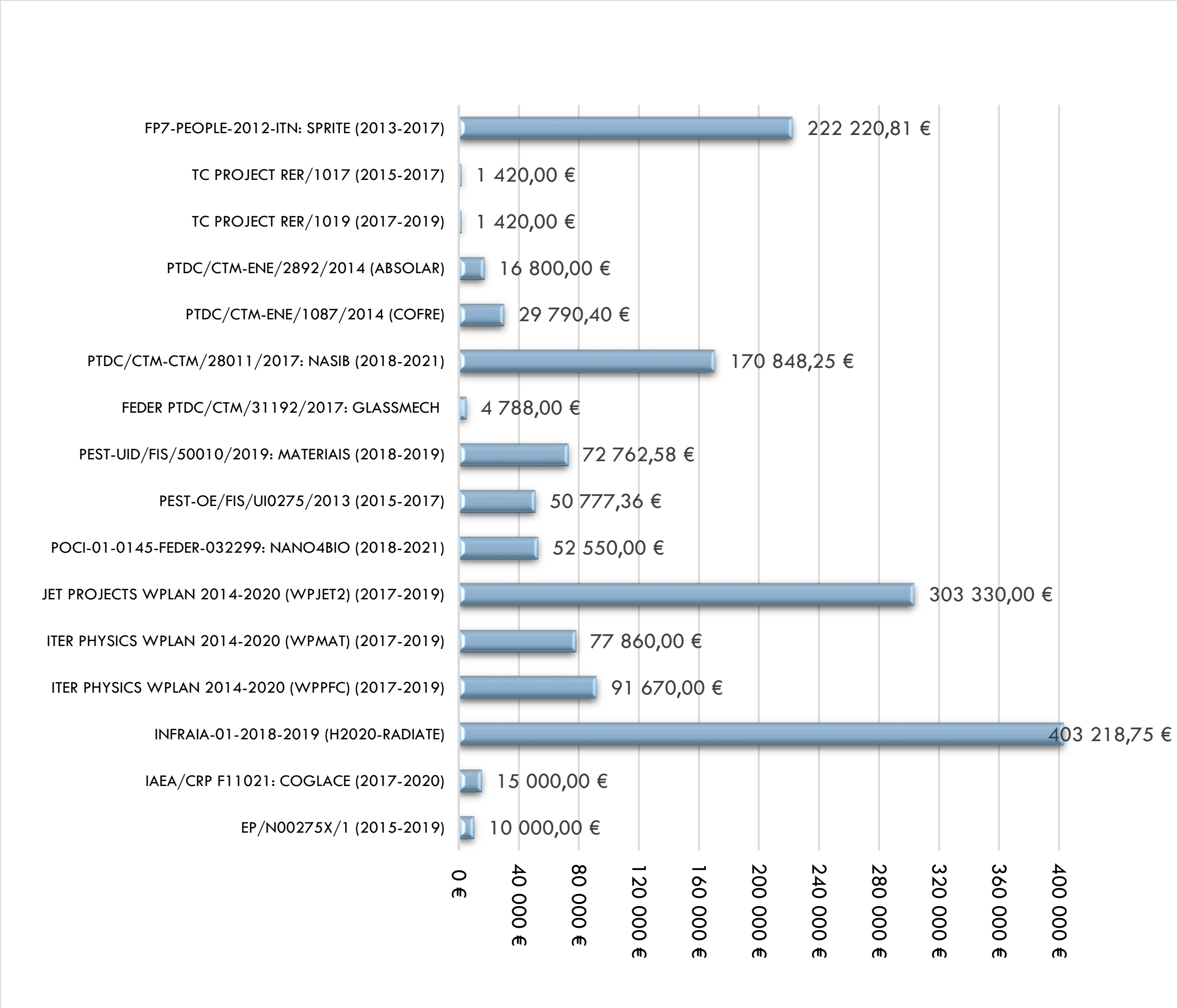
STATISTICAL TRACK RECORD





Scientific Projects: 2017-2019

Total Funds: 1.524.456,15 €



PEOPLE | 1: WORKING TEAM

R&D | PERMANENT STAFF


Eduardo Alves, Full Researcher


Katharina Lorenz, Senior Researcher (september 2018)


Nuno Barradas, Senior Researcher


Carlos Cruz, Auxiliary Researcher


José Neves, Auxiliary Researcher


Luís Cerqueira Alves, Auxiliar Researcher


Rodrigo Mateus, Auxiliary Researcher

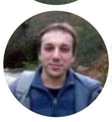

Rui Silva, Auxiliary Researcher


Rui Martins, Researcher Contract


Marta Dias, Researcher Contract


Victoria Corregidor, Researcher Contract


Sérgio Magalhães, Postdoctoral Researcher (PhD 2013)


Marco António Peres, Postdoctoral Researcher


Hélio Luís, Postdoctoral Researcher


Adam Przemyslaw Jozwik (Nattan), Postdoctoral Researcher

R&D | STUDENTS

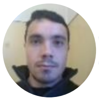

Djibril Faye, PhD Student (until 2019)


Norberto Catarino, PhD Student (until 2018); Post-doc Researcher


Dirkjan Verheij, MSc Student (until 2018); PhD Student


Daniela Pereira, MSc Student (until 2017); PhD Student


Miguel Sequeira, Researcher Grantee (2018-2019); PhD student


Francisco Antão, MSc Student (until 2019)

TECHNICIANS


Ana Faria, Graduated Technician/Executive Assistant and Accounting


Jorge Rocha, Graduated Technician/Accelerators Operator


Paula Matos, Graduated Technician/Technical Director of UTR


Teresa Pires, Graduated Technician/Multimedia/Logistics


Nuno Inácio, Graduated Technician/Irradiatior Operator Chief


Filomena Baptista, Assistant Technician/Irradiator Operator


Tiago Jesus, Assistant Technician/Irradiator Operator


Tiago Sena, Assistant Technician/Irradiator Operator

RESEARCH

Ion Beam Applications and Materials

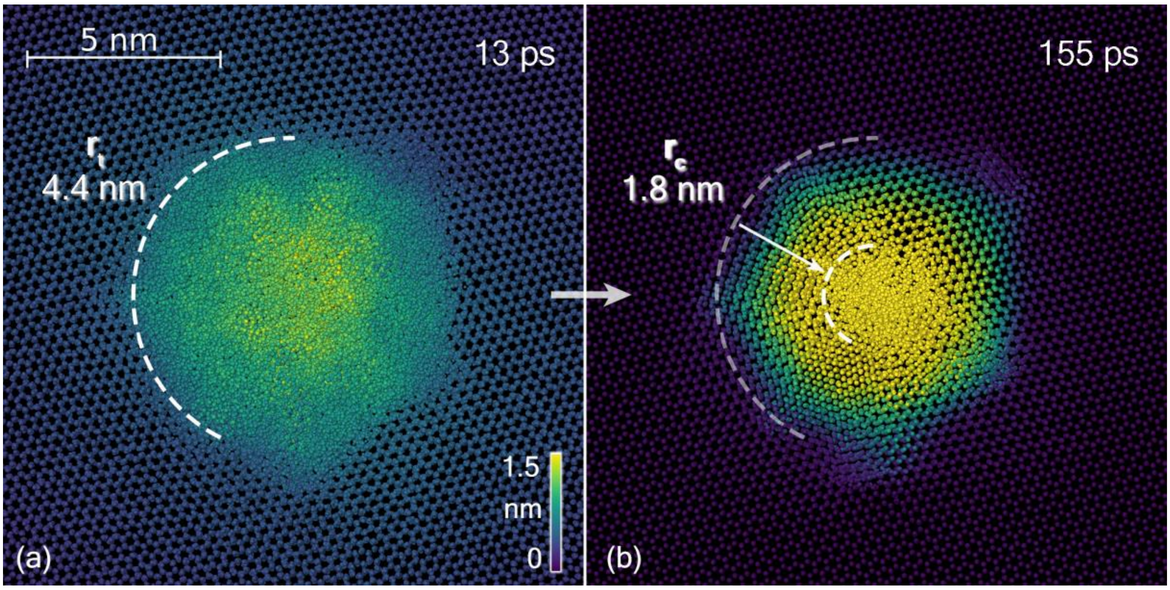
RESEARCH | 2: ION BEAM APPLICATIONS AND MATERIALS

1. Thematic Highlights

Nano-engineering of wide bandgap semiconductors using ion beams (NASIB)

In the NASIB project, in collaboration with the Universities of Aveiro and Helsinki and INESC-MN, we are studying the effects of ion irradiation on wide bandgap semiconductors such as GaN, MoO_3 and Ga_2O_3. Understanding ion-solid interactions in semiconductors is important to develop device-processing techniques based on ion implantation as well as to understand the performance of different semiconductors in radiation environments such as space. The figure shows a surprising recrystallization effect of GaN when hit by a swift heavy ion.

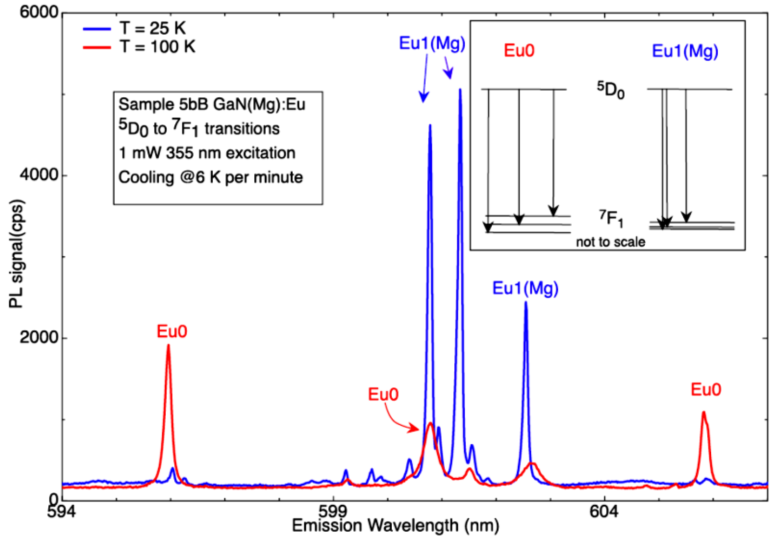
This self-recovery of the crystal, revealed by Molecular Dynamics simulations, explains the high radiation resistance of GaN to strongly ionizing radiation. NASIB furthermore exploits the radiation hardness of wide bandgap materials for the development of radiation sensors. Sensors based on GaN microwires as well as thin Ga_2O_3 membranes have been fabricated and successfully tested for proton and UV light detection.



Hysteretic photochromic switching (HPS) of europium-magnesium defects in gallium nitride: a potential route to a new solid-state qubit

In this project, in collaboration with the Universities of Strathclyde and Cambrige and Unipress, Warsaw, we implanted europium ions into Mg-doped GaN. After implantation and annealing in optimised conditions, hysteretic photochromic switching (HPS) is observed.

This switching between the two optically active Eu^{3+} centres, Eu0 and Eu1(Mg), is evidenced in strikingly different photoluminescence lines, as shown in the figure. These distinct Eu^{3+} emission lines reveal a change in the microscopic nature of the Mg-Eu defect upon cooling. Interstingly, this 2-level defect system can be switched and read optically. Learning to manipulate these states with more precision has the potential to open up new applications in quantum technologies.



Study of deposition on JET components

The activities during this research were focused on the data analysis of the spectra recorded in the LATR laboratory using WiNDF code, considering the Total-IBA approach. Ion beam analysis results support the general picture of erosion during limiter configurations with local deposition on tile ends far into the scrape off layer. Similar trends of fuel concentrations are observed in all JET operating periods.

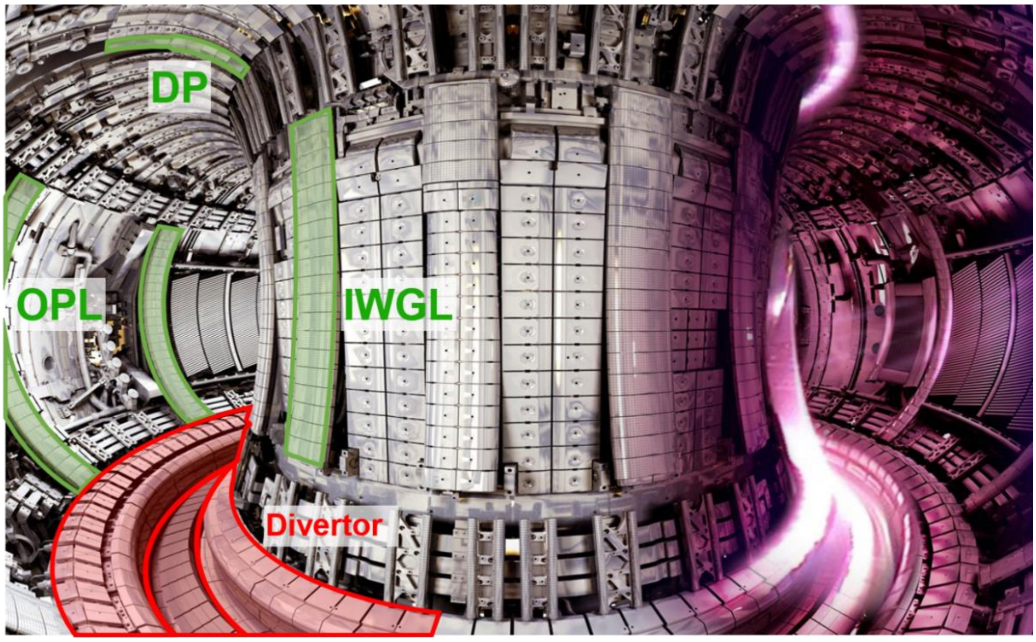


Figure 1. Schematic representation of JET ILW materials. Main chamber complied of bulk Be in upper dump plates (DP), inner wall guard limiters (IWGL), outer poloidal limiters (OPL) — highlighted and in green colour; and divertor containing W coated CFC components—highlighted in purple red.

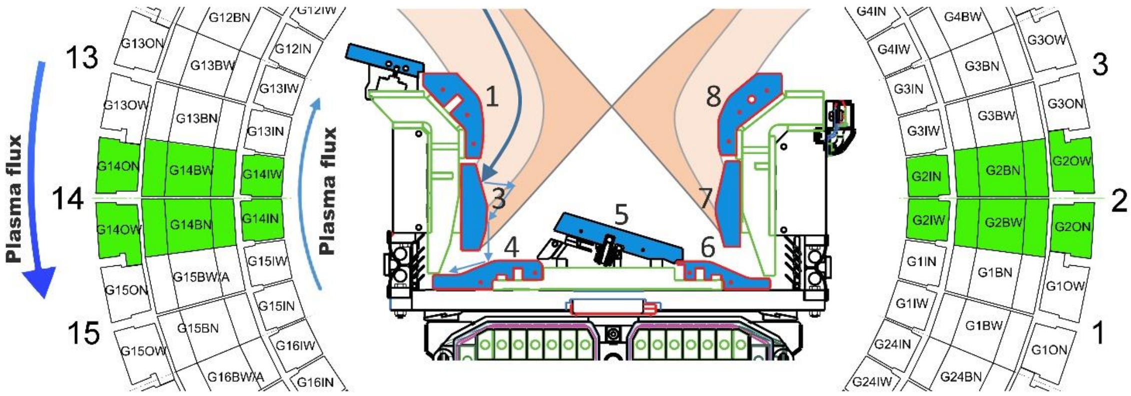


Figure 4. Schematics illustration of JET-ILW divertor tile arrangement toroidally, and a cross-section of the JET-ILW divertor with the tle number and a typical plasma equilibrium. The blue arrows indicate the direction of the plasma flux.

Data on erosion and melting of beryllium upper limiter tiles, so-called dump plates (DP), are presented for all three campaigns in the JET tokamak with the ITER-like wall- IBA analysis performed across the affected tile ridge in both poloidal and toroidal direction revealed a low D concentration, in the range 1–4 × 10^{17} D atoms cm^{-2}

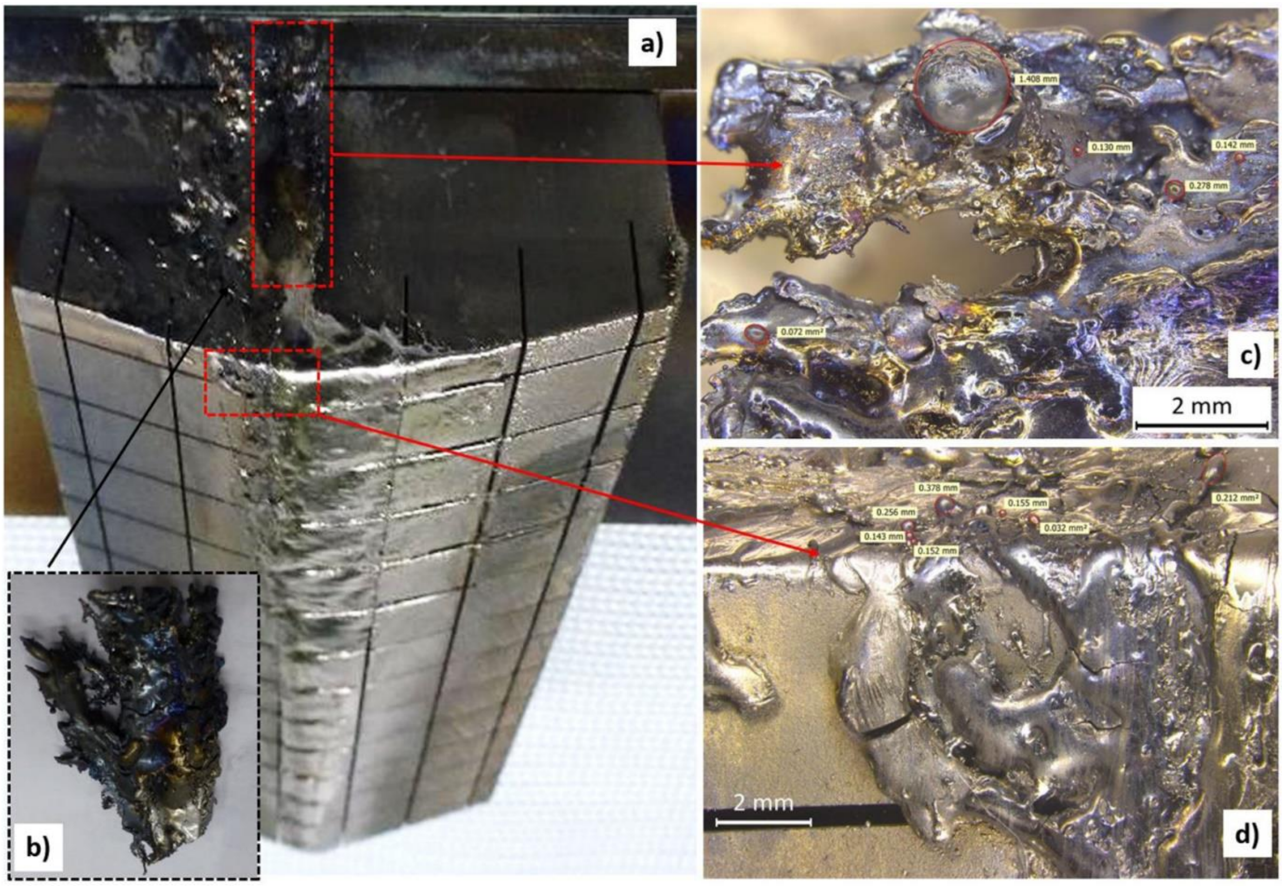


Figure 2. (*a*) Melt damage across poloidal direction on upper DP-8, with a close-up on the 'waterfall' structure in (*b*); 3D optical microscopy imaging showing complex features of the melted flake itself in (*c*) and melt damage near to the top edge of the tile in (*d*). One can notice the multitude of Be droplets in different shapes and sizes, ranging from microns to millimeters in diameter.

