DAΦNE-Light Laboratory and Activity

M. Angelucci (Ass. Ric.), A. Balerna (Resp.), M. Cestelli Guidi, R. Cimino, A. Grilli (Tecn.), R. Larciprete (Ass.), G. Mohamed (Art. 23), E. Pace (Ass.), M. Pietropaoli (Tecn.), A. Raco (Tecn.), V. Sciarra (Tecn.), V. Tullio (Tecn.), G. Viviani (Tecn.).

1 Summary

The scientific activity at the DAΦNE-Light laboratory, in 2015, was performed using conventional sources and for some specific experiments the DAΦNE synchrotron radiation beam. More than 50 experimental teams got access to the DAΦNE-Light laboratory coming from Italian Universities and research Institutions, and some of them also from EU countries within the EU CALIPSO project that ended successfully in May. Within this project, more than the 600 promised hours, where given to EU users in different research fields like material science, biology and medicine.
The DAFNE-Light laboratory, in 2015, has been involved in the workshop *What Next at LNF: material science* held in Frascati on the 26 and 27 of February and in the International Schools: INSPYRE 2015 and EDIT 2015. Within EDIT 2015, one of the two weeks laboratory courses, was dedicated to synchrotron radiation with experiments and detectors tests performed in a wide energy range form IR to soft x-rays. The experimental activities, performed in 2015, included also upgrades of the beamlines, and the installation of new instrumentation.

2 Activity

2.1 SINBAD - IR beamline

The experimental activity on the SINBAD IR beamline mainly concerns micro-imaging and FTIR (Fourier Transform InfraRed) spectroscopy in different research areas, including material science, biology, radiobiology, live cell imaging, cultural heritage and geophysics. All these studies are possible owing to the imaging capabilities of the IR microscope coupled to the synchrotron source. The institutions involved were Italian and the some International teams funded be the EU-FP7 transnational access project CALIPSO. The biological clean chamber laboratory was used to grow cell cultures for some CALIPSO experimental proposals that required sample preparation *in situ*.
In 2015 the Vertex70V interferometer of the SINBAD beamline has been upgraded with new equipment. The added accessories were: a Platinum ATR that is a single reflection diamond ATR accessory with temperature control, an Aquaspec Cell that is a flow-through cuvette for the measurement of aqueous protein samples, a wide band detector and beam splitter that allow to measure the FAR (130-600 cm^{-1}) and MID (600-4000 cm^{-1}) IR range simultaneously and a MCT narrow band detector for the Hyperion 3000 microscope.
Some of the scientific studies performed at the SINBAD-IR beamline are here summarized:

1. *Studying the role of skin sodium accumulation in mineralocorticoid induced hypertension - Jagiellonian University, Krakow, Poland*

   The main objective of the project was to widen the knowledge about pathogenesis of DOCA-salt hypertension, which is suggested to be a model of essential and drug-resistant hypertension in humans. Crucial information were evaluated after quantification and precise determination of the Na+ ions localization in the skin layers as well as examination of reactions of

other skin components on sodium storage. The project was based on the first pathophysiological studies results, that have been obtain by Titze et. al. showing, that deoxycorticosterone-acetate (DOCA) and salt lead to electrolyte and water content changes at the total body level. This process finally causes salt sensitive hypertension, which is believed to be responsible for essential hypertension in human which is usually drug resistant.
Male Sprague-Dawely rats were used in the experiment. Precise protocol of tissues preparation was described in the proposal. During the measurements performed at DAΦNE-Light, two different type of were examined: control group (4 samples) and DOCA-treated (7 samples). The tissues of the rat ear skin were selected for the FTIR analysis (Fig. 1). Each sample was previously sectioned into 3 following sections of ∼10 micron thickness, between each of them was a 100 microns distance. The tissue sample sections were placed on the ZnSe substrates and a set of 33 samples was selected for the FTIR measurements. This research was performed in the framework of the EU-CALIPSO project.