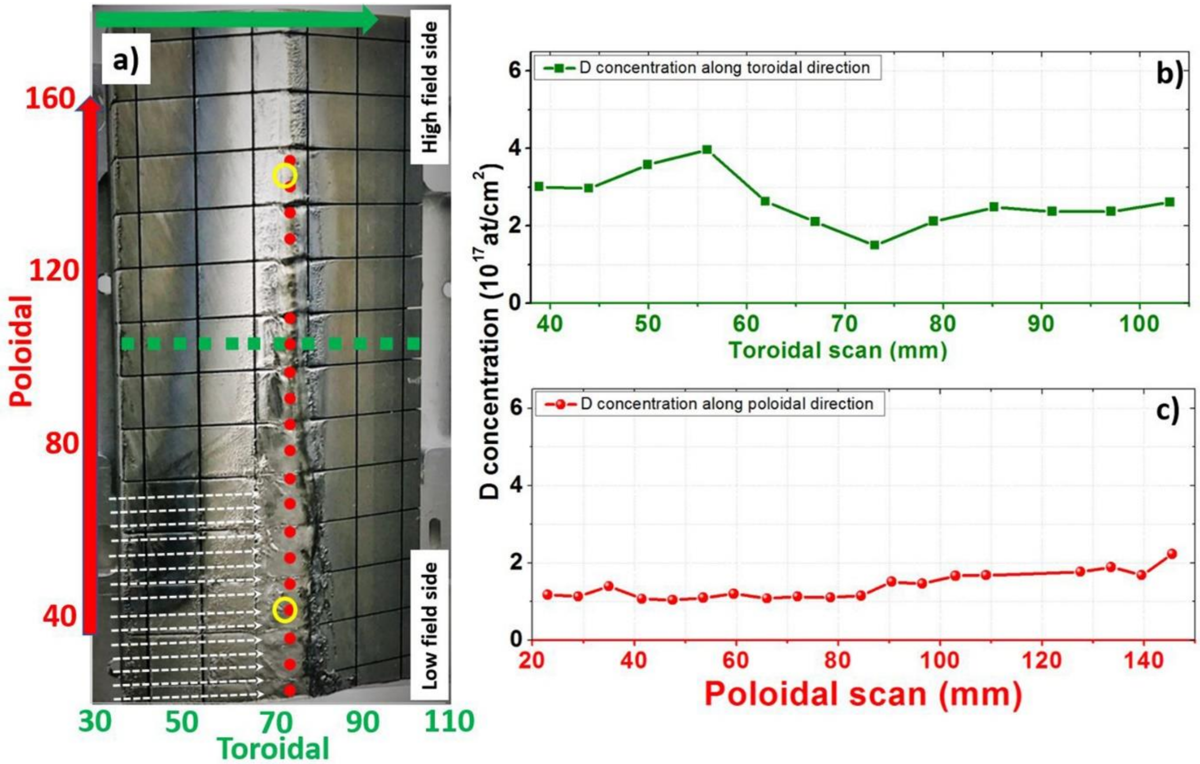
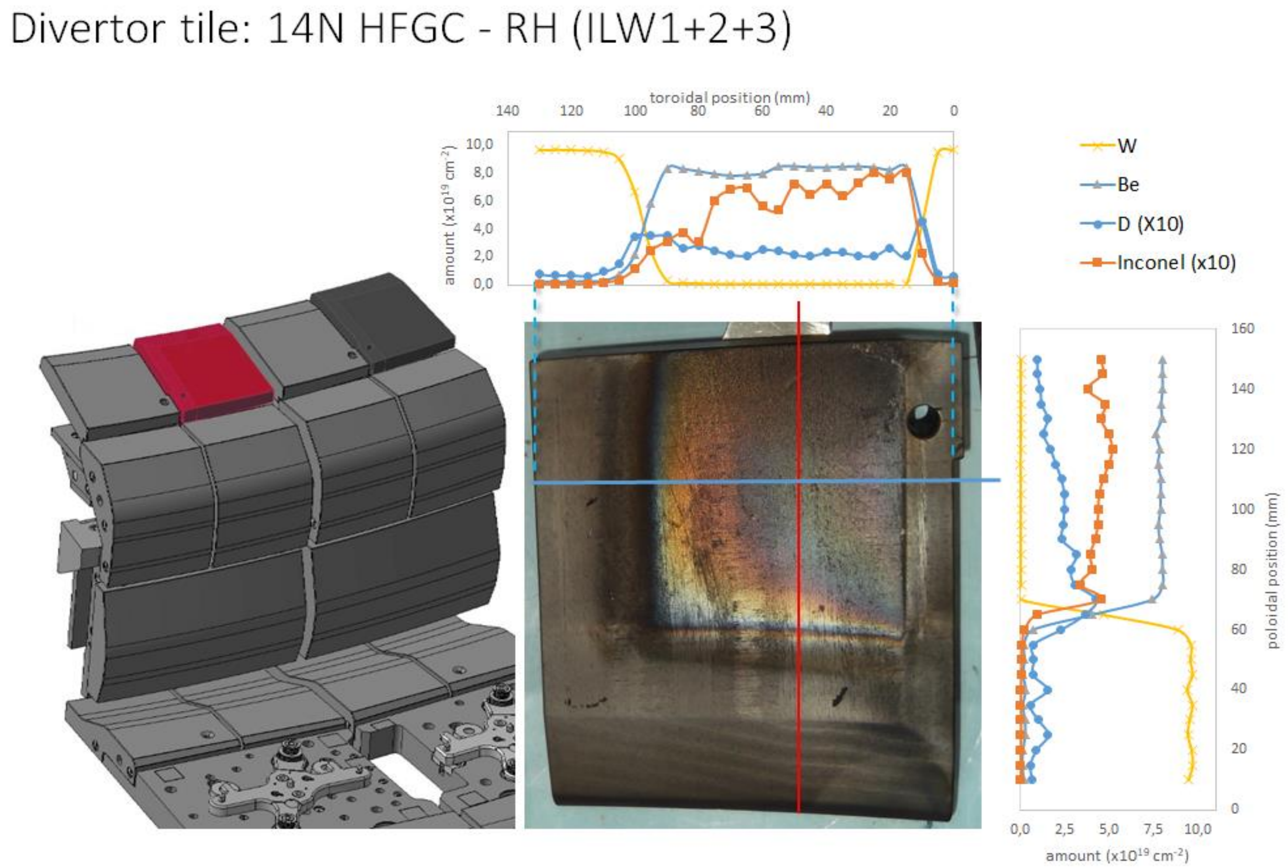
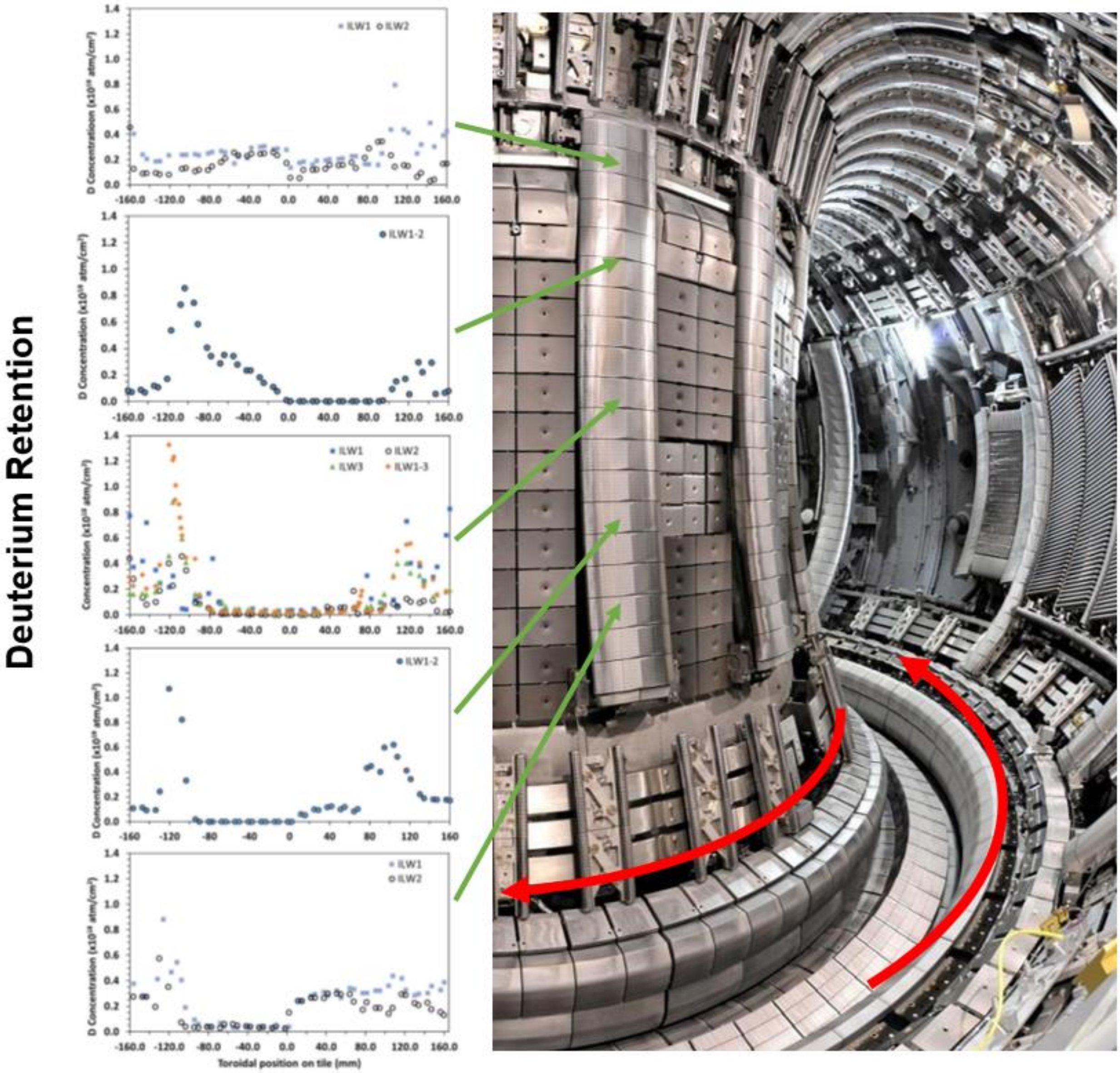


Figure 3. (a) IBA analysis performed on DP-8 along poloidal and toroidal direction; (b) D concentration along toroidal direction highlights a lower D presence on the melted areas along the top ridge of DP-8; (c) D concentration along poloidal direction shows a lower D presence across the melted area of DP-8 with the lowest values reached where the most damage is achieved, in the low field side of the tile and where the Be waterfall structure is generated.



Mid-plane limiter tiles exposed during ILW1, ILW2, ILW3 operating plasma regimes

JET had completed three operating periods, ILW1, ILW2 and ILW3, giving an opportunity to make comparisons between tiles exposed to different plasma regimes and compare tiles exposed for all the three periods, ILW1-3 (2011-2016).



Our results give updated fuel inventories and provide comparisons of individual mid-plane limiter tiles exposed during ILW1, ILW2, ILW3 with ones exposed throughout the full operation, ILW1-3. For example, results for D concentration in deposits at the ends of the mid-plane IWGL tile are of the order of 0.1-1 x 10^{18} D/cm^2 for tiles exposed in individual campaign, whereas results from a tile exposed for all campaigns show D concentrations at least a factor of three higher. This indicates continual accumulation of fuel in deposits, with no release due to heating. In the central eroded region, exposed to highest heat flux, retention values remain low for all tiles analysed.

Analysis of IBA data from ILW1, ILW2, ILW3 along the inner and outer wall limiters extending poloidally shows the complex fuel retention and erosion/deposition pattern from the top to the bottom of the vessel. Most interaction occurs in the central region, which correlates with the heat flux patterns seen from infrared cameras.

In addition, divertor tiles also reveal a similar deposition patterns after each individual campaign. The cumulative results after the 3 campaigns show are shown in figure below. The high deposition rate of Be occurs on tile 1 together with deuterium. Shadowed areas of tile 4 reveal the presence of different impurities (C and O) as well as Be and D. A detailed overview of all the results can be found in the contributions presented at conferences and published in reference journals.

The studies on the chemical reactivity and phase formation in materials involving Be/C/N/O/W prove the impact that temperature and impurities (O, C) represent on the retention of D in the mixed deposits during plasma wall interactions.

Optical activation of different optical centres based on rare earths in Ga2O3

During the last two years a special effort has been done in order to optimize the implantation conditions of different optical active centres based on rare earths. Two publications resulted from these studies, about the Eu implantation in Ga_2O_3 and several oral and poster presentations. More recently promising results were obtained about optical activation of Pr inGa_2O_3 (not published yet). Regarding this recent study about Pr implantation it is being exploited the potential of the up conversion process involving the interionic lowest level 4f5d with a short lifetime, for the development of single photon emitters in Ga_2O_3 for applications in quantum technologies.

FCT Grant PTDC-FIS-PLA-31629-2017

"Liquid metal walls for plasma reactors (LMwalls)"

The LMwalls project is dedicated to the production of Li-Sn alloys with Li contents as high as 25 at.%, and to the chemical and structural modifications imposed by their irradiation with ^{2}H plasmas. In 2019, the project was focused in the production and analysis of some of the alloys involving Li contents down to 1 at.%. IBA techniques were used to quantify the depth profiles of Li by NRA down to depth ranges close to 15 μm by following the depth yield of the ^{7}Li(p,α)^{4}He nuclear reaction.

Simultaneously, the Sn depth profile and possible C and O environmental contamination at the surface were measured by EBS with 2000 keV $^{1}H^{+}$ ion beams. The microprobe facility was also used to investigate the homogeneity of Li in the alloys by μ-NRA and μ-EBS, as the amounts and areal distribution of heavier impurities by μ-PIXE.

EUROfusion work programme WP19 PFC SP5.4/IST

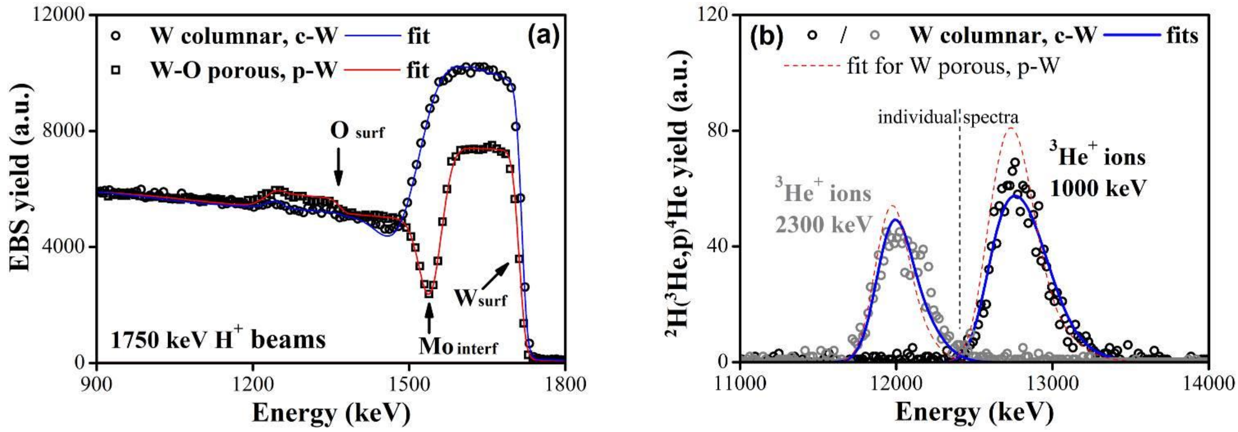
"Preparation of efficient PFC operation for ITER and DEMO (SP5: Post-mortem analysis and material migration SP5): Development of mixed-material reference coatings"

W-based Coatings

W-based coatings with distinct morphologies, W columnar (c-W) and W-O porous (p-W), were deposited on Mo plates by pulsed laser deposition (PLD) at ENEA, Milan, and sent to IST aiming to prepare coatings with high ^{2}H contents by ion implantation. The c-W and p-W coatings were implanted simultaneously using three different implantation stages with a sequential decrease in the energy of incident ions. The corresponding ion beam energies and fluencies of the first, second and third stages were, respectively, 150 keV and 2×10^{17} ion/cm^{2}, 100 keV and 2×10^{17} ion/cm^{2}, and 50 keV and 1×10^{17} ion/cm^{2}, being the total dose equal to 5×10^{17} ion/cm^{2}. The main goal is to produce square-like depth profiles for the retained ^{2}H. Earlier experiments performed with similar coatings implanted by $^{4}He^{+}$ ions evidenced the same expected effect as shown by simulations using the SRIM code (see Surf. Coat. Technol. 355 (2018) 215).

The as-deposited and as-implanted coatings were analysed by EBS using a 1750 keV $^{1}H^{+}$ ion beam to profile the O and W contents and by NRA using both 1000 keV $^{3}He^{+}$ and 2300 keV $^{3}He^{+}$ to quantify the final $^{2}H^{+}$ retained amounts taking advantage of the $^{2}H(^{3}He,p)^{4}He$ nuclear reaction.

As expected, the analytical results showed significant O contents and higher $^{2}H^{+}$ retention in porous p-W coatings.



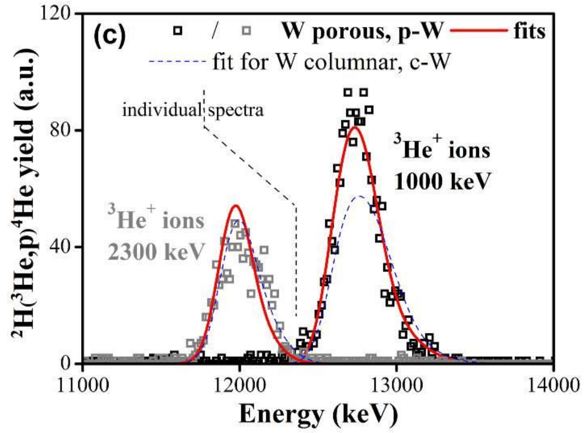


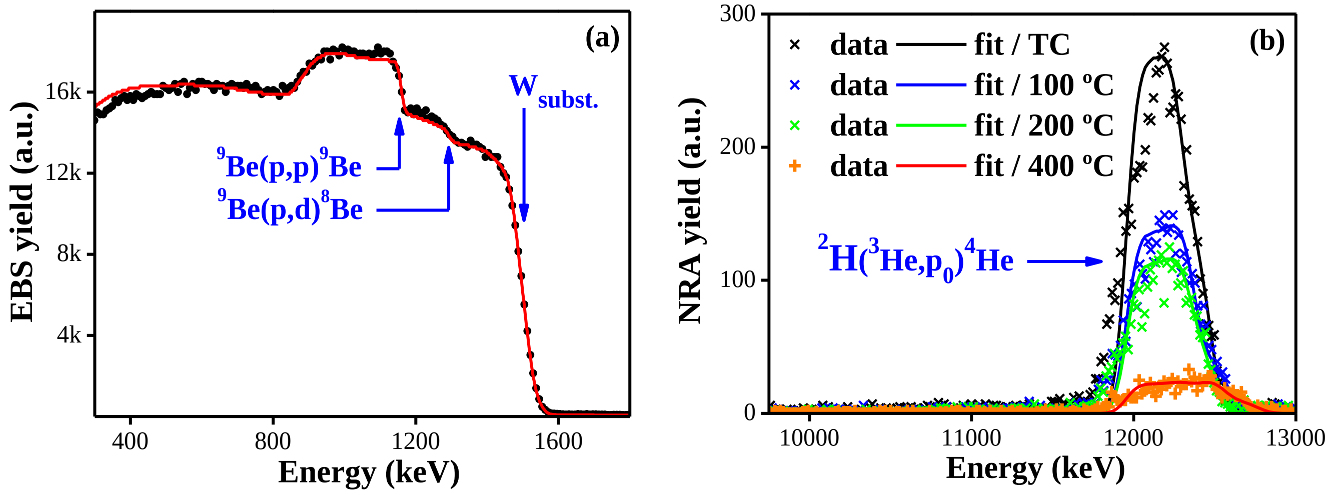
Fig. 1. IBA analysis of as-implanted c-W and p-W coatings: EBS spectra collected with 1750 keV and related fit lines (a); individual NRA spectra collected with 1000 keV and 2300 keV $^{3}He^{+}$ ion beams and related fit lines for the analysis of c-W (b) and of p-W coatings (c).

Al-based and Be-based Coatings

Experiments with Al-based coatings are important in the nuclear fusion domain, while most of the European laboratories cannot work with Be samples and both Al-based and Be-based materials present some similar physical and chemical properties. In other tasks within the EUROfusion work programme, Al-based and Be-based coatings were sent to IST for IBA quantifications.

In Be activities, IST is quantifying the retained contents of ^{2}H in coatings grown with plasma deposition techniques. In one of the experiments, coatings with nominal ^{2}H contents of 5 at.% or 10 at.%, Be-D(5at.%) and Be-D(10at.%), respectively, were deposited in W plates at the same plasma parameters under distinct buffer temperatures, from room temperature up to 400º C.

An additional Be-D(10at.%) coating was also deposited under a temperature regime that mimics the environment filled in the walls of the Joint European Torus (JET) under ^{2}H plasma operation, i.e., JET-like pulses. The as-deposited coatings were analysed by EBS with a 1800 keV $^{1}H^{+}$ ion beam to profile Be and W and by NRA using a 2200 keV $^{3}He^{+}$ ion beam to quantify the retained ^{2}H amounts. As expected, the analytical results shown a deeply decrease in the retained amounts by increasing the buffer temperature, and retained amounts in the JET-like coating that typically corresponds to a constant buffer temperature close to 100º C. The result is in agreement with the measured temperatures in the JET walls.



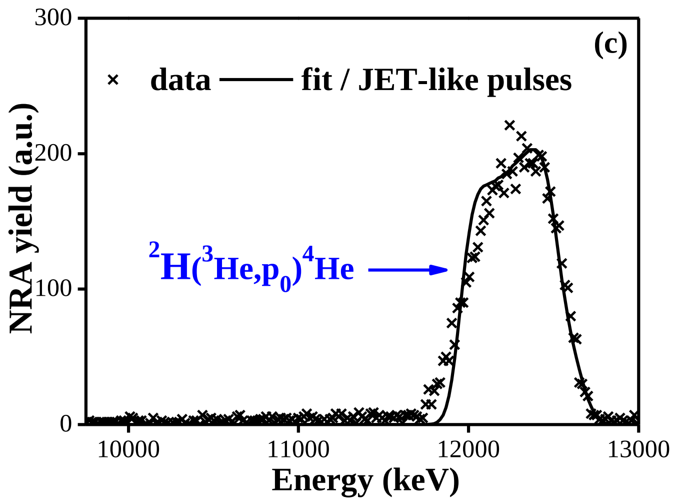
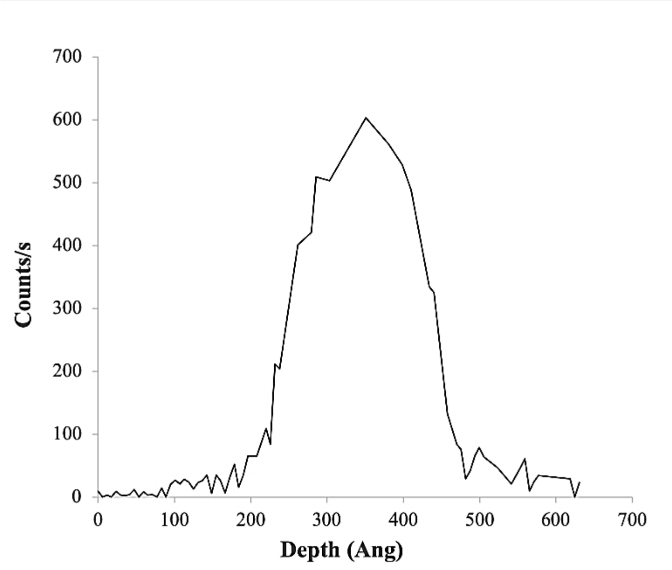


Fig. 1. EBS spectrum collected with 1800 keV H^{+} incident ion beams and related fit line achieved from the IBA analysis of coating #03, Be+D(5 at.%) deposited at 400 ºC (a); particular $^{2}H(^{3}He,p)^{4}He$ emissions in the NRA spectra and related fit lines for coatings #02 Be+D(5 at.%), #05 Be+D(5 at.%), #04 (Be+D(10 at.%) and #03 Be+D(5 at.%) (b) and also for #06 Be+D(10 at.%) referring to the JET-like pulses (c).

Depth profiling of Pt implantation in Si samples by micro-AMS

The activities during this period were focused on the installation of the depth profiling system at the micro-AMS system at LATR, the development of an in-house built oven for the ionizer assembly, measurement of deuterium profiles as well as W isotopic ratios in fusion samples. Among all the activities, some results are worth highlighting:



The Micro-AMS system at LATR has been upgraded in order to perform high-resolution depth profiles. This capability, allied with its bouncing system makes it a unique tool for stable isotope studies. To demonstrate these new capabilities, a study of the quality of a selective implantation of platinum isotopes in Silicon (to be used in isotopic optical studies) was performed with the CTN-IST implanter. Micro-AMS sensitivity, due to its use of a tandem accelerator to resolve molecular interferences, along with its ability to perform spatial and in-depth analysis makes it ideal for this type of studies.

Pure ^{28}Si isotope single crystals were implanted, at energies of 60 keV with two Pt isotopes, ^{194}Pt and ^{198}Pt, with a nominal fluency for each of the isotopes of $1x10^{14}$ cm^{-2}. A natural Pt cathode was used for the implantation, and despite the rigorous mass selection, some isotopic contamination is expected. In the figure, a depth profile of ^{194}Pt in Si can be seen.

Role of the defects created by proton irradiation in Ga_2O_3 doped with Cr and co-doped with Mg

In the context of my research, focused on materials characterization and modification using ion beams, it stands out a study about the role of the defects induced by proton irradiation and their relation with the optical activation of Cr in intentionally doped Ga_2O_3 with Cr and co-coped with Mg. By ionoluminescence complemented with PIXE it was observed that there is a direct relation of the optical properties of Cr with the content with Mg.

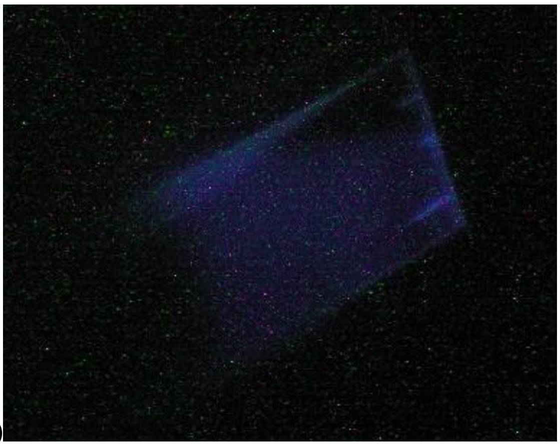
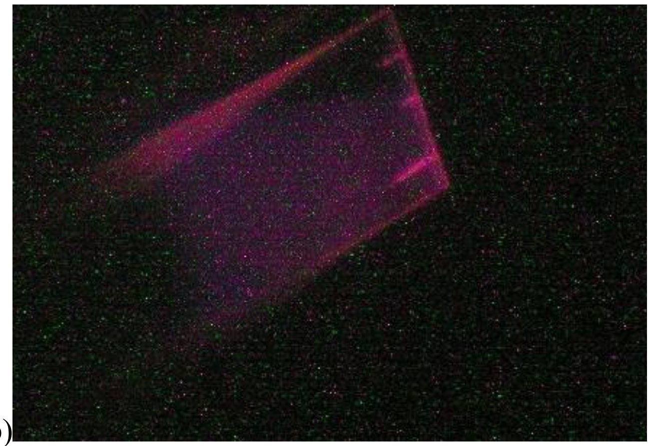
a)  b) 

Figure: a) before irradiation; b) after irradiation.

On the other hand it was observed that the defects induced by proton irradiation contributes to enhance the Cr luminescence suggesting that a deep defect level introduced by the irradiation can work as a channel of energy transfer from the Ga_2O_3 host to Cr. It cannot be excluded the possibility that small changes in the local environment around Cr can affect its charge state, and consequently its optical properties.

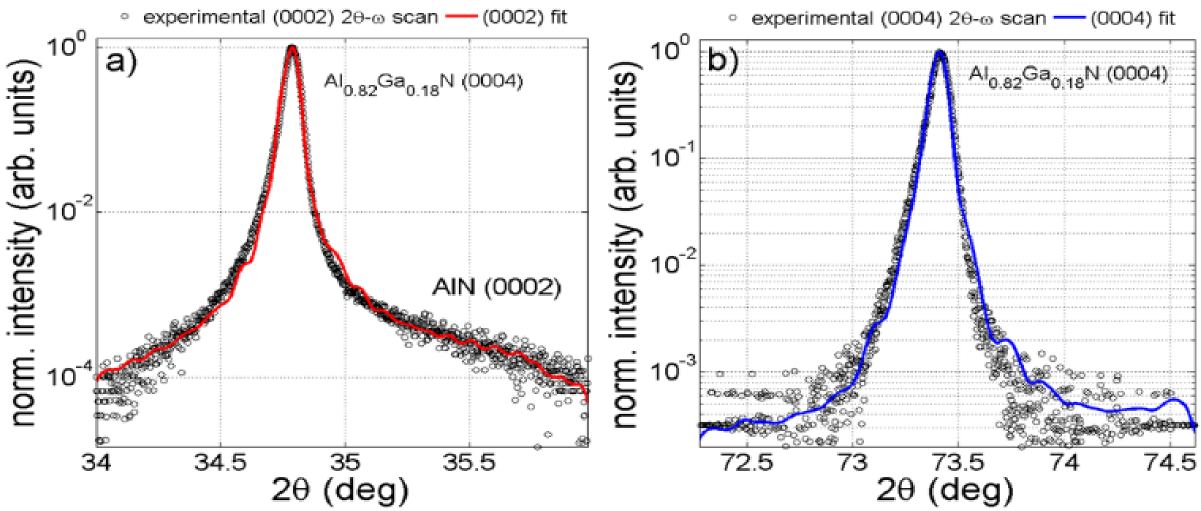
It was also observed that the defects introduced by proton irradiation can be removed by a thermal annealing at temperatures higher than 600 ºC. In this context, Ga_2O_3 doped with Cr can have a huge potential as red-emitter scintillator detector.

Multiple reflection optimization package for X-ray diffraction: simultaneous fitting

The activities during this period were focused on the implementation of the MROX code, acronym for Multiple Reflection Optimization package for X-ray diffraction radial and omega scans. The software employs the principles of the dynamical theory of X-ray diffraction on ω and 2θ-ω scans of several layered structures such as bulk materials, single layers, single quantum wells, quantum heterostructures and complex superlattices. Allow to simulate and fit different types of measurements of any implanted species. Simple to use, layers can be deleted, added, edited and crystalline layered structure easy to obtain.

Combined with the new developed code of X-ray reflectivity simulations and fittings, MROX is a powerful tool to simulate and fit the effect of ion implantation into crystals. At this moment, the effect of threading dislocations and stacking faults are being added in the code and it is planned to include special structures such as quantum dots/wires.

So far, it has been possible to publish 3 papers and 2 Master degree thesis combining pure research and academics.



IBA techniques for perovskite active layers

Perovskite (PSC) films based on $CH_3NH_3PbI_3$ prepared in a planar architecture and in a mesoporous TiO_2 scaffold were characterized by means of the nuclear microprobe. Proton and helium micro-beams at different energies were used in the analysis of PSC active layers.

Self-consistent fit of all the obtained PIXE and RBS spectra through Total IBA approach provided depth profiling of perovskite, its precursors and TiO_2 and assess their distribution in the films. PbI_2

presence and location on the active layer may hinder the charge transport and highly affect the cell performance.

IBA techniques allowed to identify regions of non-uniform surface coverage and homogeneous areas and it was possible to establish the undesired presence of PbI_2 and its quantitative depth profile in the planar architecture film. The good agreement between the best fits obtained in a Total IBA approach and the experimental data granted reliability to depth profile results for the studied perovskite films.

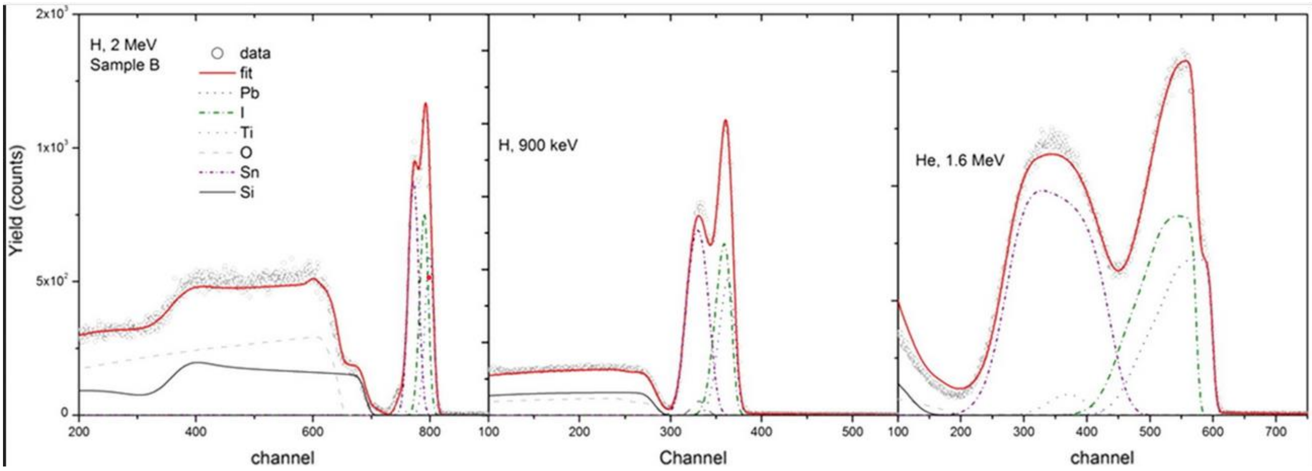


Figure: Experimental data and NDF best fits assuming a pure PSC layer on top of TiO2.
From 10.1016/j.nimb.2017.01.019.

Development of thermal barriers for nuclear fusion

The activities during this period were focused on the development of thermal barriers for nuclear fusion divided in two research lines: (i) thermal barriers materials made of Y_2O_3 reinforced Cu and CuCrZr and (ii) production of Cu based high entropy alloys.

The Cu-Y_2O_3 and CuCrZr-Y_2O_3 materials were prepared in a glove box and consolidated with spark plasma sintering between 775-800 ºC with pressures of 57 MPa with a holding time of 5-8 min. The densifications achieved are between 90-98 and decrease with the increasing of Y_2O_3 volume content. The microstructure revealed dispersions of Y_2O_3 regions in the Cu matrix with the presence of Cu oxide and Y_2O_3 agglomerates.

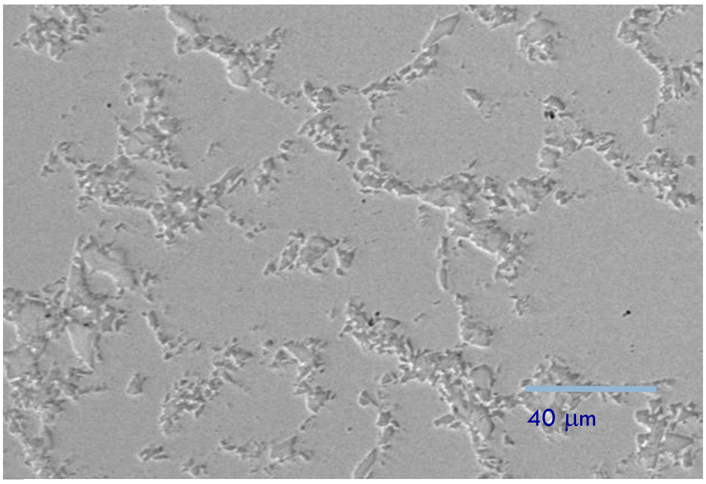


Figure: SEM image of the 85CuCrZr – 15Y_2O_3 % (V/V) sample.

TEM confirmed the presence of CuO in the Cu-Y_2O_3 materials. Moreover, the microstructure of samples with CuCrZr were similar to those with Cu however without the formation of Cu oxides. The functional graded material with Cu and with CuCrZr did not exhibit the interfaces between layers, which is a strong point on these materials.

Moreover, $Cu_xCrFeTiV$ (x = 0.21, 0.44, 1 and 1.7 molar ratio) were prepared using mechanical alloying (MA), to mix the elemental powders, followed by consolidation with spark plasma sintering (SPS) at 1178 K and 65 MPa. The equiatomic CuCrFeTiV sintered sample was irradiated at room temperature with 300 keV Ar^+ beam (to a fluence of 3×10^{20} at/m^2) in order to simulate the irradiation damage in the material. The results showed the presence of heterogenous and multiphasic microstructures in all samples. Moreover, with the increase of the Cu content it is possible to observe the formation of Cu-rich structures.

The diffractogram of the CuCrFeTiV sample revealed major peaks of a BCC crystal structure and minor peaks of a FCC crystal structure. In addition, irradation damage in the microstructure surface was only observed in samples irradiated with fluences of 3×10^{18} to ions/cm^2. Moreover, in those samples blisters were observed with a diameter less than 1 μm.

Nuclear microprobe applications: from Cultural Heritage to Functional Materials

Research work was performed under national and international funded research contracts or under collaboration with internal and external group members. Most relevant applications included characterization of advanced materials (Ga_2O_3; GaN; MoO, perovskites and CIGS solar cells) together with archaeological/historical samples (glass, stained glass, tiles, silver coins and metallic artefacts) and biology/biomedicine studies like the one for determining 3D distribution in cells of metallic nanoparticles using MeV ion beams. In terms of experimental development, automatization and tests of the ion beam tomography system at the Nuclear Microprobe beam line were accomplished.