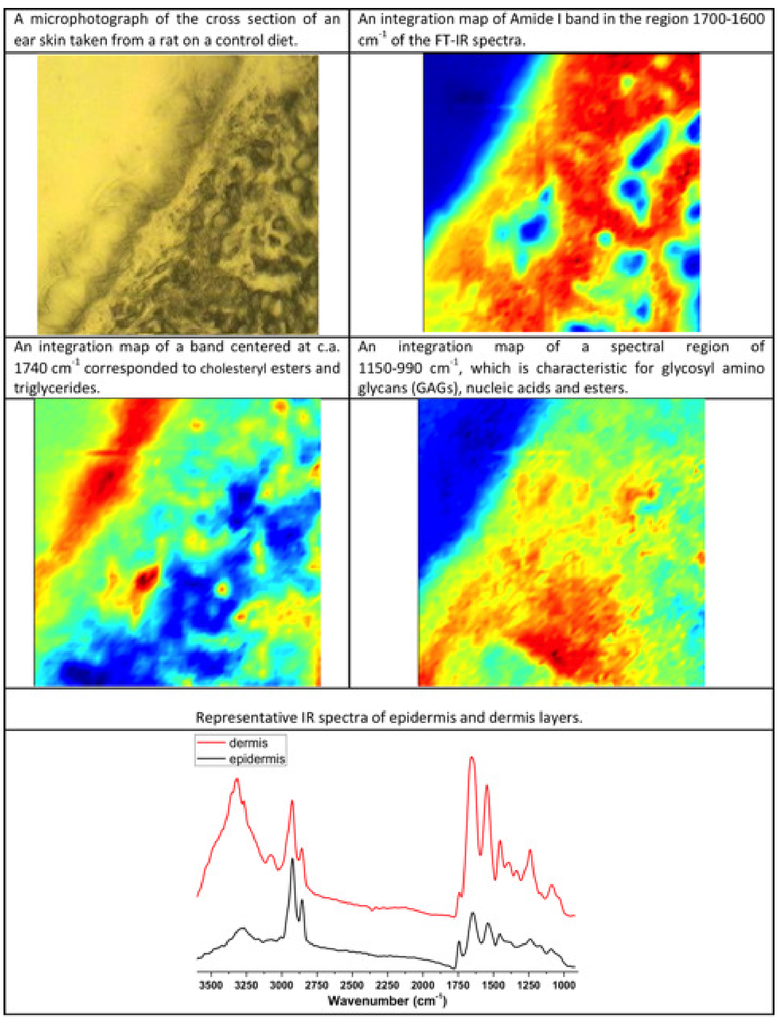

Figure 1: Representative integration maps and single IR spectra of the studied ear skin layers.

2. *Investigation of polymeric nanocomposite materials - Institute of Nuclear Physics PAN, Krakow, Poland*

Fourier-transform infrared (FTIR) imaging has been used to investigate newly created composite materials such as polymers placed on titanium which is used in various medical applications. A poly-ϵ-caprolactone (PCL), chitosan (CS) and the mixture of both of them were used in this study which allowed to perform 2D FTIR microscopy maps that were related to the vibrations of carbonyl bonds (C=O). In order to increase titanium properties it was covered with polymers such as poly-ϵ-caprolactone (PCL), chitosan (CS) and the mixture of both of them. In this study the formation of these new metal-modified biomaterials based on chitosan joint was controlled using FTIR mapping spectroscopy. The FTIR spectra were collected using Bruker spectrometer which was used with the microscope (Hyperion-3000) equipped with MCT and FPA (64x64 pixel) detectors. The main bands appearing in the spectrum of polymer matrix (CS) was due to stretching vibrations of OH groups in the range from 3750 cm^{-1} to 3000 cm^{-1} and C-H bond in -CH_2 (ν_1-2930 cm^{-1}) and -CH_3 (ν_2-2875 cm^{-1}) groups, respectively. Bending vibrations of methylene and methyl groups were also visible at ν -1380 cm^{-1} and ν-1460 cm^{-1}, respectively. In the spectra of PCL (Fig. 2) the band at 1670 cm^{-1} (related to the vibrations of carbonyl bonds (C=O)) as characteristic for this polymer it was treated as a marker of the existence of PCL in the composite. The band located near ν-1150 cm^{-1} related to asymmetric vibrations of CO in oxygen bridge and the bands near 1080-1025 cm^{-1} attributed to ν_{CO} of the ring COH, COC and CH2OH were also observed. FT-IR spectra of nanocomposite showed the change of the band intensity at around 1070 cm^{-1} (Fig. 2). This band is related to overlapping of vibrations of the secondary amide and PCL. It indicated interactions between both of polymers (Chitosan and PCL). The study show non-uniformity of the modified surface of titanium plates. Such results indicate the necessity of sample preparation procedure changes. Also this research was performed in the framework of the EU-CALIPSO project.

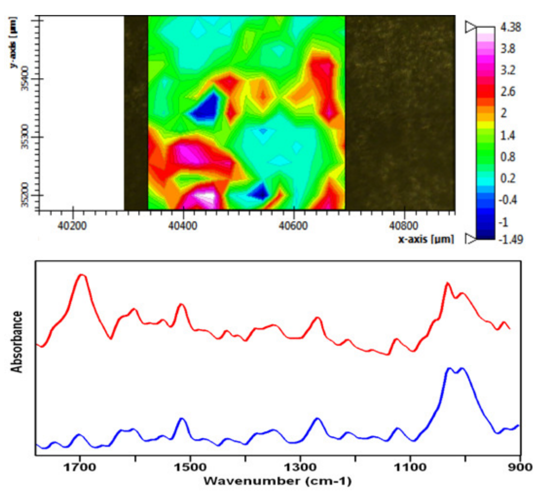

Figure 2: FTIR distribution of C=O band overlaid on titanium plate and the bottom figure shows two spectra one (red) taken in the region of high intensity of C=O band with visible high band in the region of 1700 cm^{-1} and the second (blue) one taken in the region of low intensity of C=O band with visible intense bands in the region of 1050 cm^{-1}.