Concerning the work on silver artefacts, Portuguese silver coins from the 15^{th}-17^{th} centuries were analysed by non-destructive PIXE technique in order to create an elemental data base composition in major, minor and trace elements of the silver alloys which allowed to:

1) determine a chronological framework of the silver alloy used, allowing establishing the silver ore provenance and metallurgical procedures;

2) differentiate production centers (Lisbon and Oporto);

3) allow comparison with coeval Portuguese silver objects, namely Indo-Portuguese silver jewellery from the Ancient Art Nacional Museum (MNAA);
4) help for detecting forgeries (well in accordance with the goals of the IAEA CRP F11021).

The work was performed in collaboration and using the silver coin collections from the Portuguese Mint House (ICNM – Imprensa Nacional Casa da Moeda) and from the Bank of Portugal (BdP).

The introduction in the Portuguese territory of silver coming from the "New World" Potosí mineral ore is well identified and ascribed to Au contents <100 ppm and very low Bi contents [Bor2018].

[Bor2018] Borges, R; *et. al.,* European Silver Sources from the 15th to the 17th Century: The Influx of "New World" Silver in Portuguese Currency, Heritage 1, (2018) 453–467.

IBA and cultural heritage

Cultural Heritage artefacts were studied in the nuclear microprobe, using both alternatives: measurements on vacuum and on open air. Results allowed to identify surface silver enrichment in ancient high silver alloys and also to identify European silver sources from the 15th to the 17th century.

The combination of PIXE and RBS spectra allowed the characterization of corrosion layers grown on ancient coins. Ancient manuscripts were also characterized, in this case using the external beam set-up. Low beam currents were used in order to avoid eventual radiation damage on paper. It was possible to study iron gall inks (reals and manufactured under lab conditions), the initial ingredients and paper.

The reduced penetration of the ink into the paper (less than 1 μm) makes it difficult to separate the signals from the paper and the ink by means of the characterization techniques used in this study.

Since all samples were under identical exogenous factors that can affect the paper stability, as external temperature, humidity or oxygen content, the loss of crystallinity observed in all samples, should be then related to endogenous factors, and more specifically linked to the ink.

The acidic elements of the inks result in the acid-hydrolysis of cellulose shortening the chains, thus reducing the content of the crystalline form.

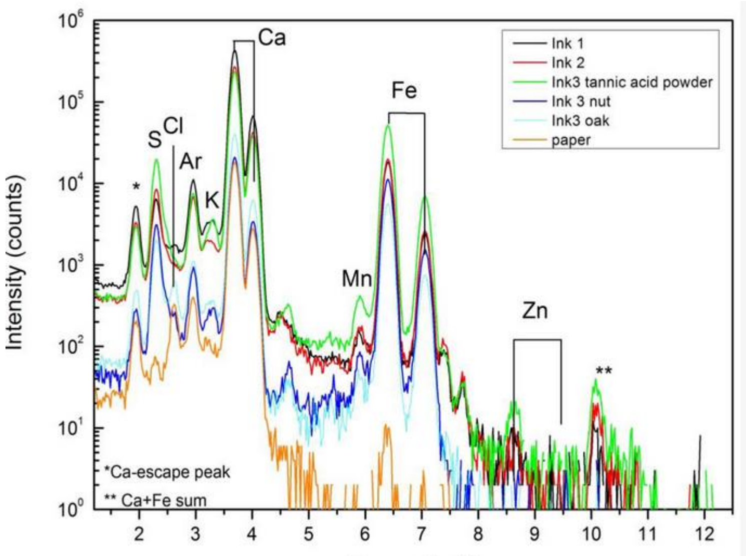


Figure: Pixe spectra from inked and bare areas of paper. 10.3390/heritage2040166.

2. Scientific Output

(Articles in scientific journals or conference proceedings, books/chapters, theses, internal reports/services, duly approved by the Unit and registered in the Library)

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[130] S.Schöche, T. Hofmann, D. Nilsson, A. Kakanakova-Georgieva, E. Janzén, P. Kühne, K. Lorenz, M. Schubert, and V. Darakchieva, “Infrared dielectric functions, phonon modes, and free-charge carrier properties of high-Al-content $Al_xGa_{1-x}N$ alloys determined by mid infrared spectroscopic ellipsometry and optical Hall effect”, *Journal of Applied Physics.* 121, 205701 (2017).

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COMMUNICATIONS

Invited Talks

2019

[1] E.Alves, Deuterium retention on Be-C-O films: in-situ vs ion implantation loading, *14th IEA International workshop on Beryllium Technology for Fusion, Long Beach,* California, October 24-25th 2019.

[2] E.Alves, Oxidation of neutron irradiatiated Be pebbles, *14th IEA International workshop on Beryllium Technology for Fusion,* Long Beach, California, October 24-25th 2019.

[3] E.Alves, Quantitative analysis of mixed films and deposits by ion beam techniques, *11th Iberiam Vacuum Conference –RIVA*, Seville (Spain), 26-28th June, 2019 (Invited).

[4] E.Alves, Structural and optical studies of aluminosilicate films doped with (Tb^{3+}, Er^{3+}) / Yb^{3+} by ion implantation, *13th European Conference on Accelerators in Applied Research and Technology (ECAART13)",* Split (Croácia), May 05-10th 2019.

[5] E.Alves, Structural studies of short period superlattices grown by MBE, *17th International Conference on Surface Science (ICSS-17) and the 2019 International Conference on Nanoscience + Technology,* Malmö (Sueden), July 1st-5th 2019.

[6] V.Corregidor, L. C. Alves, J. Cruz, Cultural heritage artefacts and ion beam analytical techniques, A Universidade de Lisboa e o Património. *2º Encontro. Faculdade de Belas-Artes*, Lisboa, 27-30 November 2019.

2018

[7] E.Alves, Total IBA a quantitative tool to study fusion materials and processes, *IAEA Technical Meeting on Advanced Methodologies for the Analysis of Materials in Energy Applications using Ion Beam Accelerators* (Ref. No.: F1-TM-1701755), IAEA, Vienna (Austria), October 8-11th 2018.

[8] E.Alves, Irradiation effects in Tungsten-Based Alloys for Fusion Reactors, *IAEA Technical Meeting on Advanced Methodologies for the Analysis of Materials in Energy Applications Using Ion Beam Accelerators*, Vienna (Austria). October 7-10th 2018.

[9] E.Alves, Laboratory of Accelerators and Radiation Technologies: An Overview, *2nd Workshop of the European Network of Small-scale Accelerator Facilities (ENSAF),* Institute of Nuclear and Particle Physics (INPP) of the National Center for Scientific Research "Demokritos" (NCSRD), Athens (Greece), October 3-6th 2018.

[10] E.Alves, Role and Perspectives for Nuclear Analytical Techniques in Forensic Science, *IAEA Consultancy Meeting to support General Conference (GC) side event on Nuclear Analytical Techniques in Forensic Science*, September 18th 2018 (invited).

[11] E.Alves, Analysis of IWC tiles and wall inserts at IST and IPP, *Meeting on "Ion Beam Analysis of Plasma-Facing Components from JETILW"*, CTN-Bobadela, April 17-18th 2018.

[12] M.Peres, L.C. Alves, E. Alves, T.S. Monteiro, S. Cardoso, M. Alonso-Orts, E. Nogales, B. Méndez, X.V.E.G S. Biquard and K. Lorenz, Ion implantation and iono-luminescence studies in β-Ga_2O_3, *SPIE Photonics West California*, United States, January 27th-February 1st (2018).

2017

[13] E.Alves, Irradiation effects in Tungsten-Based Alloys for Fusion Reactors, *13th International Topical Meeting on Nuclear Applications of Accelerators*, Quebéc (Canadá) July 31st-August 4th, 2017.

[14] K.Lorenz, D.N. Faye, M. Peres, E. Alves, X. Biquard, E. Nogales, B. Méndez, B. Daudin, L.H.G. Tizei, M. Kociak, P. Ruterana, Ion implantation of GaN nanowires, FOR3NANO*: Formation of 3D Nanostructures by Ion Beams*, Helsinki, Finland, June 28-30 (2017).

[15] K.Lorenz, M. Peres, E. Alves, E. Nogales, B. Méndez, X. Biquard, E. G. Víllora, K. Shimamura, Europium doping of Ga_2O_3 by ion implantation, *23rd International Conference on Ion-Surface Interactions (ISI-2017)*, Moscow, Russia, August 21-25 (2017).

[16] K.Lorenz, Radiation Effects and Quantum Well Intermixing in InGaN/GaN Multi Quantum Wells, *19th International Conference on Radiation Effects in Insulators (REI-19)*, Versailles, France, July 2-7 (2017).

Oral Talks

2019

[1] J.Cruz, R.J.C. Silva, V. Corregidor, L.C. Alves, µ-PIXE/µ-EBS and SEM analysis of surface spots in gold coins/discs from the Portuguese Mint House, *16th International Conference on Particle Induced X-ray Emission,* Caldas da Rainha, Portugal (24-29 March 2019).

[2] M.Dias, N. Catarino, L.C. Alves, N.P. Barradas, S. van Til, M. Zmitko, E. Alves, "Oxidation behavior of neutron irradiated Be pebbles", *14th International workshop on Beryllium Technology (BeWS-1 Chair),* Long Beach, California, U.S.A., October 2019.

[3] M.Dias, HHFM 3.3.2.D2 "Fabrication of Cu reinforced with Y_2O_3 particles – process optimization, *Project Monitoring Meeting*, Karlsruhe, Germany, June 2019.

[4] M.Dias, HHFM 3.3.2.D2 "Thermal barrier materials made of Y_2O_3 reinforced Cu and CuCrZr, *Project Monitoring Meeting*, Garching, Germany, November 2019.

[5] M.Peres *et al*, "*In Situ* Characterization and Modification of Ga2O3 Using an Ion Micro-Probe", *Ion Beams for future Technologies*, Dubrovnik, Croatia, April, 1-3 (2019).

[6] S.Magalhães, P. Mendes, *et al*, "Comparison of strain induced by ion implantation of GaN with different orientations", *European Research Materials Society (E-MRS)*, Warsaw, Warsaw, Poland, 09 16-19 (2018).

[7] V.Corregidor, E. Poli, "Economic evaluation of a radiotherapy shielding design as a function of treatment techniques", *3rd International Conference on Dosimetry and its Applications (ICDA3)*, Lisbon, Portugal, May 27-31 (2019).

[8] V.Corregidor, J. Cruz, L.C. Alves. "Cultural heritage artefacts and ion beam analytical techniques", *2.º Encontro – A Universidade de Lisboa e o Património*, Lisbon, Portugal, November 25-29 (2019).

[9] V.Corregidor, J. Cruz, L.C. Alves. "Ion beam analytical techniques to discover what is behind the cultural heritage artifacts", *10th International Symposium on Materials*, Lisbon, Portugal, April 14-17 (2019).

[10] V.Corregidor, M.A. Barreiros, P.M.P. Salomé, M.J. Brites, L.C. Alves, "PIXE and RBS on CIGS solar cells to study the elemental distribution In-depth inhomogeneities on solar cells materials by PIXE and RBS", *PIXE* (2019).

[11] V.Corregidor, M.A. Barreiros, P.M.P.Salomé, M.J. Brites, L.C. Alves, "Study of In-depth inhomogeneities in solar cell materials by PIXE and RBS", *16th International Conference on Particle Induced X-ray Emission*, Caldas da Rainha, Portugal (24-29 March 2019).

[12] V.Corregidor, R. Dias, N. Catarino, C. Cruz, L.C. Alves, J. Cruz, (2019). "Reflectance Transformation Imaging to study of cultural heritage objects", *A Universidade de Lisboa e o*

Património. 2º Encontro. Faculdade de Belas-Artes, Lisboa, 27-30 November. (oral, V. Corregidor).

2018

[13] D.R. Pereira, C. Díaz-Guerra, M. Peres, S. Magalhães, J. G. Correia, J. G. Marques, A. G. Silva, E. Alves, K. Lorenz, "Strain and electrical conductivity induced by ion implantation in α-MoO3 lamellar crystals", *1st Iberian meeting of materials science* (CNMAT), Salamanca, Spain, July 4-6, 2018 (oral).

[14] D.Verheij, M. Peres, S. Cardoso, L. C. Alves, E. Alves, C. Durand, J. Eymery, K. Lorenz, "Radiation sensors based on GaN microwires grown by MOVPE", *1st Iberian meeting of materials science* (CNMAT), Salamanca, Spain, July 4-6, 2018 (oral).

[15] M.Dias, HHFM 3.3.2.D1 "Fabrication of Cu reinforced with Y_2O_3 particles – process optimization, *Project Monitoring Meetin*g, San Sebastian, Spain, May 2018.

[16] M.Peres, L.C. Alves, E. Alves, F.J. Oliveira, A.J.S. Fernandes, T. S. Monteiro, S. Cardoso, M. Alonso-Orts, E. Nogales, B. Méndez, E. G. Víllora and K. Shimamura, K. Lorenz "Flexible β-Ga2O3 micro-flakes for Thermal Actuators", *1st Iberian meeting of materials science (CNMAT)*, Salamanca, Spain, July 4-6, 2018.

[17] M.Peres, L.C. Alves, E. Alves, T. S. Monteiro, S. Cardoso, F.J. Oliveira, A.J.S. Fernandes, E. G. Víllora, K. Shimamura, K. Lorenz, "Proton irradiation of β-Ga_2O_3 metal-semiconductor-metal radiation sensors: an in-situ study", *21st International Conference on Ion Beam Modification of Materials (IBMM 2018*), San Antonio, USA, June 24-29 (2018).

[18] N.Tuccori, T. Pinheiro, T. Peña, L.C. Alves, M.J. Botelho, J. Raimundo, C. Vale, "Modelling the uptake of suspended materials and salts in nearshore waters by plastics using nuclear microscopy and depth profiling analytical tools", *16th International Conference on Nuclear Microprobe Technology and Applications (ICNMTA2018)*, Surrey, UK, July 8-13 (2018).

2017

[19] I.Coutinho, F. Pulido Valente, L.C. Alves, T.Medici, Glass bracelets in medieval Portugal: insights on production and circulation, IV Congresso Internacional Medieval Europe in Motion: A Global Context? *Instituto de Estudos Medievais - NOVA FCSH*, 13-15th December 2017, Fundação Calouste Gulbenkian, Lisboa Portugal.

[20] J.Cruz, V. Corregidor, M. Manso, L.C. Alves, L. Carvalho, Combined μ-XRF and μ-PIXE/μ-EBS analysis of ancient copper coins. *TECHNART 2017: Non-destructive and microanalytical techniques in art and cultural heritage*, Bilbao, Spain, May 2 - 6, (2017).

[21] M.Dias, N. Catarino, D. Nunes, E. Fortunato, I. Nogueira, M. Rosinski, J.B. Correia, P.A. Carvalho, E.Alves, "Helium and deuterium irradiation effects in W-Ta composites produced by pulse plasma compaction", *20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017),* Lisbon, Portugal, July 2017.

[22] M.Dias, HHFM 3.3.2.D1 "Fabrication and characterization of optimized WC-Cu materials with and without functional gradient*", Project Monitoring Meeting*, Lisbon Portugal, June 2017.

[23] M.Dias, HHFM 3.3.2.D1 "Fabrication of Cu reinforced with Y_2O_3 particles ", Project monitoring meeting, Garching, Germany, November 2017.

[24] M.Peres, L.C. Alves, E. Alves, K. Lorenz, T. S. Monteiro, S. Cardoso, M. Alonso-Orts , E. Nogales, B. Méndez, E.G. Víllora and K. Shimamura, "*In-situ* optical and electrical characterisation of ß-Ga2O3 during proton irradiation", *20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-20*), Lisbon, Portugal, July 9-14, 2017.

[25] N.Ben Sedrine, J. Cardoso, A Alves, J. Rodrigues, A. F. Martins, D. Nd Faye, M. Belloeil, M. Peres, B. Daudin, K. Lorenz, E. Alves, A. Neves, M.R. Correia, T. Monteiro, "Eu-implanted AlxGa1-xN nanowires for solid state light emission", *Nanotechnology VIII, Barcelona*, Spain, 8 – 10 May, 2017 (oral).

[26] V.Corregidor, L.C.Alves. Ion beam techniques to study paintings on copper and polymers used as consolidants *IAEA Technical Meeting,* Amsterdam, The Netherlands, June 24-29 (2017).

Poster Presentations

2019

[1] A.Topete, A.P. Serro, B. Saramago, N.P. Barradas, L.C. Alves, E. Alves, "Ion beam studies of therapeutic silicone based hydrogels", *24th International Conference on Ion Beam Analysis (IBA2019)*, Antibes, France, October 13-18th (2019).

[2] D.Faye, M. Dias, N. Sousa, R. E. Rojas-Hernandez, Luís F. Santos, Rui M. Almeida, E. Alves, "Structural and optical studies of aluminosilicate films doped with (Tb^{3+}, Er^{3+}) / Yb^{3+} by ion implantation", *13th European Conference on Accelerators in Applied Research and Technology (ECCART 2019),* Split, Croatia (2019).

[3] E.Alves, "Deposition in the tungsten divertor during the 2011-2016 campaigns in JET with ITER-like wall", *17th International Conference on Plasma-Facing Materials and Components for Fusion Applications,* (PFMC17_2019), Eindhoven (Holanda), 20-24th May (2019).

[4] E.Alves, "Deuterium retention in Li-Sn alloys", *19th International Conference on Reactor Fusion Materilas*, LaJolla (California, USA), October 27th - November 1st (2019).

[5] E.Alves, "Ion beam studies of therapeutic silicone based hydrogel", *24th International conference on Ion Beam Analysis*, Antibes (France), October 8th-13th (2019).

[6] J.Cruz, V. Corregidor, M. Manso, M.L. Carvalho, L.C. Alves, "μ-XRF and μ-PIXE/μ-EBS analysis of XV-XVI Portuguese copper coins", MATERIAIS 2019, *XIX Congresso da Sociedade Portuguesa de Materiais and X International Symposium on Material*s, Lisbon, Portugal, April 14-17th (2019).

[7] L.C. Alves, I. Bogdanovic, T. Calligaro, M. Chiari, O. Girshevitz, Ho Manh-Dung, Z. Kasztovszky, M. Krmpotić, S.M.E. Mangani, B. Maróti, K. Mizohata, J. Raisänen, Ž. Šmit, N.P. Barradas, A. Simon, IBA and NAA as complementary non-destructive tools for the authentication of silver coinage, *24th International Conference on Ion Beam Analysis (IBA2019)*, Antibes, France, October 13-18 (2019).

[8] M.Bandiera, M. Vilarigues, M. Veritá, L.C. Alves, L. Saguí, "Roman opaque red glass, considerations and improvements on the application of PIXE analyses on archaeological glass", *16th International Conference on Particle Induced X-ray Emission*, Caldas da Rainha, Portugal, March 24-29th (2019).