3. *SR-FTIR imaging of single cell/fiber interaction for recognition of amphibole-related lung pathogenesis.*

   University of Bordeaux, France

FTIR imaging was used to benefit from synchrotron radiation source for fast acquisition purposes on single cells with micron-level resolution. The utilization of synchrotron radiation source was expected to obtain higher signal-to-noise ratio in short acquisition time, thus allowing analyzing the dynamics of molecular contents and their changes over time. Therefore, one may consider that this technology is state-of-the-art for minute SR-FTIR imaging at high-resolution, allowing to analyze separately the nucleus and the cytosol of cells. The project was to use FTIR microscopy at DAΦNE-Light Facility for micron scale analysis of nuclear and cytosolic locations on cells with/without the action of the asbestos fibers. SR-FTIR imaging is expected to allow analyzing specifically the cytosol and nucleus of cells in an attempt to shed some light on asbestos fibers toxicity pathways.

A first series of measurements (Fig. 3) were performed with A549 lung cells exposed to low but gradual amounts of mineral fibers - Crocidolite* $Na_2(Fe^{3+})_2(Fe^{2+})_3Si_8O_{22}(OH)_2$ and Tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$ - with 0 (control), 1, 5, and 10 μg/cm^2 of fibers. First IR images show that lipid/protein ratio is higher in controls compared to 1, and 5 μg/cm^2 of fibers ($P<0.05$), but lower with 10 μg/cm^2 of fibers ($P<0.05$). These preliminary results are consistent with a previous study using the same methodology (paper under press), where cells exposed to fibers at amounts > than 10 μg/cm^2 exhibited toxicity parameters. At this stage of the experimental development of the single cell imaging by SR-FTIR microscopy it is thus hypothesized that cell already have to adapt to the presence of amphiboles at very low amounts. If confirmed by next experiments using synchrotron radiation for acquisition of high-quality spectral images from cells, one should therefore consider that official exposition levels to mineral fibers might be revised in industry and public safety regulations. Also this research was performed in the framework of the EU-CALIPSO project. The methodology developed allows characterizing toxicity of xenobiotics in single cells analyzed by FTIR microscopy. The large absorption species (amides and fatty acyl chains) could be further detailed to explore the molecular origins of the major changes observed here.

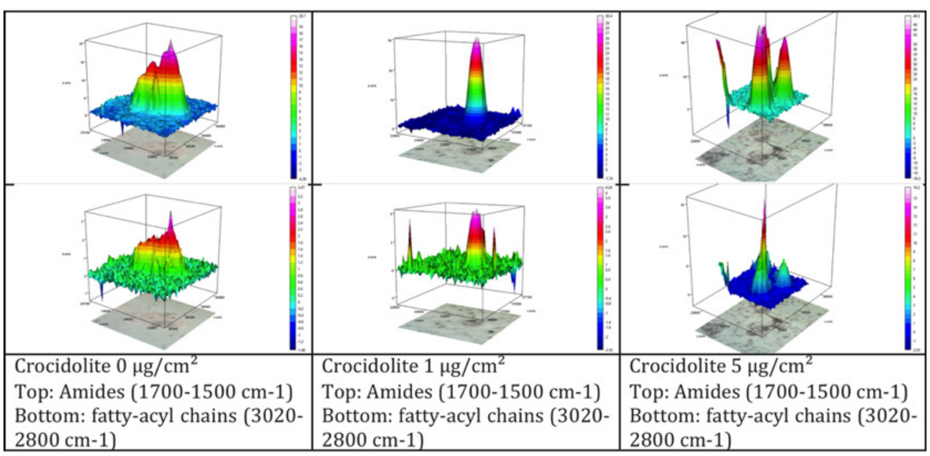

Figure 3: Distribution of amides and fatty acyl chains absorption in single cells exposed to 1 and 5 μg/cm^2 crocidolite fibers for 24 hours.

4. *Speciation and diffusion profiles of H_2O in water-poor beryl: comparison with cordierite.* *Univ. Roma Tre, Rome, Italy*

   Measurements were performed on water speciation and diffusion in synthetic beryl samples treated in CO_2-rich atmosphere, at 700 MPa and 700 and 800°C, respectively. The study has been conducted by means of polarized FTIR (Fourier transform infrared) integrated with FPA (focal plane array) imaging. As expected, the infrared spectra show the presence of CO_2 but also of minor H_2O interpreted as resulting from moisture present in the starting materials used for the experiments. FPA-FTIR images show that H_2O diffuses into the beryl matrix along the structural channels oriented parallel to [001]. Spectra collected along profiles parallel to the c-axis show subtle changes as a function of the distance from the crystal edge; these changes can be correlated to a progressive change in the H_2O coordination environment in the channel, as a response to the varying H_2O/alkali ratio. In particular, the data show that when $2H_2O > Na^+$ apfu (atoms per formula unit), H_2O can assume both type I and type II orientation; in the latter case, each Na cation coordinates two $H_2O^{[II]}$ molecules (doubly coordinated H_2O). If $2H_2O < Na^+$ apfu, then $H_2O^{[II]}$ molecules are singly coordinated to each Na cation. The same type of feature is observed and commented for the structurally related cordierite. Diffusion coefficients and activation energies have been also determined for both types of water molecules.

During 2015, Dr. Gihan Mohamed worked up to the end of June as researcher (Art.23) on the IR beamline in the framework of the CALYPSO project and afterwards she was employed at the EMIRA IR beamline at SESAME (Jordan) as principal beamline scientist. Dr. Marco Angelucci had a Post-doc position at the UV-IR beamline that ended in July 2015 and Deborah Schierano from the University of Florence ended her Master Thesis on *Atmospheres in a test tube*, on the setup of the instrumentation to realize a database of FTIR spectra of gas atmospheres in different pressure and temperature conditions, to be used for comparison with the spectra collected by existing and future space missions. Some results were presented at the Astrobiology Science Conference 2015 (Chicago, Illinois - USA)

2.2 DXR1 - Soft X-ray Beamline

The DAΦNE soft X-ray beamline, DXR-1, is mainly dedicated to soft X-ray absorption spectroscopy. The X-ray source of this beamline is one of the 6-poles equivalent planar wiggler devices installed on the DAΦNE electron ring (0.51 GeV) for the vertical beam compaction. The 6 wiggler poles and the high storage ring current (higher then 1 Ampere) give a useful X-ray flux for measurements well beyond ten times the critical energy. The useful soft X-ray energy range is 900 eV - 3000eV where the lower limit is given by the Beryl crystals used in the double-crystal monochromator and the higher limit is given by the wiggler working conditions.
At the end of 2015, first tests have been performed to check the top up operation mode and to check the presence of hardware problems. In order to control the new working conditions in 2016 measurements will be performed using this operation condition in the presence of good and stable beam conditions.
The soft X-ray beamline is equipped with a microfocus W x-ray source to test samples and also to perform X-ray fluorescence (XRF) measurements using the available SDD detector and a vacuum compatible experimental chamber to test samples containing low Z materials. Using this systems preliminary tests of the digital data acquisition system of the ARDESIA project (ARray of DEtectors for Synchrotron radIation Applications), for the development of a new detection system for XAFS measurements in fluorescence mode, based on arrays of SDD (Silicon Drift Detector)

with high energy resolution and able to handle high count rates. A scientific result obtained at the DXR1soft x-ray beamline is here reported:

- *Studies of valence of selected rare earth silicides determined using Si K and Pd/Rh $L_{2,3}$ XANES and LAPW numerical studies.*

  Institute of Physics, University of Silesia, Poland

  The study concerns the investigation of Si and Pd/Rh chemical environments using X-ray Absorption Near Edge Spectroscopy in two different families of rare earth silicides R_2PdSi_3 (R = Ce, Nd, Tb, Dy, Ho, Er) and $HoRh_{2-x}Pd_xSi_2$ (Fig. 4)(x = 0, 0.5, 0.75, 1.0, 1.5, 1.8, 2.0). The Si K, Pd L_3 and Rh L_3 absorption edges were recorded in order to follow their changes upon the variation of $4f$ and $4d5s$ electron numbers. In both cases it was found that the Si K edge was shifted 0.5 eV toward lower energies, relative to pure silicon. In the first family, the shift decreases with increasing number of f-electrons, while the Si K edge remains constant upon rhodiumpalladium substitution. In all cases the Pd L_3 edge was shifted to higher energies relative to metallic Pd. No visible change in the Pd L_3 position was observed either with a varying $4f$ electron count or upon Pd/Rh substitution. Also, the Rh L_3 edge did not change. For two selected samples, Ho_2PdSi_3 and $HoPd_2Si_2$, the Wien2K09 (LDA + U) package was used to calculate the electronic structure and the absorption edges. Si K edges were reproduced well for both compounds, while Pd L_3 only exhibited a fair agreement for the second compound. This discrepancy between the Pd L_3 theory and experiment for the Ho_2PdSi_3 sample was attributed to the specific ordered superstructure used in the numerical calculations. The observed changes indicate that despite possessing a formal inter-metallic character, the chemical bond between the R-Si and R-Pd interactions were different. The variation and the direction of the chemical shift of the Si K edge suggested a weak ionic character of the R-Si bonds, in agreement with the localized character of the $4f$ electrons. In turn, the changes of the Pd/Rh edge are consistent with a metallic band that is affected by its long range chemical environment.