[9] M.Dias, F. Antão, J.B. Correia, R.C da Silva, A.P. Gonçalves, U.V. Mardolcar, E. Alves., "Synthesis and characterization of $CrNbTaVW_x$ high entropy alloys", *19th International Conference on Fusion Reactor Materials (ICFRM 2019)*, La jolla, California, U.S.A (2019).

[10] M.Peres, "Ion beam induced current analysis in GaN microwires", *2nd Portuguese Condensed Matter Physics Meeting,* Porto Portugal, 8-10th May (2019).

[11] M.Peres, "Transparent Molybdenum Oxide Thin Films Grown on Flexible Substrates ", *Materials* 2019. Caparica, Portugal, April 14-17th (2019).

[12] M.Peres, "Effects of oxygen ion implantation on the structural and electrical properties of α-MoO_3 lamellar crystals". *2nd Portuguese Condensed Matter Physics Meeting*, Porto, 8-10th May, (2019).

[13] R.Borges, L.C. Alves, M.F. Araújo, A. Candeias, V. Corregidor, R.J.C. Silva, "15th to 17th century Portuguese silver coins: alloy chronological composition and coeval silver jewellery", *Joint ICTP-IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science*, Trieste, May 20-24th (2019).

[14] R.Borges, R.C.J. Silva., L.C. Alves, M.F. Araújo, A. Candeias, V. Corregidor, "Portuguese silverware alloy compositions from the 16th century", MATERIAIS 2019, *XIX Congresso da Sociedade Portuguesa de Materiais and X International Symposium on Materials*, Lisbon, Portugal, April 14-17th (2019).

[15] V.Corregidor, J. Cruz, L.C. Alves, "Ion beam techniques for cultural heritage studies in Portugal", *Joint ICTP-IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science*, Trieste, May 20-24th (2019).

[16] V.Corregidor, L.C. Alves, A. António, S. Cabo Verde. "Heavy elements in chestnuts detected by PIXE", *16th International Conference on Particle Induced X-ray Emission (PIXE)*, Lisbon, Portugal, March 24-29th (2019).

[17] V.Corregidor, L.C. Alves, A. António, S. Cabo Verde. "Ultra-Fast Low-Temperature Crystallization of Solar Cell Graded Formamidinium-Cesium Mixed-Cation Lead Mixed-Halide Perovskites Using a Reproducible Microwave-Based Process", *International Conference on Perovskite and Organic Photovoltaics and Optoelectronics (IPEROP19)*, Kyoto-shi, Japan, January 27-29th (2019).

[18] V.Corregidor, R. Dias, N. Catarino, C. Cruz, L. C. Alves, J. Cruz, Reflectance Transformation Imaging to study cultural heritage objects, *A Universidade de Lisboa e o Património. 2º Encontro.* Faculdade de Belas-Artes, Lisboa, November 27-30 (2019).

2018

[19] D.R. Pereira, C. Díaz-Guerra, M. Peres, S. Magalhães, J. G. Correia, J. G. Marques, A. G. Silva, E. Alves, K. Lorenz, "Strain and defect engineering of molybdenum oxide lamellar crystals by ion implantation", *21st International Conference on Ion Beam Modification of Materials (IBMM 2018*), San Antonio, USA, June 24-29, 2018.

[20] E.Alves, "Strain and defect engineering of molybdenum oxide lamellar crystals by ion implantation", *21st International Conference on Ion Beam Modification of Materials*, San Antonio, Texas (EUA), 24-29th June 2018.

[21] E.Alves, "Analysis of retained deuterium on Be-based films: ion implantation vs. in-situ loading", *23rd International Conference on Plasma Surface Interactions in Controlled Fusion Devices"* (PSI-23), 18th-22nd June, Princeton University, NY (EUA), 2018.

[22] J.Cruz. V. Corregidor, L.C. Alves. "Combined μ-PIXE/μ-EBS analysis of surface stains in 99.9% gold coins/discs", *16th International Conference on Nuclear Microprobe Technology and Applications (ICNMTA)*, Surrey, UK, July 8-13 (2018).

[23] K.Lorenz, D.N. Faye, M. Peres, E. Alves, X. Biquard, E. Nogales, B. Méndez, B. Daudin, L.H.G. Tizei, M. Kociak, P. Ruterana, "Assessing implantation damage in GaN nanowires", *Spring Meeting of the European Materials Research Society (E-MRS)*, Symposium Y: New developments in the modeling and analysis of radiation damage in materials, Strasbourg, France, June 18 - 2, (2018).

[24] L.C. Alves, M.F. Araújo., P. Valério, A.M.M. Soares, & R. Borges, "Uses of a nuclear microprobe setup (Cultural Heritage meets functional materials)", *2nd Workshop C2TN: Radiation for Science and Society*. Campus Tecnológico e Nuclear, Bobadela, December 11 (2018).

[25] M.Dias, F Antão, N. Catarino, A. Galatanu, M. Galatanu, P. Ferreira, J.B Correia, R.C da Silva, A.P Gonçalves, E. Alves, "Irradiation of the copper based high entropy alloys for nuclear applications", *SOFT 2018, Symposium on Fusion Technology* , Naxos, Sicilia, Italy (2018).

[26] M.Peres, L.C. Alves, E. Alves, T. S. Monteiro, S. Cardoso, A. Kuramata, E. G. Víllora, K. Shimamura, K. Lorenz, "Spatial characterization of Schottky barriers formed in β-Ga2O3 using a proton u-probe", *16th International Conference on Nuclear Microprobe Technology and Applications (ICNMTA2018)*, Surrey, UK, July 8-13 (2018). (best poster award)

[27] M.Peres, L.C. Alves, E. Alves, T. S. Monteiro, S. Cardoso, M. Alonso-Orts, E. Nogales, B. Méndez, E. G. Víllora and K. Shimamura, K. Lorenz, "Electro-optical characterization to understand the UV-blue emission bands in Ga2O3", *SPIE Photonics West Oxide-based Materials and Devices IX*, San Francisco, USA, January 27 – February 1, (2018).

[28] P.Almodóvar, M. Peres, C. Díaz-Guerra, J. Ramírez, K. Lorenz, J. González-Calbet, "Laser-induced localized optical activation of Eu ions in implanted h-MoO3 microrods", *1st Iberian meeting of materials science (CNMAT 2018)*, Salamanca, Spain, July 4-6 (2018).

[29] V.Corregidor, A. Barreiros, L.C. Alves. "Multi-energy IBA to study solar energy conversion materials", *16th International Conference on Nuclear Microprobe Technology and Applications (ICNMTA2018)*, Surrey, UK, July 8-13 (2018).

[30] V.Corregidor, J. Cruz, L.C. Alves, "Evolution of impurities in metals used in cultural heritage objects", *16th International Conference on Nuclear Microprobe Technology and Applications (ICNMTA2018),* Surrey, UK, July 8-13 (2018).

2017

[31] A.Ruza, M. Dias, A. Galatanu, M. Galatanu, N. Catarino and E. Alves, "Implantation in copper based high entropy alloys", *20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017)*, Lisbon, Portugal, July 9-14 (2017).

[32] E.Alves, "A study of solar thermal absorber stack based on CrAlSiNx/CrAlSiNxOy structure by ion beams", *23rd International conference on Ion Beam Analysis*, Shangai (China), October 8th-13th, 2017.

[33] E.Alves, "AlN influence on radiation damage of Ar and Xe implanted AlGaN", *19th International Conference on Radiation Effects in Insulators*, Versailles (France), July 2nd-7th 2017.

[34] H.Luis, N. Franco *et al*., "Micro-AMS analysis of low dose Pt implantation in Si", *International Accelerator Mass Spectrometry Conference (AMS-14*), University of Ottawa, Ottawa, Canada, August 14-18 (2017).

[35] H.Luis, N. Franco *et al*., "Micro-AMS analysis of low dose Pt implantation in Si", *International Conference on Surface Modification of Materials by Ion Beams (SMIIB-2017)*, Lisbon, Portugal, July 9-14 (2017).

[36] I.Coutinho, F.P. Valente, L.C. Alves, T. Medici, "Glass bracelets in medieval Portugal: insights on production and circulation", *IV Congresso Internacional Medieval Europe in Motion: A Global Context? Instituto de Estudos Medievais-NOVA FCSH*, Fundação Calouste Gulbenkian, Lisboa Portugal, December, 13-15 (2017).

[37] J.Cruz, V. Corregidor, M. Manso, L.C. Alves, L.Carvalho. "Combined μ-XRF and μ-PIXE/μ-EBS analysis of ancient copper coins", *Non-destructive and microanalytical techniques in art and cultural heritage, (TECHNART 2017)*, Bilbao, Spain, May 2-6 (2017).

[38] K.Heinola, T. Ahlgren, S. Brezinsek, N. Catarino, V. Corregidor, I. Jepu, S. Krat, A. Lahtinen, J. Likonen, G. F. Matthews, M. Mayer, A. Widdowson and JET Contributors. "Experience on

divertor fuel retention after two JET ITER-Like Wall campaigns", *16th International Conference on Plasma-Facing Materials and Components for Fusion Applications*, Neuss, May 16-19 (2017).

[39] M.A. Barreiros, V. Corregidor, M. J. Brites, J. Pinto, M.J. Mendes, L.C. Alves. "Macro and micro characterisation of a mixed cation/mixed halide perovskite", *Industry Day, Printed Electronics and Solar Cells*, Lisbon, Portugal, April 7 (2017).

[40] M.Alonso-Orts, J. Dolado, M. Peres, K. Lorenz, I. López, E. Nogales, J. Piqueras, B. Méndez, "Synthesis and Physical Properties of Doped Gallium Oxide*", Fall Meeting of the Materials Research Society (MRS), Symposium EM04: Wide- and Ultra-Wide-Bandgap Materials and Devices*, Boston (MA), USA, November 26-December 1, (2017).

[41] M.Alonso-Orts, J. Dolado, M. Peres, K. Lorenz, I. López, E. Nogales, J. Piqueras, B. Méndez, "Optical and electronic properties of doped β-Ga2O3 micro- and nanostructures", *2nd International Workshop on Gallium Oxide and Related Materials (IWGO-2)*, Parma, Italy, September 12-15 (2017).

[42] M.Dias, F. Guerreiro, E. Tejado, U.V. Mardolcar. J.B. Correia, T. Palacios, J.Y. Pastor, P.A. Carvalho, E. Alves, "Thermal properties of novel WC-Cu cermets for fusion applications", *EuroMat 2017*, Thessaloniki, Greece, September (2017).

[43] M.Peres, D.N. Faye, X. Biquard, E. Nogales, M. Felizardo, A. Redondo-Cubero, T. Auzelle, B. Daudin, L.H.G. Tizei, M. Kociak, . Ruterana, B. Méndez, E. Alves, K. Lorenz, "Incorporation of Europium into GaN nanowires by ion implantation", *12th International Conference on Nitride Semiconductors (ICNS-12)*, Strasboug, France, July 24-28, (2017).

[44] M.Peres, L.C. Alves, E. Alves, K. Lorenz, T. S. Monteiro, S. Cardoso, M. Alonso-Orts, E. Nogales, B. Méndez, E. G. Víllora and K. Shimamura, "Reversible modulation of the UV band in β-Ga_2O_3", *2nd International Workshop on Gallium Oxide and Related Materials (IWGO-2*), Parma, Italy, September 12-15 (2017).

[45] N.Catarino, M. Dias, J. Lopes, E. Alves, "Helium and deuterium irradiation effects in Tungsten-based alloys with Titanium", *20th International Conference on Surface modification of Materials by Ion Beams (SMMIB-2017)*, Lisbon, Portugal, July 2017.

[46] V.Corregidor, L.C. Alves, M. J. Brites, J. V. Pinto, M.J. Mendes, M.A. Barreiros. "Ion beams to study mixed cation/mixed halide perovskite layers", *21st International Conference on Surface Modification of Materials by ion beams (SMMIB 2017)*, Lisbon, Portugal, July 9-14 (2017).

Other Seminars

2019

[1] R.Borges, L. C. Alves, M. F. Araújo, A. Candeias, V. Corregidor, R. J. C. Silva, "15th to 17th century Portuguese silver coins: alloy chronological composition and coeval silver jewellery*", Joint ICTP-IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science,* Trieste, Italy, May 20-24th (2019).

[2] V.Corregidor "On beam analytical techniques to discover what is behind the cultural heritage artifacts*", Seminar. Mestrado em Proteção e Segurança Radiológica – IST*, Lisbon, Portugal, November 6th (2019).

[3] V.Corregidor, J. Cruz and L.C. Alves, "Ion beam techniques for cultural heritage studies in Portugal*", Joint ICTP-IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science,* Trieste, Italy, May 20-24th (2019).

2018

[4] K.Lorenz, "Accelerators and development of new materials", Instituto Superior Técnico, *Seminar of the Physics Department*, April 18th (2018).

2017

[5] K. Lorenz, "Ion implantation in GaN thin films and nanowires", C2TN, Instituto Superior Técnico, *Workshop on Advanced Materials*, November 20th (2017).

[6] K. Lorenz, "Ion implantation of GaN nanowires", CEA Grenoble, France, October 13th (2017).

[7] L.C. Alves, V. Corregidor, "MeV ion beams in CH studies", Research seminars, CORES, Ph.D. Programme in the Conservation and Restoration of Cultural Heritage, FCT/UNL, Caparica, Portugal, October 29th (2017).

[8] L.C. Alves, V. Corregidor, "Microscopy with MeV ion beams", *C2TN Workshop on Advanced Materials & ChemMat Doctoral Programme*, IST/CTN, Pólo de Loures, Bobadela, Portugal, November 20th (2017).

[9] L.C. Alves, V. Corregidor, "Particle Induced X-ray emission (PIXE) in cultural heritage studies: examples of applications", *The HERACLES Fall School - "Characterization Techniques in Cultural Heritage",* FCT/UNL, Caparica, Portugal, October 11-12th (2017).

[10] M. Peres, "Materials Characterization and Modification Using Ion Beams", *Complutense University of Madrid*, *Department of Physics*, Madrid, Spain, February (2017).

PROJECTS

Running Projects

[1] EP/N00275X/1: *Hysteretic photochromic switching (HPS) of europium-magnesium defects in gallium nitride: a potential route to a new solid-state qubit* (2015-2019). Total Budget: €508.002,00, **IST Budget: €10.000,00** (Spent Amount). Prime Contractor: Strathclyde University, Scotland, UK. Coordinator: Kevin P. O'Donnell. IST Coordinator: Katharina Lorenz.

[2] IAEA/CRP F11021 Research Contract nº22195 (2017-2020): *Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences* (COGLACE). **IST Budget: €15.000,00 €** (€5.000,00 per year). Prime Contractor: IAEA (Coordinator: L.C. Alves). IST Coordinator: L.C. Alves.

[3] INFRAIA-01-2018-2019 (H2020): *Research And Development with Ion Beams – Advancing Technology in Europe* (RADIATE). **IST Budget: €403.218,75**. Portuguese Coordinator: E. Alves.

[4] ITER PHYSICS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (Work Package: WPPFC). *Preparation of efficient PFC operation for ITER and DEMO*, IST/IPFN. **IST Budget: €91.670,00.** IST (Period: 2017-2019). Coordinator: E. Alves.

[5] ITER PHYSICS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (Work Package: WPMAT, IST/IPFN). **IST Budget: €77.860,00** (Period: 2017-2019)**.** IST Coordinator: E. Alves.

[6] JET PROJECTS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (Work Package: WPJET2, *Plasma-facing)*. **IST Budget: €303.330,00** (Period: 2017-2019). IST Coordinator: E. Alves.

[7] POCI-01-0145-FEDER-032299 (2018-2021): *Plasmonic Nanoparticles for Bio-detection* (NANO4BIO). Total: €230.083,17; UMinho: € 117.558,20; **IST Budget: €52.550,00**. IST Coordinator: E. Alves.

[8] PROJECTO ESTRATÉGICO: PEST-OE/FIS/UI0275/2013 (2015-2017), *Materials Processing and Characterization.* **IST Budget: €50.777,36.** Group leader: E. Alves.

[9] PROJECTO ESTRATÉGICO: PEST-UID/FIS/50010/2019 (2018-2019), *Materials Processing and Characterization.* **IST Budget: €36.381,29,00 (2019).** Group leader: E. Alves.

[10] PTDC/CTM/31192/2017: *Surface Engineered Glass Ceramics with Improved Mechanical Properties* (GLASSMECH). IST Budget: €237,288. **IST Budget: €20.000,00**. Member: E. Alves. IST Coordinator: L. Santos.

[11] PTDC/CTM-CTM/28011/2017 (2018-2021): *NAno-engineering of Wide Bandgap Semiconductors Using Ion Beams* (NASIB). Total Budget: € 223.623,25, **IST Budget: €170.848,25.** Prime Contractor: IST-ID, Portugal (Coordinator: Katharina Lorenz). IST Coordinator: Katharina Lorenz; Team member: M. Peres (25%).

[12] PTDC/CTM-ENE/1087/2014: *Photonic Crystal-assisted Frequency Conversion Phosphor Layers for Energy Applications* (COFRE). Total Budget: €194.823,00, **IST Budget: €29.790,00**. Member: E. Alves.

[13] P2020-PTDC/CTM-ENE/2892/2016: *Solar Selective Absorber for High Temperature Applications* (ABSOLAR). Total Budget: €100.548,00€, **IST Budget: €16.800,00**. IST Coordinator: E. Alves.

[14] TC PROJECT RER/1017 (2015-2017): *Using Advanced Radiation Technologies for Materials Processing*. **IST Budget: €1.420,00**. National Counterpart: E. Alves.

[15] TC PROJECT RER/1019 (2017-2019): *Enhancing Standardized Radiation Technologies and Quality Control Procedures for Human Health, Safety, Cleaner Environment and Advanced Materials*. **IST Budget: €1.420,00**. National Counterpart: E. Alves.

[16] FP7-PEOPLE-2012-ITN (2013-2017): *Supporting Postgraduate Research with Internships in industry and Training Excellence* (SPRITE). **IST Budget: 222.222,81€**. IST Coordinator: E. Alves.

EDUCATION

PhD Theses

2019

[1] K.Lorenz, Supervisor (E.Alves, Co-Supervisor) of **Djibril Nd. Faye**, PhD in Materials Engineering: *Ion implantation in* $Al_xGa_{1-x}N$ *alloys and GaN nanostructures*, IST/Univ. Lisboa, January 2019.

2018

[2] E.Alves, Supervisor (M. Dias, Co-Supervisor) of **Norberto José Sobral Catarino**, PhD in Technological Physical Engineering: *Study of Irradiation Effects in Tungsten and Production of Tungsten Alloys for Fusion Devices*, IST/Univ. Lisboa, December 2018.

2017

[3] E.Alves, Supervisor of **Maria Isabel Guerreiro Fialho**, PhD in Technological Physical Engineering: *Study of the Influence of Al Content on Optical Activity and Lattice Site Location of Rare Earth Implanted* $Al_xGa_{1-x}N$, IST/Univ. Lisboa, SFRH/BD/78740/2011, July 2017.

MSc Theses

2019

[1] K.Lorenz, Supervisor (Co-Supervisor M. Pavlov/QUANTOM) of **Francesca Martin**, MSc in Energy Engineering and Management: *PV plant performance data analysis and modelling - Diagnostic of PV Module Defects,* IST/Univ. Lisboa, December 2019.