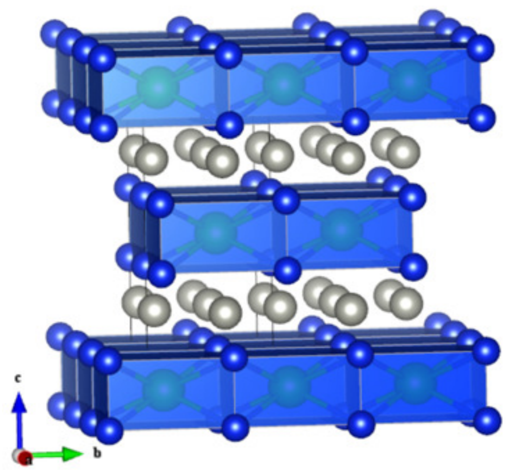

Figure 4: Projection of the tetragonal crystal structure of $Ho(Pd,Rh)_2Si_2$ along ab plane and c crystallographic directions.

2.3 DXR2 -UV branch Line

The DXR2 beamline at DAΦNE- Light operates with UV radiation on an extended spectral range from 120 nm to 650 nm. The UV radiation can be used in a wide range of experiments such as reflectance/transmittance, ageing and response of optical systems and detectors. The UV light has been used at the DXR2 branch-line in many and different research fields from biological to high energy physics experiments, to study solar-blind UV diamond-based detectors or FOAM for space missions. Furthermore, coupling the UV radiation and IR spectroscopy it is possible to study the evolution of analyzed samples in real time, measuring the variation of IR spectra during UV exposure. The facility operates with UV radiation obtained as synchrotron radiation (SR) or standard sources (HgXe lamp in the 200-650 nm range and Deuterium lamp for the Deep UV 120-250 nm).

During 2015, the activity of the DXR2 Synchrotron Radiation Beamline was characterized by improvements of the instrumentation and experiments by users and by the DXR-2 team as core research.

Concerning the improvements, the SEM (Scanning Electron Microscope) microscope was equipped, at the beginning of the year, with a EDX (Energy Dispersive X-ray Spectroscopy) system. This instrument allows nano- and micro-scale pre-analysis of samples. EDX provides information on the elemental composition of the material under investigation. Therefore, SEM and EDX used together provide morphological information as well as the elemental distribution (see Fig. 5) and biological and dielectric materials can also be investigated.

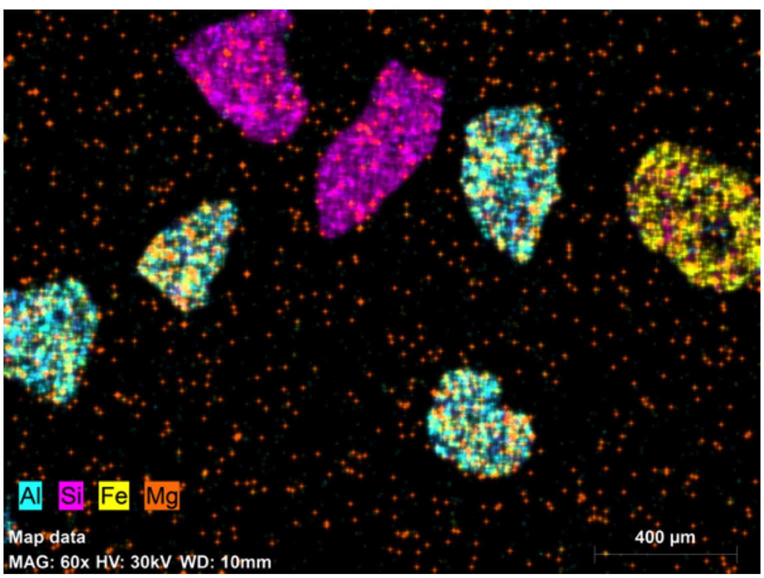

Figure 5: Elemental mapping of microscopic fragments of a meteorite.

The DXR-2 experimental facility provides different light sources covering the whole VUV-UV-VIS wavelength range and in particular, standard lamps are available besides synchrotron radiation. These lamps were characterized in order to know the 2D distribution of the light beam at the focus, its size and uniformity, its intensity at different wavelengths and the power delivered in the spot at the focus. The characterization included also a setup configuration useful for the different experiments. In order to map the intensity distribution (see Fig. 6) of the radiation beam on the focal plane, a bi-axial stepping motor based on piezo-translator, thus assuring a high spatial resolution, was developed.

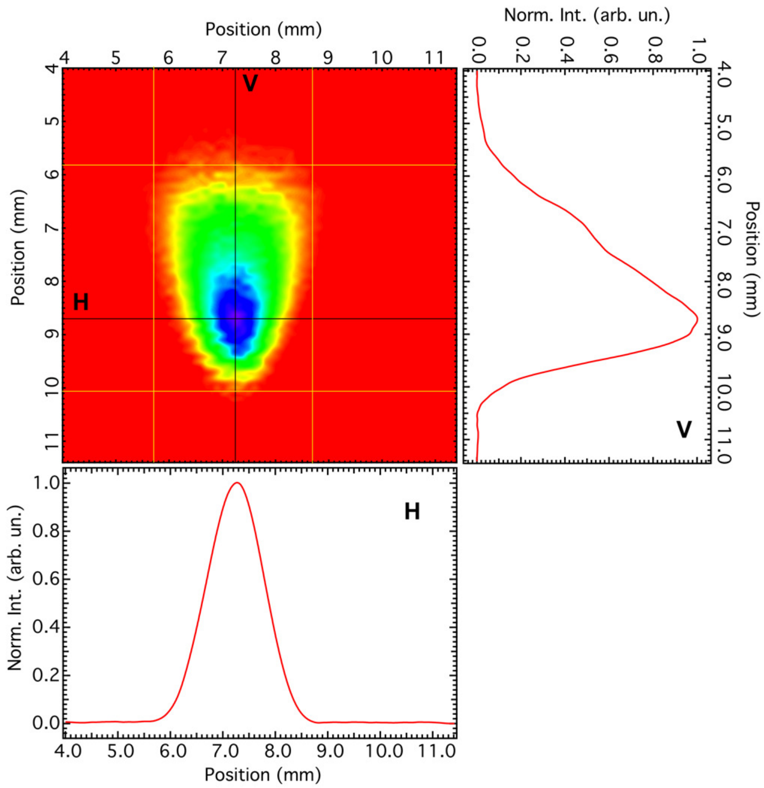

Figure 6: HgXe source spatial intensity distribution.

Some of the scientific results obtained, at the DXR2 -UV beamline, in users's measurements are here summarized:

1. *Characterization of Multi-Pixel Photon Counters for high energy physics experiments.*

   The Mu2e (muon-to-electron-conversion) experiment, that involves the INFN- National Laboratories of Frascati, is looking for Charged Lepton Flavor Violation by studying the coherent neutrinoless muon-to-electron conversions in the field of an atomic nucleus. The produced electrons will be measured in a calorimeter using the fluorescence produced of BaF_2 or CsI crystals. The main fluorescence emissions of the crystals are centered at 220 and 310 nm for BaF_2 and CsI respectively. In this context, the DXR2 UV beamline aims to characterize and test the crystals that will compose the calorimeter.
   The transmittance is an important parameter to check the quality of the crystals and can be measured using the continuum spectrum produced by synchrotron radiation in the UV range between 120 and 600 nm. The same radiation can be used also to stimulate the fluorescence emission, in order to estimate the efficiency of the crystals. Furthermore, the emitted light from the CsI crystals can be measured using a Hamamatsu Multi-Pixel Photon Counter (MPPC) to characterized it in the UV range below 300 nm.
   In the Mu2e experiment, the light produced by the fluorescence of the CsI crystals is measured with a Hamamatsu Multi-Pixel Photon Counters (MPPC). With UV radiation it is

possible to analyze the quantum efficiency of the system and understand the behavior at different wavelengths. The current generated by the MPPC, placed at the exit of the Horiba monochromator, was measured with a Keithley current amplifier. In order to obtain the maximum gain, a 73 V external bias was applied. The spectrum measured with the MPPC was compared with that obtained with a standard calibrated photodiode. The achieved results were in perfect agreement with the company's technical specifications.

2. *Elemental characterization of Micro-Meteorite with a SEM coupled to EDS.*

   The installation of a SEM apparatus with EDS analysis gives the possibility to obtain morphological and elemental information. With elemental analysis it is possible to discriminate the elements content in a meteorite sample (Fe, Si, Mg, Al, O) or due to external contaminations (Zr, K, Ca, Cu, C). Furthermore with SEM-EDS apparatus it was possible to analyze different micro-meteorite in order to investigate the different composition. An example of the analysis on the micro-meteorite is reported in Fig. 5. It is possible to observe the different compositions of the micro-particles.

3. *SEM characterization of UV-irradiated FOAM.*

   FOAM is a new material developed for space application. Memory FOAM materials can be modified, stretched, pressed and turned, for specific applications and recover the original configuration under specific condition, generally being warmed up to 100°C. The study of this material, using UV radiation, is important to understand its behavior under solar-UV radiation in space.
   A FOAM sample has been irradiated with UV light, with a power of 130 mW/cm^2 for withe beam, for several hours (from 1 to 14 hours) and analyzed with the SEM microscope at different steps (Fig. 7). The morphological characterization shows a standard degeneration of the system, in agreement with previous results. Analyzing the surface quality in the same area before and after 14 h exposure, there is no evidence of breaking points at a microscale.

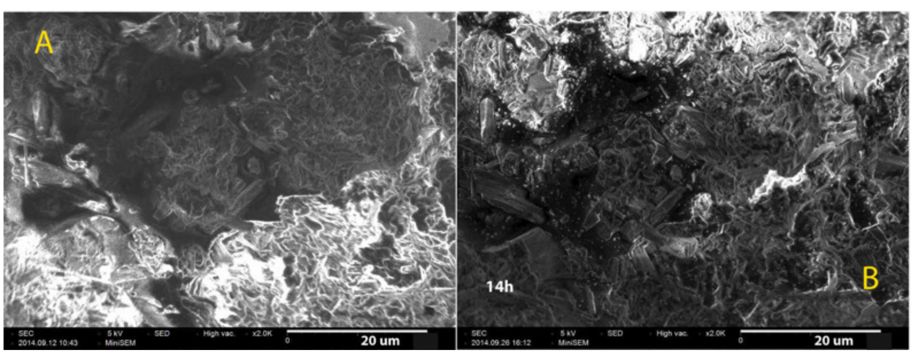

Figure 7: SEM image of the same area before (panel A) and after (panel B) 14h of exposure.