[2] M.Dias, Supervisor (Co-Supervisor R. da Silva) of **Francisco José Neto Antão**, MSc in Materials Engineering: *HEAs: High Entropy Alloys for Advanced Systems and Engines,* IST/Univ. Lisboa, September 2019.

[3] S.Magalhães, Supervisor of **João Salgado Cabaço**, MSc Thesis: *Effect of Ar Implantation Energy and Angle on the Reflection Pattern of Nitrides*, Universidade do Porto, January 2019.

2018

[4] K.Lorenz, Supervisor (Co-Supervisor S. Magalhães) of **Pedro José de Sousa Mendes**, MSc in Engineering Physics: *Measuring Strain Caused by Ion Implantation in GaN*, IST/Univ. Lisboa, June 2018.

2017

[5] K.Lorenz, Supervisor (Co-Supervisor S. Freitas) of **Dirkjan Verheij**, MSc in Technological Physical Engineering: *Radiation Sensors Based on GaN Microwires*, IST/Univ. Lisboa, November 2017.

[6] K.Lorenz, Supervisor (Co-Supervisor A.G. Silva) of **Daniela Filipa Rodrigues Pereira**, MSc in Engineering Physics: *Modificação das Propriedades Elétricas de MoO_3 por Tratamento Térmico e Irradiação*, U. Nova de Lisboa, November 2017.

[7] M.Dias, Supervisor (Co-Supervisor A.P. Gonçalves, C2TN) of **André Felipe de Jesus Lopes Ruza**, MSc in Materials Engineering: *High Entropy Alloys for Fusion Applications*, IST/Univ. Lisboa, December 2017.

[8] M.Dias, Supervisor (Co-Supervisor N. Pinhão, IPFN) of **Rita Fonseca Faustino**, MSc in Materials Engineering *Production, Characterization and Modeling of WC-Cu Cermets*, IST/Univ. Lisboa, November 2017.

[9] V.Corregidor, Supervisor of **Karthik Vengatesan** (83389), MSc Thesis in Energy Engineering and Management: *Windows Film to Glass: Numerical Simulation Software for Avoiding Thermal Stress*, September 2017.

CLASSES/TEACHING

2019

[1] V.Corregidor, Responsible for "*IST Summer Internship*". Student: **Renato Dias**. MEEC-IST, June-September 2019.

2018

[2] H.Luís, Marker of the *"Physics Olympiad Experimental Exams"* at the International Physics Olympiad IPhO, Lisbon, Portugal, 2018.

[3] H.Luís, Invited Professor, Faculdade de Ciência e Tecnologia da Universidade Nova de Lisboa. Disciplines: "*Física III*", in the Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Física", 2018.

2017

[4] E.Alves, 2017-2019 – Teaching: "*Plasma Facing Interactions*" of the unit "Methodologies and Techniques" of PhD programme Advanced Programme in Plasma Science and Engineering (APPLAuSE), IST/IPFN.

[5] E.Alves, 2017-2019 – Teaching: "*Experimental classes on Nuclear Reactions"*. Unit "Laboratório de Física Experimental Avançada", DF/IST. Laboratório de Aceleradores e Tecnologias de Radiação (LATR), IST/CTN.

[6] E.Alves, 2017-2019 – Teaching: "*Experimental classes on Nuclear Physics",* Master degree on "Engenharia Física Tecnológica", DF/IST. Laboratório de Aceleradores e Tecnologias de Radiação (LATR), IST/CTN.

[7] H.Luis, Invited Professor, Faculdade de Ciência e Tecnologia da Universidade Nova de Lisboa. Disciplines: "*Física Nuclear"*, Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Física", 2017.

[8] K.Lorenz, Invited Professor at IST. Discipline: "*Advanced Characterisation of Functional Materials",* in the Curricular Plans for PhD Students on "Diploma de Estudos Avançados em Engenharia Física Tecnológica". Academic years: 2018/2019; 2019/2020.

[9] K.Lorenz, Invited Professor at IST. Disciplines: "*Advanced Experimental Physics Laboratory";* "*Material Science for Nuclear Technologies";* "*Photovoltaic Solar Energy";* "*Nanotechnologies and Nanoelectronics"* and "*Physics and Technology of Semiconductors"*, in the Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Física". Academic years: 2018/2019; 2019/2020.

[10] K.Korenz, Invited Professor at IST. Disciplines: "*Material Science for Nuclear Technologies"* and "*Photovoltaic Solar Energy"*, in the Curricular Plans for MSc Students on "Mestrado Bolonha em Engenharia e Gestão da Energia". Academic years: 2017/2018; 2018/2019; 2019/2020.

[11] K.Lorenz, Invited Professor at IST. Disciplines: "*Mechanics and Waves"* and "*Electromagnetism and Optics"*, in the Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Electrotécnica e de Computadores". Academic years: 2016/2017; 2017/2018.

[12] M.Peres, Invited Auxiliary Professor at IST. Discipline: "*Laboratório de Física Experimental Avançada (LFEA4)"* in the Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Física".

[13] V.Corregidor, 2017-2018 – Teaching: "*Electromagnetism and Optics"*. 2nd year – 1st and 2nd Semesters, Integrated Master in Civil Engineering, IST/Univ. Lisboa, Portugal.

[14] V.Corregidor, 2016-2017 – Teaching: "*Electromagnetism and Optics"*. 2^{n}d year – 1st Semester, Integrated Master in Civil Engineering, IST/Univ. Lisboa, Portugal.

[15] V.Corregidor, 2016-2017 – Teaching: "*Electromagnetism and Optics"*. 2nd year – 2nd Semester, Master Degree LMAC and MEBiom, IST/Univ. Lisboa, Portugal.

[16] V.Corregidor, Responsible for "*IST Summer Internship"*. Student: **Francisco Manuel Neves Moreira de Azevedo**, MEEC-IST, June-September 2017.

TRAINING COURSES

2019

[1] E.Alves, Doctoral Programme on Materials: *Advanced Techniques of Materials Characterization*, Universidade de Aveiro, CTN/IST, November 2019.

[2] E.Alves, Master Programme on Mining Engineering: *Energy: Challenges for the 21st century*, IST, February 28th, 2020.

[3] E.Alves, Physics Degree on Nuclear and Particle Physics & Condensed Matter Physics: *Accelerators and Ion Beam Applications*, Universidade de Coimbra, CTN/IST, April 2019.

[4] V.Corregidor, Participation in *ICTP-IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science*, Trieste, Italy, May 2019.

2018

[5] E.Alves, Doctoral Programme on Materials: *Advanced Techniques of Materials Characterization*, Universidade de Aveiro, CTN/IST, November 2018.

[6] E.Alves, Nuclear and Particle Physics & Condensed Matter Physics of Physics degree, Universidade de Coimbra, *Accelerators and Ion Beam Applications*, CTN/IST, May 2018.

2017

[7] E.Alves, Master Programme in Physics Engineering: Characterization Techniques of Structures-Ion Beam*, Techniques on Materials Science Studies*, University of Aveiro, IST/CTN, December 2017.

[8] V.Corregidor, Participation in *Technical Meeting on Developing Strategies for Safe Analysis of Paintings and Paint Materials*, Rijksmuseum, Amsterdam, the Netherlands, June 2017.

JURY MEMBERSHIP

2019

[1] E.Alves, Arguing member, PhD thesis of **João Pedro Simões Loureiro**, *Liquid Tin and Lithium-Tin as plasma facing components for nuclear fusion device*, IST, Universidade de Lisboa, May 2019.

[2] K.Lorenz, MSc thesis of **Frederik Eistrup**, *Semiconductor Triplet Sensitizer for Triplet Fusion Upconversion* (Master Physics), IST, 2019.

[3] S.Magalhães, MSc thesis **João Salgado Cabaço**, *Effect of Ar implantation Energy and Angle on the reflection pattern of nitrides* (Master in Physics), Universidade do Porto, Porto, 2019.

[4] V.Corregidor, PhD thesis of **Sandra Rubio Aguado**, *Materiales semiconductores II-VI en lámina delgada y volumen para aplicaciones fotovoltáicas y detectores de radiación"* (PhD in Physics), Autonoma University of Madrid, Madrid, October 2019.

2018

[5] E.Alves, Vogal, PhD thesis of **Hugo Miguel Martins Ferreira da Silva**, *Elastic scattering of protons and oxygen ions from light nuclei"*, FCT-UN, 2018.

[6] K.Lorenz, MSc thesis of **Ana Rita de Campos Pereira**, *Síntese e Caracterização de 2D-MoS2* (Master Physics), U. Aveiro, 2018.

[7] K.Lorenz, MSc thesis of **Ricardo César Carvalho Teixeira**, *Local probe studies in Jahn-Teller distorted manganites* (Master Physics), IST, 2018.

[8] K.Lorenz, PhD thesis of **Ângelo Rafael Granadeiro Costa**, *Lattice location of impurities in Silicon Carbide* (PhD in Physics), IST, Lisbon, 2018.

[9] K.Lorenz, PhD thesis of **Idris A. Ajia**, *Optical and temporal carrier dynamics investigations of III- nitrides for semiconductor lighting* (PhD in Physics), KAUST, 2018.

2017

[10] E.Alves and K.Lorenz, PhD thesis of **Maria Isabel Fialho**, *Study of the influence of Al content on optical activity and lattice site location of rare earth implanted* $Al_xGa_{1-x}N$ (PhD in Physics), IST, Lisbon, 2017.

[11] K.Lorenz, MSc thesis of **José Pedro de Sousa Cardoso**, *Caracterização Ótica de Nanofios de AlN Implantados com Európio* (Master Physics), U. Aveiro, 2017.

[12] M.Peres, MSc thesis of **Dirkjan Verheij**, *Radiation Sensors Based on GaN Microwires* (Master in Mestrado Integrado em Engenharia Física Tecnológica), Instituto Superior Técnico, Lisboa, november 2017.

EVALUATOR

2019

[1] E.Alves, **Professor Coordenador**, Notice n.º 20771/2019, Radiology, *D.R. n.º 249, Série II, de 27 de dezembro de 2019 | Edital EDT-P-54/2019, de 20 de dezembro; Politécnico do Porto,* Escola Superior de Saúde (2019).

[2] E.Alves, **Investigador Auxiliar**, Notice n.º 299/2019, of Department of Engineering and Nuclear Sciences, *Diário da República, 2.ª série — N.º 42 — 23 de fevereiro de 2019,* IST (2019).

[3] E.Alves, **Professor Auxiliar**, Notice n.º 187/20199, Department of Physics, *Diário da República, 2.ª série — N.º 19 — 28 de janeiro de 2019, Universidade de Coimbra* (2019).

[4] E.Alves, **Professor Associado**, Notice n.º 486/2019, IST, field of "Nuclear Technologies and Radiological Protection from the Department of Nuclear Sciences and Engineering", disciplinary field of "Particle and Nuclear Physics from the Department of Physics" (2019).

[5] E.Alves, **Professor Associado,** Notice n.º 1664/2019 of Department of Physics, *Diário da República, 2.ª série, n.º 251 de 31 de dezembro,* FCT-UN (2019).

[6] E.Alves, **Professor Adjunto**, Nuclear Medicine, Escola Superior de Tecnologia da Saúde de Lisboa, *Despacho n.º 194-IPL/2019, de 22 de novembro 2019,* Instituto Politécnico de Lisboa (2019).

[7] E.Alves, **Professor Adjunto**, Radiology, Escola Superior de Tecnologia da Saúde de Lisboa, *Despacho (extrato) n.º 3547/2019, Diário da República, 2.ª série — N.º 62 — 28 de março de 2019* (2019).

2018

[8] E.Alves, **Senior Scientific Associate**, External Evaluator of Iva Iva Bogdanović Radović (promotion), Ruder Boskovic Institute, Croatia", March (2018).

[9] E.Alves, **Professor Auxiliar**, Notice n.º 762/2018, Department of Physics, *Diário da República, 2.ª série n.º 157 - 16 de agosto 2018*, FCT-UNL (2018).

2017

[10] E.Alves, **Investigador Auxiliar**, Notice n.º 980/2017, Department of Physics, *Diário da República, 2.ª Série, n.º 244 de 21 de dezembro 2017*, FCT-UNL (2017).

[11] E.Alves, **Investigador Principal**, Notice n.º 898/2017, Department of Engineering and Nuclear Sciences, *Diário da República, 2.ª série — N.º 223 — 20 de novembro de 2017*, IST (2017).

[12] E.Alves, **Investigador Coordenador**, Notice n.º 902/2017, Department of Engineering and Nuclear Sciences, *Diário da República, 2.ª série — N.º 224 — 21 de novembro de 2017*, IST (2017).

HABILITATION

[1] E.Alves, Member of the Jury of Habilitation of **Miguel Adrião Mateus dos Reis**, *Despacho n.º 9029/2017 - Diário da República n.º 197/2017, Série II de 2017-10-12,* IST (2017).

CONFERENCE/COURSE ORGANIZATION

Conferences Organization

[1] E.Alves, Chair of the *"AIEA Regional Workshop on the Implementation of Upgraded Quality Management Systems to Improve Radiation Processing Procedures"*, Bobadela, Lisbon, Portugal. December 10-14, 2018 (21 participants).

[2] E.Alves, Chair of the *EUROfusion JET2-IBA Meeting on "Ion Beam Analysis of Plasma-Facing Components from JET-ILW"*, IST/CTN, Bobadela, April 17-18, 2018 (16 participants).

[3] E.Alves, Chair of the *"20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017)"*, Lisbon (Portugal), July 9-14, 2017 (250 participants).

[4] E.Alves, Chair of the *"AIEA Regional Meeting to Complete the Harmonized Guidance Material and Protocols for Quality Control/Quality Assurance in radiation Processing Management at the Regional Level"*, Bobadela, Portugal, 29 May – 2 June 2017.

[5] E. Alves, Chair of the NuPECC LRP2017 Town Meeting, Darmstadt, Germany, January 11-13, 2017.

[6] K.Lorenz, Chair of the Workshop *"Ion Beams Meet Semiconductors" (SMIB-2019)*, Instituto Superior Técnico, Lisbon, Portugal, June 17-18, 2019.

[7] K.Lorenz, Co-chair of the Symposium *"New developments in the modelling and analysis of radiation damage in materials"*, *EMRS Spring Meeting*, Strasbourg, France, June 18-22, 2018.

[8] K.Lorenz, Co-chair of the Symposium *"Wide-bandgap semiconductors"*, *1st Iberian Meeting on Materials Scienc*e, Salamanca, Spain, July 4-6, 2018.

[9] M.Dias, Member of the Organizing Committee of the "*20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017)"*, Lisbon, Portugal, July 9-14, 2017.

[10] M.Dias, Organizing Committee of *WPMAT-HHFM: Project Monitoring Meeting*, Lisbon, Portugal, June 20 - 21, 2017.

[11] M.Peres, Member of the Organizing Committee of the *"20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017)"*, Lisbon, Portugal, July 9-14, 2017.

[12] V.Corregidor, Member of the Organizing Committee of the *"20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017)*, Lisbon, Portugal, July 9-14, 2017.

[13] V.Corregidor, Member of the Organizing Committee of the *"International Conference on Ion Beam Modification of Materials (IBMM-2020)*, Lisbon, Portugal, July 5-10, 2020.

TECHNICAL COMMITTEES

[1] E.Alves, Member of the external "Review Board Center for Integrated Nanotechnologies", Sandia National Laboratories, Los Alamos, USA, since 2018.

[2] E.Alves, Elected Member of "International Committee of the International Conference Series on Surface Modification of Materials by Ion Beams", since 2017.

[3] E.Alves, Member of "Nuclear Physics European Coordination Committee, NuPECC". Portuguese Representaive, since 2016.

[4] E.Alves, Member of "Scientific Review Panel" of CERIC-ERIC (European Research Infrastructure Consortium), since 2016.

[5] E.Alves, Chair of "International Programme Advisory Committee (iPAC)", CIMAP-CIRIL, Caen, since 2015.

[6] E.Alves, Member of "Comissão de Vagas" of DECN, since 2014.

[7] E.Alves, Deputy Director of "Laboratório de Aceleradores e Tecnologias de Radiação", since 2013;

[8] E.Alves, Member of the "Executive Board of Instituto de Plasmas e Fusão Nuclear", Group leader of Materials Processing and Characterisation, since 2013.

[9] E.Alves, Member of "Scientific Council of IST", since 2012 (2º term.).

[10] E.Alves, Elected Member of "International Committee of the International Conference Series on Ion Beam Modification of Materials", since 2006.

[11] E.Alves, Elected Member of "International Committee of the International Conference Series on Radiation Effects in Insulators", since 2001.

[12] K. Lorenz, Member of the "Advisory Editorial Board of Nuclear Instruments and Methods in Physics research, Section B: Beam Interactions with materials and Atoms", since 2019.

[13] K. Lorenz, Member of the "EMIR&A Scientific Committee", French National network of accelerators for irradiation and analysis of molecules and materials, since 2019.

[14] K. Lorenz, Member of the "ISOLDE and Neutron Time-of-Flight Experiments Committee – INTC", CERN, Switzerland, since 2019.

[15] K. Lorenz, Evaluator of a "Proposal for New Graduate Schools" ("Ecole Universitaire de Recherche") for the Agence Nationale de la Recherche (ANR), France, 2017.

[16] K. Lorenz, Evaluator of "Research Project of the National Science Centre," Poland, 2017.

[17] K. Lorenz, Evaluator of "Researcher Performance for the National Research Foundation", South Africa, 2017.

[18] K. Lorenz, Member of the "User Selection Panel at the Ion Beam Centre, Helmholtz-Zentrum Dresden-Rossendorf", Germany, since 2014.

[19] K. Lorenz, Member of the "Panel of Reviewers of beam time proposal at Centro de Micro-Análisis de Materiales, Madrid", Spain, since 2011.

[20] M. Peres, Member of the "Scientific Council of IPFN", since 2015.

COLLABORATIONS

[1] A. Barreiros, Unidade de Materiais para a Energia (UME), LNEG. Characterization of materials for solar energy conversion.

[2] Andres Redondo Cubero, June 17 – 18, 2019, U Autonoma de Madrid, project meeting.

[3] Bruno Daudin, June 17-18, 2019, CEA Grenoble, project meeting.

[4] Daniel Galaviz, Professor FCUL, Collaboration in detector testing measurements at LATR.

[5] Flyura Djurabekova, June 17-18, 2019, University of Helsinki, project meeting.

[6] J. Cruz, Universidade Nova de Lisboa. Characterization of materials using IBA techniques.

[7] João Pedro Araújo, Paula Quitério, January 1, Universidade do Porto, Hematite samples (2019-2020).

[8] J.L. Plaza, Universidad Autónoma de Madrid. Characterization of single crystals.

[9] K. Lorenz, Collaborator of INESC-MN, since 2017.

[10] Kai Nordlund, June 17-18, 2019, University of Helsinki, project meeting.

[11] M. Peres, Collaborator of INESC-MN, since 2017.

[12] Maria Fonseca, Professor FCT/UNL, Collaboration in PIGE measurements at LATR.

[13] Nabiha Ben Sedrine, June 17-18, 2019, Universidade de Aveiro, project meeting.

[14] P. Salomé, INL. Characterization of materials for solar energy conversion.