2.4 XUV beamlines and laboratory

Aim of this laboratory is to host two bending magnet beamlines covering the photon energy range from 30 eV to 1000 eV. One beam line will cover the low energy part of this interval (30-200 eV) and is called LEB (Low Energy Beam line), the other will cover the range from 60 eV to 1000 eV and is called HEB (High Energy Beam line). Both beam lines are in UHV and directly connected to the vacuum of the main DAΦNE ring. All the safety protocols and control systems are ready and tested. Since the beginning of last year, the two beam lines are ready to start commissioning with light. The complex procedures of commissioning the two XUV beamlines (usually more than six months at full time operation) will start as soon as the necessary beam conditions and a long term schedule will become available.

In 2015 the XUV laboratory has hosted the projects GARFIELD and IMCA [9-13], funded by INFN National Scientific Committee V, both expired at the end of the year. Both projects have benefited from the ultra high-vacuum stations equipped for XPS and SEY studies and from the micro Raman set-up. As an example, Fig. 8 (left panel) shows the results of XPS measurements aimed at establishing the presence of contaminants in commercial copper foils (Alpha Aesar, thickness 0.05mm) used to grow graphene by high pressure CVD within the GARFIELD project. Although the foils are commercialized as 99% pure, the XPS analysis has revealed the presence of Ca and P contaminants, in addition to C and O usually detected on samples exposed to atmosphere. The presence of metal contaminants favors the nucleation of defects in graphene preventing the achievement of large crystalline domains. In order to remove the impurities, the foils were treated with an etching bath. The comparison between the black and the red spectra in Fig. 8 shows that the chemical processing decreases the amount of oxygen (O1s at 530 eV and O KVV at 743 eV) reducing the oxidized phases of Cu that after etching shows a more intense metallic component. However the chemical bath is not effective in removing completely the contaminants whose concentration remains above the XPS detection limits (0.05 - 0.1 ML), demonstrating that they are not confined at the foil surface but are present also in the bulk of the sample.

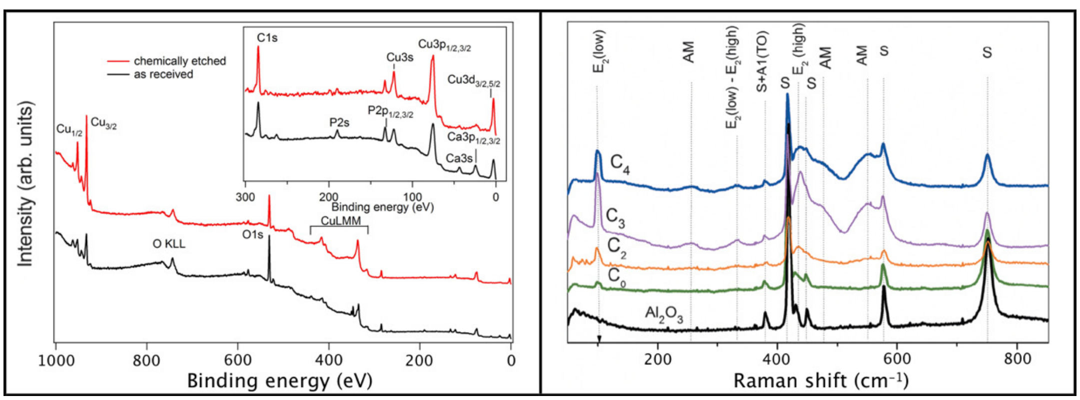

Figure 8: (Left panel) Comparison between the XPS spectra measured on Alpha Aesar copper foils before (black) and after (red) chemical etching. (Right panel) Raman spectra of different ZnO films (C_0-C_4) showing the fundamental ($E_2{}^{low}$, $E_2{}^{high}$) modes of ZnO and disorder active additional modes (AM, $B_1{}^{low}$ and $B_1{}^{high}$). S indicates the sapphire vibrations. Raman spectra measured on highly oriented pyrolytic graphite (HOPG) and on graphene/SiO_2.