[15] R. Borges, Universidade Nova de Lisboa. Characterization of cultural heritage silver artefacts.

[16] Rosário Correia, June 17 – 18, 2019, Universidade de Aveiro, project meeting.

[17] Susana Cardoso de Freitas, June 17 – 18, 2019, INESC-MN, project meeting.

[18] V. Corregidor, Laboratório Hercules, Universidade de Évora. Collaboration to characterize cultural heritage artefacts.

SERVICES

Accelerators, Nuclear Instrumentation and Irradiation

SERVICES | 3: R&D AND INDUSTRY

SECTOR 1 | R&D Services: Accelerators

IBL | 1: Description

Ion Beam Laboratory Group (IBL) have experimental beam lines for in situ analysis of samples for R&D purposes. Established a network of collaborations with researchers from all over the world to perform studies on this areas taking advantage of the non-destructive and quantitative nature of the ion beam techniques.

IBL | 2: Team

Name	Category	Time Allocated
Eduardo Alves	Full Researcher (Coordination)	100%
Katharina Lorenz	Senior Researcher (Permanent Member), sept.2018	100%
Nuno P. Barradas	Senior Researcher (CERN Permanent Member)	100%
Carlos Cruz	Auxiliary Researcher (Permanent Member)	50%
Luís Alves	Auxiliary Researcher (C^2TN Permanent Member)	100%
Rodrigo Mateus	Auxiliary Researcher (Permanent Member)	100%
Rui Silva	Auxiliary Researcher (Permanent Member)	100%
Marta Dias	Researcher Contract (Permanent Member)	100%
Rui M.S. Martins	Researcher Contract (Permanent Member)	100%
Victoria Corregidor	Researcher Contract (Permanent Member)	100%
Hélio Luís	Postdoctoral Researcher (Permanent Member)	100%
Marco Peres	Postdoctoral Researcher (Permanent Member)	100%
Norberto Catarino (PhD 2018)	Postdoctoral Researcher (Permanent Member)	100%
Sérgio Magalhães (PhD 2013)	Postdoctoral Researcher (Permanent Member)	100%
Adam Przemyslaw Jozwik (Nattan)	Project Collaboration (Oct.2018-Sept.2020)	100%
Daniela Pereira (MSc 2017)	PhD Scholarship Student	100%
Djibril Faye (PhD 2019)	PhD Scholarship Student	100%
Isabel Fialho (PhD 2017)	PhD Student	100%
Miguel C. Sequeira (MSc 2017)	PhD Scholarship Student (2019)	100%
Dirkjan Verheij (MSc 2018)	PhD Scholarship Student	100%
Francisco Antão (MSc 2019)	MSc Scholarship Student	100%
Jorge Rocha	Principal Specialist Technician	100%
Ana Faria, Income/Logistics	Graduated Technician	30%
Teresa Pires, Web Designer/Logistics	Graduated Technician	30%
Filomena Baptista	Assistant Technician (2017-2018)	30%

IBL | 3: Experimental Equipment

The Ion Beam Laboratory (IBL) hosts two electrostatic accelerators and an implanter. A 2.5 MV Van de Graaff with three experimental beam lines, with all the relevant ion beam techniques available, RBS, PIXE, NRA, Channeling, ERDA and a Nuclear Microprobe.

A 3.0 MV Tandem with a micro AMS (Accelerator Mass Spectrometry) line with depth scan profiling capabilities, high resolution PIXE (10-12 eV) setup, a Universal Ion Beam Analysis End Station and a dedicated line for nuclear physics experiments. A 210 kV Danfysik Ion Implanter with an implantation area of 20x20 cm^2 allowing implantations of nearly all the chemical species of the periodic table in the temperature range of 77 K up to 1273 K, in a controlled way. The connection of the implantor to the RBS chamber of the van the Graaff Accelerator, allows situ analysis during the implantation.

IBL | 4: External Visits

Due to the mandatory confinement resulting from the Covid-19 epidemic, 2020 was an atypical year, with no study visits to the campus allowed after March. Follow-up visits to the Ion Beam laboratory, as indicated below:

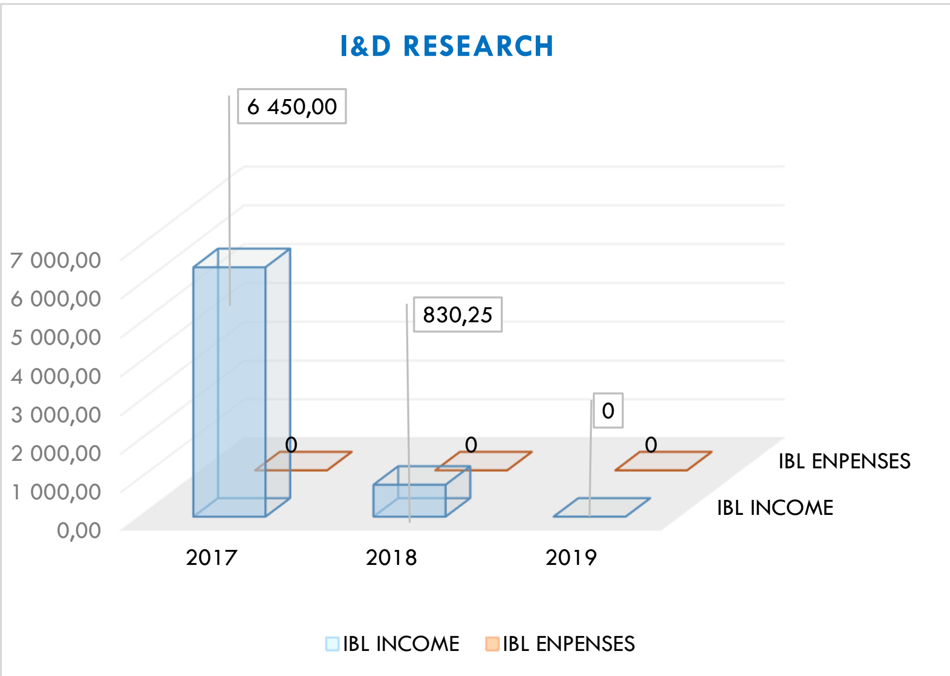
Description	Visits / Visitants 2016		Visits / Visitants 2017		Visits / Visitants 2018		Visits / Visitants 2019		Visits / Visitants 2020	
Secondary Schools	6	188	9	317	6	150	10	380	4	185
Universities	2	80	3	92	4	60	1	60	1	36
Other Visits*	1	50	1	43	1	12	1	60	---	---
Sub-Total			**13**	**452**	**12**	**382**	**12**	**500**	**5**	**221**

***Other Visits:**

- MEFT - Cadeira de Laboratório de Física Experimental Avançada, February 2020 (36).
- XIV Encontro Nac. Est. Eng. Biomédica, LATR, February 11, 2019 (60).
- Seniores – Ciência Viva, May 2018 (12).
- Encontro Nacional de Estudantes de Física 2017, February 2017 (43).
- Universidade Senior, S. João da Talha, IST/CML, 2016 (50).

IBL | 5: Statistical Record

In-situ characterization samples:



Total Income: € 7.280,25 vs Total Expenses: € 0,00

SECTOR 2 | Nuclear Instrumentation: design, marketing and consulting

NI | 1: Description

The Nuclear Instrumentation (IN) group is the successor of a multidisciplinary group that, for many long years, has accumulated substantial experience in several areas of peaceful applications of Nuclear Technologies. In particular, in the development of instruments, devices and applications, directed to the various sectors of the national economy, to the industries foremost, but also collaborating with diverse research groups, participating in scientific projects inside and outside the IST/ CTN institution, in Portugal and abroad.

Main activities summary:

- Consulting, project, installation, repairing and maintenance of nuclear equipment for industrial enterprises and scientific institutions (external services);
- Participation in R&D projects;
- Design and maintenance of electronic equipment for CTN's Groups and external clients;
- Marketing and sale of nuclear instrumentation (brand IST/LATR) for the national and international markets;
- Small series manufacturing and quality control of equipment (brand IST/LATR).

NI | 2: Team

Name	Category	Time Allocated
Eduardo Alves, Coordination	Senior Researcher	---
José Neves, Electrotechnical Engineer	Auxiliary Researcher	100%
Nuno Inácio, Repairing/Maintenance	Graduated Technician	50%
Tiago Jesus, Repairing/Maintenance	Assistant Technician (left April 2018)	30%
Ana Faria, Income/Logistics	Graduated Technician	35%
Teresa Pires, Web Designer/Logistics	Graduated Technician	5%

NI | 3: Main Achievements

We have increased our client base in order to enlarge sales (nationally and internationally), in the field of nuclear equipment fabrication (made in Portugal, brand IST/LATR), as well as in consulting and technical assistance in Portugal.

CONSULTING, DESIGN & TECHNICAL ASSISTANCE IN THE FIELD OF ENGINEERING APPLICATIONS OF RADIATION AND RADIOISOTOPES

Major tasks carried out over the 2017-2020 period:

- Collaboration with the *Gas Discharges and Gaseous Electronics Group* (GEDG) of "Instituto de Plasmas e Fusão Nuclear" (IPFN), in the experimental work on methane conversion using Dielectric Barrier Discharge (DBD), searching for new connected applications.
- Technical / Lab support work, to the new IST "Mestrado em Proteção e Segurança Radiológica" (MPSR).

- Part in the Development / Improvement work of the Linear Electron Accelerator (LINAC), which can produce beams with energies from 4 MeV to 10 MeV.
- We have carried out some training of electro-technical and electronic nature for the chemical Eng. Pedro Santos, intended to the regular operation launch of this large and complex equipment. It should be noted that this great instrument involves a wide spectrum of uncommon technologies, such as electron gun, microwave beam acceleration, magnetron, thyratron, EM waveguides, collimator/ quadrupoles, BT, AT, MAT and UPS Power Supplies, programmable logic controller (PLC), high-vacuum pumps, complex software and "intensive" and wide-ranging electronics.
- In 2018, we have carried out some work to improve/ modernize the RPI Model (Reactor Português de Investigação), to be exhibited in several events including on Técnico Day.

2017 - TOTAL INCOME: € 22.708,09

In 2017, we have carried out several maintenance and repair works, including some calibration and quality control actions on diverse instruments/ equipment. Several electronic / nuclear devices and equipment were manufactured and sold as well.

For example:

- Four digital instruments **"RADX100"** (Personal Radiation Dosimeter) were produced and sold;
- One electronic equipment "*Detetor Gama de Nível de Líquidos em Garrafas*" was tested and repaired as well as one RADX100;
- Two Packs of special stainless steel cathode disks, for the *Irish Environmental Protection Agency*, Dublin (the disks are used in the Electrodeposition laboratory equipment, made in IST/LATR).

2018 - TOTAL INCOME: € 49.646,84

In 2018, the group carried out a lot of maintenance and repair works on diverse instruments/ equipment, mainly for industrial Portuguese companies.

For example:

- Check-up and Technical Certification of 25 nuclear equipment, for **Navigator** (Figueira da Foz)
- Annual multi-equipment Check-up for **CELBI** (Leirosa/ Figueira da Foz)
- Annual multi-equipment Check-up for **Navigator** (Cacia)
- Annual multi-equipment Check-up and removal of several radioactive sources for **Navigator** (Figueira da Foz)
- Removal of several radioactive sources and a number of other works for **Repsol Polímeros, SA** (Sines)
- Removal and storing of several radioactive sources for **Super Bock Bebidas**.

- Annual multi-equipment Check-up (13 equipment) for **EQS GLOBAL- Centro Petroquímico** (Galp/ Leça da Palmeira)

Several electronic/ nuclear devices and equipment were manufactured and sold:

- Seven digital instruments **“RADX100”** (Personal Radiation Dosimeter).

2019 - TOTAL INCOME: € 37.299,75

As usual, we have provided numerous services to some large Portuguese companies/ institutions such as:

- Arsenal do Alfeite/ Marinha Portuguesa
- Repsol Polímeros, SA (Sines)
- TecniLab (Lisbon)
- Celbi - Celulose da Beira Industrial, SA (Leirosa/ Figueira da Foz)
- Cimpor/Intercement (Souselas)
- Cimpor - Indústrias de Cimentos, SA (Souselas)
- Caima - Indústria de Celulose, SA (Constância, Santarém)
- Galp (Sines)
- CMP/Secil (Maceira e Pataias)

We have increased our client base in order to enlarge sales (nationally and internationally), in the field of nuclear equipment fabrication (made in Portugal, brand IST/LATR), as well as in consulting and technical assistance in Portugal.

NI | 4: New Markets

Local customers:

- 2018 – SUPER BOCK BEBIDAS
- 2018 – EQS-Global, for services to be held on GALP Energia (Refinaria de Matosinhos).

IN | 5: Internationalization

Presence on foreign markets:

- 2017 – EPA - Environmental Protection Agency (Ireland): Electrodeposition spare parts.
- 2018 – National Center for Nuclear Sciences and Technologies (Tunisia): Electrodeposition spare parts.

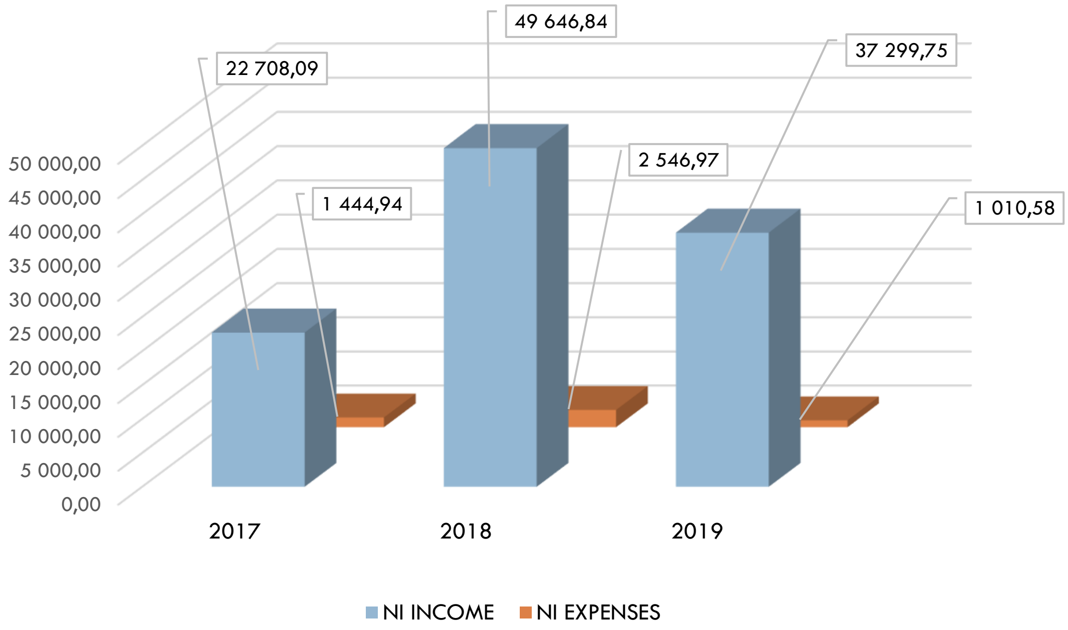
NI | 6: Infrastructures

Small electronic workshop for nuclear instrumentation purposes.

NI | 7: Income Track Record

Fluctuation of revenues over these years was due essentially to the loss of human factors, namely our milling machine specialist that was retired (responsible for the fabrication and assembling of the electrodeposition equipment, that stopped being sold - only sold until stock runs out -, with losses of about €5000/year), as well as the lack of other inside labour resources (locksmith workers and painters) that should have accompany our nuclear instrumentation technician to the factories for helping him in other specialized tasks.

NI INCOME: 2017-2019



Total Income: € 109.659,68 vs Total Expenses: € 5.002,49

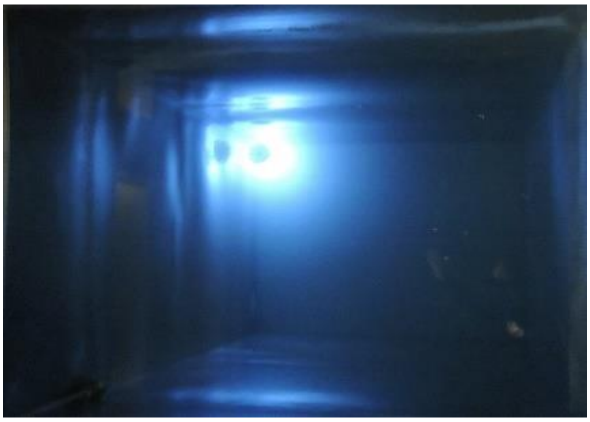
SECTOR 3 | Application of ionizing radiation technology to the industry

UTR | 1: Description

The Portuguese Gamma Radiation Facility (UTR) was installed in 1981 at Campus Tecnológico e Nuclear from Instituto Superior Técnico, Loures Pole, Bobadela.

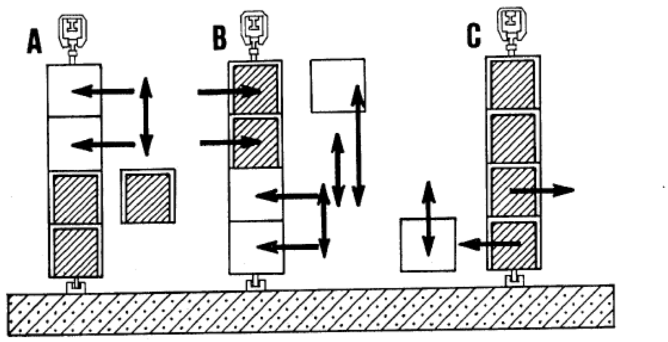
Actually, this unit plant is a Cobalt-60 dry storage continuous facility with a nominal capacity of ≃170 kCi and designed for the sterilization of medical devices. However, it can be used for the irradiation of other products such as medical prosthesis, cork stoppers, plastics and a limited number of food and feed.

This plant was developed with the support of IAEA under the Programme of Cooperation and Technical Assistance (POR/8/002), for the period 1983-1988.



The initial capacity is 1.1×10^{16} Bq (295 kCi) and the throughput capacity 103 ton for product with a bulk density of 0,2 g/cm^3 treated with a minimum absorbed dose of 25 kGy. Complementary control devices were installed: ventilation system, closed water refrigeration circuit, internal TV system, detection and extinction fire system and emergency power group. It must be emphasized that the best attention was given to the conception and efficiency of the interlock safety system.

The irradiation cell, which is of high-density concrete, has walls 1.8 to 2 m thick, with an area of 30.75 m^2. The labyrinth surround the irradiator cell is 23.3 m long. The irradiator, with an over-all area of 0.864 m2, consists of 30 stainless-steel tubes. The Cobalt-60 sources, stainless steel double encapsulated are enclosed in those tubes.



Schematic diagram of loading/unloading station. A - Charge mechanism. B - Rearrangement mechanism. C - Discharge mechanism.
→ - Box movement. ↕ - Elevator movement.

In the storage, the irradiator is in a concrete pit, shielded with iron steel blocks. An electromechanical system raises the sources to the working position. The product is carried by 40 carriers, suspended from an overhead monorail conveyor. There are two rows of 7 carriers each side of the source, each one can be loaded with 4 product boxes (0.4x0.4x0.4 m^3). An irradiation cycle has 56 different irradiation positions. Between the 14th and the 15th position, the carriers rotate 180º and present the opposite face of the box to the source. After the 28th position, each carrier returns to the loading/unloading station.

The two boxes of the upper level take place on the lower level, which is empty as the other two boxes were unloaded. A new pair of boxes are loaded on the upper level and the carrier goes back to the irradiation cell. In each half cycle, the two boxes of the lower level receive the dose fixed and the two boxes of the upper level receive the first half of this dose. The dwell-time is set according the product density and de required dose.

The facility is operated and controlled from the control desk inside the control room. A visual survey of the loading/unloading area can be made from there. The loading/unloading station consists of charge, rearrange and discharge mechanisms, associated with a rolling carpet at the inlet and outlet of products. The plan design fives good dose uniformity, the efficiency is about 19% for 0.2g/cm^3 density and 25 kGy. The facility is fully automatic and works in continuous mode.

A preventive maintenance plan has been set up for all several types of electrical and mechanical systems of the facility. The labyrinth entrance has no physical barrier, therefore to guarantee the necessary radiological protection and furthermore to insure a correct sequence of operations several kinds of interlocks systems were installed.

UTR | 2: Team

Name	Category	Time Allocated
Eduardo Alves, Coordination	Senior Researcher	---
Paula Matos, Technical Director/Quality	Agro-food Engineer	100%
Carlos Cruz, Radiological Protection/Maintenance	Auxiliary Researcher	50%
Ana Faria, Income/Logistics	Graduated Technician	35%
Teresa Pires, Web Designer/Logistics	Graduated Technician	10%
Nuno Inácio, Irradiator Operator Chief	Graduated Technician	50%
Filomena Baptista, Irradiator Operator	Assistant Technician (since 2018)	70%
Tiago Jesus, Irradiator Operator	Assistant Technician (since 2018)	70%
Tiago Sena, Irradiator Operator	Assistant Technician (since 2016)	100%

UTR | 3: Advantages of Ionizing

Are the following:

- Process safe and environmentally friendly;
- Treatment in the final package (eliminating cross contamination risk);
- Treatment nonthermal;
- Leaves no residue (the product does not require quarantine period).

UTR | 4: Process Control

To establish the dwell-time and ensure the application of the dose required, according the product density, an electronic cycle timer was installed. This cycle timer allows resuming the process at the same point where it stopped wherever any accident or system failure occurs. It is adjusted only to compensate the radioisotope decay.

During the irradiation of products, routine dosimeters are placed inside a number of selected boxes in the zones of minimum and maximum doses.

The dosimeters are removed, read and the results recorded. Colour-changed indicators to distinguish irradiated from non-irradiated products are used.

UTR | 5: Responsibility and Organization

As a basic principle, the irradiator operator has the responsibility for delivering the absorbed dose specified by the primary manufacturer.

In 2017, provisions are being made to train the convenient and qualified plan staff capable to accomplish the safe operation of the plan and a correct irradiation process. When operating, the product unit dimension and density should be verified upon reception. After this control, each product unit will receive an identifying label with the following data: name and address; minimum absorbed dose; date and reference client number, colour change indicator.

Irradiation Certificates complying with international recommend Good Radiation Practice is issued as well as the Quality Certificate, issued by TÜV Rheinland, stating conformity assessment of quality management practices according to **EN ISO 9001-2008** (30-12-2016 to 14-09-2018) and **EN ISO 9001-2015** (03-12-2018 to 29-12-2019), for the scope "Sterilization an decontamination of products by gamma radiation".

In addition to those, UTR Unit accomplished in December 2017:

- **Dosimetry Certificate**, issued by *Laboratory for Measurements of Technological Doses* (LMTD/Poland), accredited by *Polish Centre of Accreditation*: attesting the "First phase of the dose intercomparision exercise conducted to improve QA/QC procedures in radiation processing", obtained under the framework of TC Project RER/1/017 (IAEA).

To keep in track with clients' opinions, Customer Satisfaction Surveys are made annually.

UTR | 6: Main Achievements

Quality Management System Compliance

- 2019: Internal audit to consider the degree of compliance of the Quality Management System according to the Normative Reference NP EN ISO 9001:2015. Scope: "Sterilization and decontamination of products with gamma irradiation". IST/DPSR Auditors: Luís Santos & Ana Amaral, October 23rd.

Training Courses

- **2017/2018**: *"Curso de Formação para Operadores de Instalação de Irradiação Gama Co-60/Training Course for Gamma Irradiation Installation Operators Co-60"*, 200h (140h on job-training), UTR/IST. Trainees: Paula Matos, Nuno Inácio, Tiago Sena and Filomena Baptista.
- **2018**: *"Professional Training course of Quality Management Systems - Implementation of NP EN ISO 9001: 2015"* (16 hours), November 19-20th, IPQ/CEDINTEC, Lisbon/Portugal. Trainee: Paula Matos.
- **2018**: "*Professional Training course of Quality Management Systems - Implementation of NP EN ISO 9001: 2015*" (16 hours), 2018 December 6-7th, IPQ/CEDINTEC, Lisbon/Portugal. Trainees: Eduardo Alves and Filomena Baptista.
- **2019**: *"1^{4th} Tihany Symposium on Radiation Chemistry"*, Siófok, Jungary, 2019 May 25-30th. Participation: Paula Matos.

UTR | 7: Internationalization

Presence on foreign markets: mainly Spain.

UTR | 8: Projects

- **IAEA TC Project RER/1/017 (2015-2017)** – "Using Advanced Radiation Technologies for Materials Processing". Achievements: "First Phase of the Dose Intercomparison Exercise Conducted to Improve QA/QC Procedures in Radiation Processing", issued by the Laboratory for Measurements of Technological Doses (LMTD), Institute of Nuclear Chemistry and technology (INCT), Warsaw, Poland accredited by Polish Centre of Accreditation. Eduardo Alves, Portuguese Coordinator.

UTR | 9: Facility Visits

Follow-up visits to the UTR Unit, as indicated below:

Description	Visits / Visitants 2017		Visits / Visitants 2018		Visits / Visitants 2019	
Secondary School	4	174	4	79	7	281
University	2	30	2	150	1	6
Other Visits	1	43	2	40	1	60
Auditors	5	6	2	3	2	2
Sub-Total	**12**	**253**	**10**	**272**	**11**	**349**

***Other Visits:**

- VF Pharmaceuticals, July, 2020 (Dr. Miguel Santos).
- XIV Encontro Nac. Est. Eng. Biomédica, UTR, February 11, 2019 (60).
- Câmara Municipal de Loures: Visite o Concelho, UTR, October 19, 2018 (28).
- Seniores – Ciência Viva, May 2018 (12).
- CITEFORMA – Centro de Formação Profissional. Curso de Especialização Tecnológica de Técnico Especialista em Gestão da Qualidade, Segurança e Ambiente, no âmbito das UFCD's "Agentes Físicos" e "Agentes Químicos e Biológicos", June 2017 (16).
- Encontro Nacional de Estudantes de Física 2017, February 2017 (43).

Local Auditors:

- CTN/DPSR – Quality Manual; Procedures; Quality Processes and Records. **Luis Santos**, 22/10/2018.
- CTN/DPSR – Quality Manual; Procedures; Quality Processes and Records. **Luis Santos** and **Ana Amaral**, 16/11/2017.

External Auditors:

- HOVIONE – Client: Quality Manual; Procedures; Quality Processes and Records. According to Internal Circular UTR, nº9/2019, **Joana Mates**, 12/12/2019.
- TÜV Rheinland – Quality Management System Certification: Renewal of certification for the Norma ISO 9001:2015. **Herminio Henrique**, 20/12/2019.
- TÜV Rheinland – Quality Management System Certification, 2nd Monitoring and Transition to NP EN ISO 9001:2015. **Herminio Henrique** and **Ana Rita Esteves**, 07/09/2018.
- TÜV Rheinland – Quality Management System Certification: Quality Manual; Procedures; Quality Processes and Records. **Ana Santos Carreira**, 30/11/2017.

- LUSOMEDICAMENTA – Client (Recipharm Lisbon): Quality Manual; Procedures; Quality Processes and Records; Contrato de Prestação de Serviços. **Teresa Ferreira**, 21/07/2017.
- HOVIONE – Client: Quality Manual; Procedures; Quality Processes and Records. **Joana Mates**, 20/03/2017.

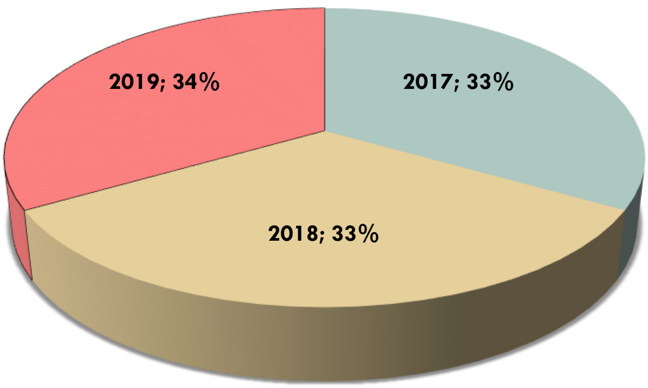
UTR | 10: Future Goals

- To enlarge application of ionizing radiation to industry (in particular the food one), through legalization of ISO standards and accreditation processes;
- To increased our client base in order to enlarge sales (nationally and internationally). This can be afforded with a targeted marketing program to enlarge audience and a better presence on internet;
- Rechargment of Cobalt sources in near future.

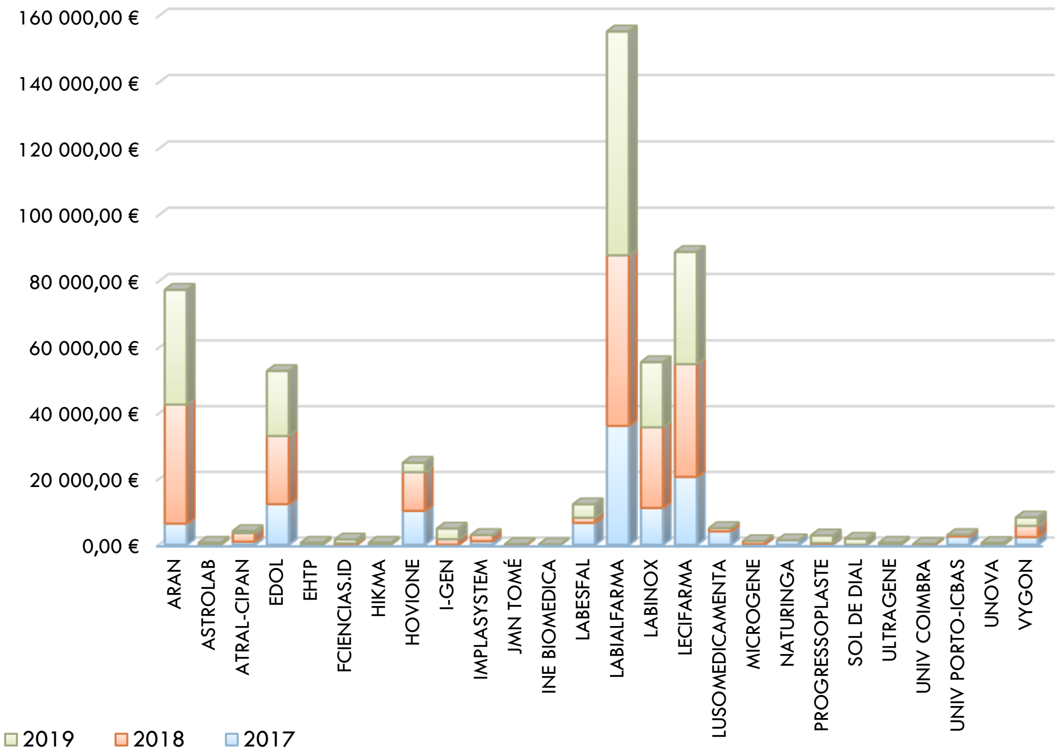
UTR | 11: Income Track Record

CLIENTS	2017	2018	2019	TOTALS
ARAN	6 443,12 €	36 305,00 €	34 681,00 €	77 429,12 €
ASTROLAB	0,00 €	0,00 €	615,00 €	615,00 €
ATRAL-CIPAN	910,27 €	2 644,50 €	615,00 €	4 169,77 €
EDOL	12 383,77 €	20 756,21 €	19 806,49 €	52 946,47 €
EHTP	0,00 €	0,00 €	615,00 €	615,00 €
FCIENCIAS.ID	0,00 €	430,50 €	1 168,50 €	1 599,00 €
HIKMA	0,00 €	0,00 €	615,00 €	615,00 €
HOVIONE	10 326,99 €	11 795,78 €	2 865,89 €	24 988,66 €
I-GEN	0,00 €	1 692,64 €	3 247,20 €	4 939,84 €
IMPLASYSTEM	1 076,25 €	1 875,75 €	0,00 €	2 952,00 €
JMN TOMÉ	0,00 €	177,12 €	0,00 €	177,12 €
INE BIOMEDICA	123,00 €	0,00 €	0,00 €	123,00 €
LABESFAL	6 667,37 €	1 562,10 €	4 083,60 €	12 313,07 €
LABIALFARMA	36 235,98 €	51 613,28 €	67 506,21 €	155 355,47 €
LABINOX	11 207,76 €	24 584,01 €	19 830,73 €	55 622,50 €
LECIFARMA	20 671,51 €	34 366,16 €	33 812,70 €	88 850,37 €
LUSOMEDICAMENTA	4 072,17 €	996,30 €	0,00 €	5 068,47 €
MICROGENE	157,44 €	954,48 €	0,00 €	1 111,92 €
NATURINGA	1 359,77 €	0,00 €	0,00 €	1 359,77 €
PROGRESSOPLASTE	246,00 €	257,07 €	2 333,93 €	2 837,00 €
SOL DE DIAL	0,00 €	0,00 €	1 845,00 €	1 845,00 €
ULTRAGENE	0,00 €	0,00 €	615,00 €	615,00 €
UNIV COIMBRA	0,00 €	246,00 €	0,00 €	246,00 €
UNIV PORTO-ICBAS	2 521,50 €	430,50 €	0,00 €	2 952,00 €
UNOVA	0,00 €	0,00 €	553,50 €	553,50 €
VYGON	2 324,70 €	3 444,93 €	2 535,72 €	8 305,35 €
	116 727,60 €	**194 132,33 €**	**197 345,46 €**	**508 205,39 €**

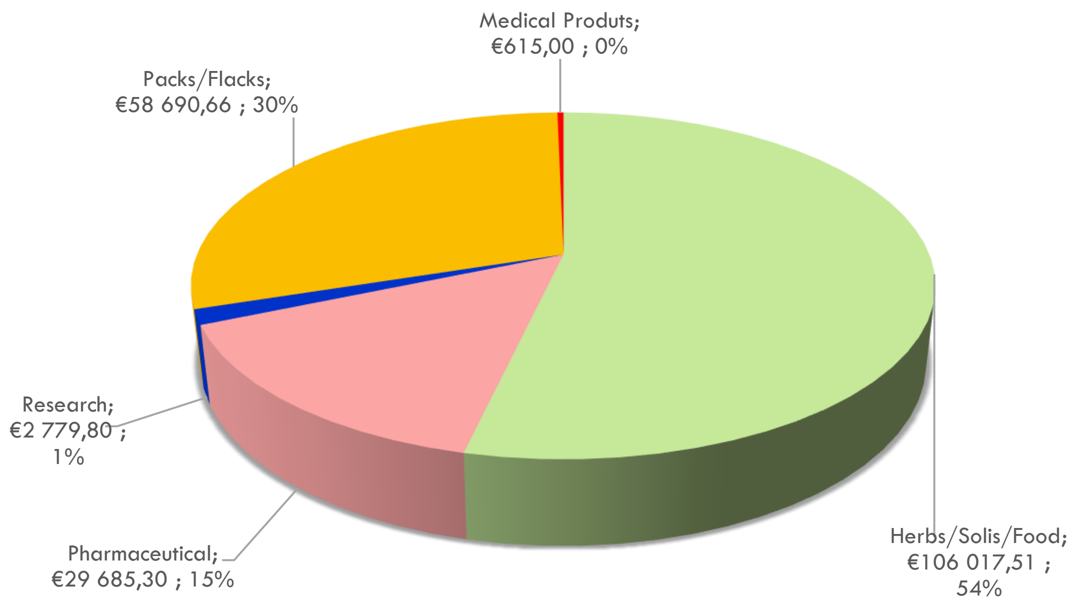
UTR INCOME 2017-2019: € 508 205,39



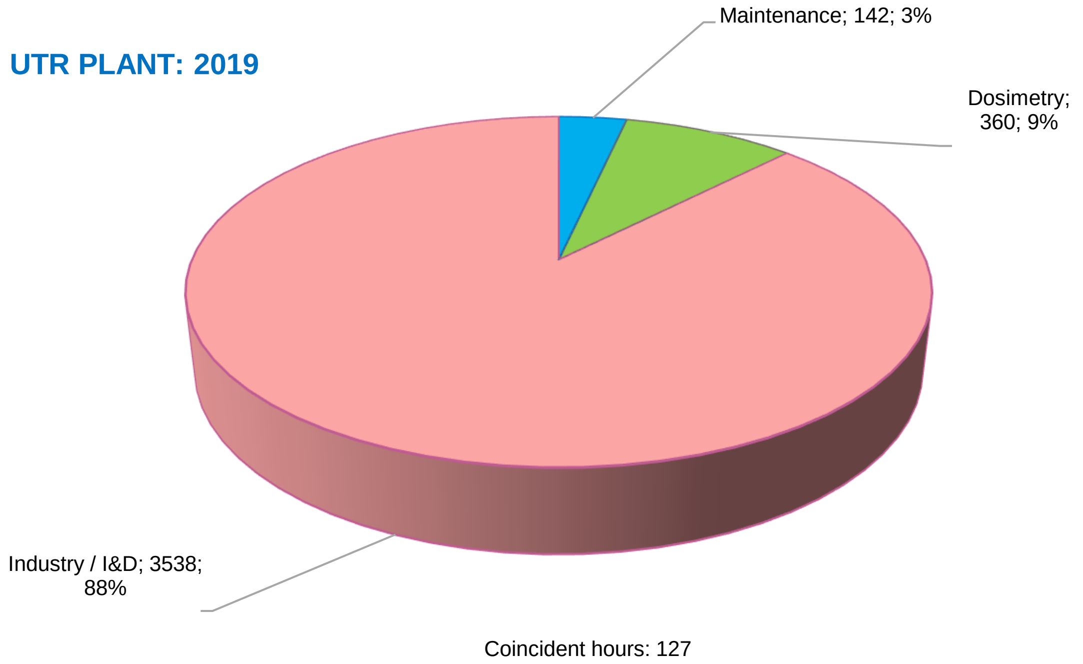
INCOME: 2017-2019 (CLIENTS)



INCOME: 2019 (SECTORS)



UTR | 11: Working Hours



Laboratório de Aceleradores e Tecnologias de Radiação
Campus Tecnológico e Nuclear
Pólo de Loures do Instituto Superior Técnico
Estrada Nacional 10 (km 139,7)
2695-066 Bobadela LRS, Portugal
Phone +351 21 994 6000
http://www.ctn.tecnico.ulisboa.pt