Since June 2015 the laboratory hosts the experimental activities of the Work Package 4.4 of the European EuroCirCol Project , focused on issues related to the cryogenic vacuum system and its stability upon photon, electron and/or ion irradiation. In order to initiate the experiments on cold samples a full maintenance of the cryogenic manipulator, whose cooling system was completely dismantled and repaired, was carried out. Furthermore the laboratory has been updated with a high performance close cycle water refrigerator in order to be able to run all close cycle cryostats autonomously. The laboratory has been recently equipped with an in air scanning tunneling microscope (STM), which in 2014/2015 has been upgraded to be used at variable temperature and in UHV, incrementing the analysis capabilities for funded studies as well as the general appeal and the available techniques of the laboratory. The sample manipulator of the XPS system, used to study different samples without breaking vacuum by STM and XPS, is presently being upgraded. The Raman system has been intensively used for the activities of the GARFIED project. Raman [1] and XPS [14] have been used for many characterizations in several studies within different scientific collaborations. One of the scientific results obtained using the *state of the art* micro-Raman station is here reported:

- *The effect of Co doping on the conductive properties of ferromagnetic $Zn_x Co_{(1-x)} O$ films. CNR - Istituto dei Sistemi Complessi, Roma*

  Fig. 8 (right panel) shows the Raman spectra taken on Co-doped ZnO thin films deposited by pulsed laser deposition on sapphire substrates. The Raman analysis was carried out to investigate the possible presence in the ZnO films of Co-rich phases (CoO, Co_3O_4 or $ZnCo_2O_4$) since this technique is highly sensitive to the position of the dopant ions in the host ZnO lattice as well as to the presence of possible non-metallic precipitates and structural defects. It was found that the spectra features arising in the Raman spectra correspond to the fundamental modes of ZnO and of the sapphire substrate, thus ruling out the presence of Co oxides in Co-doped ZnO films.

3 List of Conference Talks

1. A. Balerna, ″The DAΦNE-Light facility″, Workshop What Next at LNF: Scienza dei materiali. LNF, Frascati, 26-27 February 2015.
2. M. Cestelli Guidi, ″Infrared Imaging″, Workshop What Next at LNF: Scienza dei materiali. LNF, Frascati, 26-27 February 2015.
3. R. Cimino, ″Material Science applied to HEP accelerators″, Workshop What Next at LNF: Scienza dei materiali. LNF, Frascati, 26-27 February 2015.
4. R. Larciprete, ″Growth, characterization and applications of new two dimensional materials″ Workshop What Next at LNF: Scienza dei materiali. LNF, Frascati, 26-27 February 2015.
5. E. Pace, ″Diamond detectors″, Workshop What Next at LNF: Scienza dei materiali. LNF, Frascati, 26-27 February 2015.
6. G. Kamel, ″Biomedical Applications of FTIR-Microspectroscopy at SINBAD″. The 6th International Conference on Optical Spectroscopy, Laser and their Applications, NRC, Cairo, Egypt, 07-09 April 2015
7. R. Cimino, ″ Low Energy Secondary Electron Yield and Material Science studies at LNF for next generation Accelerator systems″, International Workshop on Functional Surface Coatings and Treatment for UHV/XHV Applications, Chester (UK), 30 September 2015
8. A. Balerna, ″DAΦNE-Light INFN-LNF synchrotron radiation facility″, RAIN15 - RAdiazione per l'INnovazione 2015, LNF - ENEA , Frascati, 12-13 October 2015.

4 Lectures

1. A. Balerna, ″The synchrotron light: a brilliant torch and its uses″, INternational School on modern PhYsics and REsearch (INSPYRE 2015), LNF, 16-20 February 2015

2. M. Cestelli Guidi, ″Diagnostic techniques for cultural heritage: applications of Synchrotron FourierTransform Infrared (FT-IR) spectroscopy″, INternational School on modern PhYsics and REsearch (INSPYRE 2015), LNF, 16-20 February 2015
3. M. Cestelli Guidi, ″FTIR microspectroscopy and imaging on single cells: experimental procedures and data handling″, 50° Zakopane School of Physics Breaking Frontiers: Submicron Structures in Physics and Biology, Zakopane, Poland, 18-23 May 2015
4. A. Balerna, ″Acceleratori come sorgenti di luce″, Open Labs 2015, LNF, 23 May 2015
5. A. Balerna, ″Introduction to Synchrotron Radiation″, XIII School on Synchrotron Radiation: Fundamentals, Methods and Applications, Grado, Italy 14-25 September 2015
6. R. Larciprete, ″Nanotechnologies and new materials″, International school EDIT 2015 (Excellence in Detectors and Instrumentation Technologies), LNF, Frascati, 20-29 October 2015
7. M. Cestelli-Guidi, ″La spettroscopia IR e i Beni Culturali: gli spettri ed i materiali″, Scuola di Spettroscopia IR Applicata alla Diagnostica dei Beni Culturali: IV edizione - Venaria Reale (TO), 9-12 November 2015.

5 Publications

1. S. Visentin, N. Barbero, F. Bertani, M. Cestelli Guidi, G. Ermondi, G. Viscardi and V. Mussi, ″Multivariate Analysis Applied to Raman Mapping of Dye-Functionalized Carbon Nanotubes: a Novel Approach to Support the Rational Design of Functional Nanostructures.″, Analyst **150**, 5754-5763 (2015)
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