First users on the SMIS IR beamline: biology and biomedical on the agenda

The SMIS beamline (SMIS stands for Spectroscopy and Microscopy in the Infrared region using Synchrotron) has been open to experts colleagues since December 1st, 2007, and to general users since January 23rd, 2008. They all enjoyed the very high stability of the beam for their experiments. Convenience combined with high flux and spectral quality.

On November 7th, the extraction of the infrared beam and its coupling to the first of twomicroscopes were successful, and made the SMIS team able to welcome colleagues and users.
It soon became apparent that the synchrotron beam was remarkably stable, both in the short and long term. It is therefore much more user-friendly, since few adjustments need to be made during experiments. This stability remains optimum over several days. In addition, the acquisition is perturbed very little during injection, and users can carry out their experiments under laboratory-type conditions.

First results

The activities of the expert colleagues and then the general users have mainly concentrated on biological and biomedical studies.

Biomarkers and leukaemia treatment

The first experts colleagues invited by the SMIS team were two physicians: Prof. A Turhan and Prof. A. Bennaceur, from Paul Brousse Hospital and Poitiers Hospital. They have undertaken a search for biomarkers of drug treatment of leukaemia cells, and their resistance behavior to the drug. They obtain very promising results, demonstrating how the combination of high quality spectra with high lateral resolution is essential to reveal the biochemical composition and changes inside the nucleus of single cells, and exhibits biomedical relevance.

Plant biology

The first official expert users, Fabienne Guillon, Paul Roberts and Cécile Baron, from INRA (Institut National Recherche Agronomique), were closely assisted by Frédéric Jamme (INRA-SOLEIL), who was the first official local contact of the beamline.
They studied the chemical composition of aleurone cell walls during the development of wheat grain. In plants, the cell wall has many functions, including the provision of strength

and shape to the cell and rigidity to the whole plant; control of the rate and direction of growth; protection from attack by pathogens and predators; participation in cell to cell communication exerting a profound influence on plant development and morphology. Their results are making it possible to determine the precise composition of glucan (β-glucan, arabinoxylan) along the cell walls.

Individual cancer cells

Individual cell studies have also been carried out by two groups: on drug treated cancer cells, and activation using light irradiation (photodynamic therapy) (S. Srichan, F. Jamme, M. Réfrégiers et al., SOLEIL), and on lung cancer cells (Dr Josep Sule Suso, University Hospital of North Staffordshire and Keele University, and Dr Ganesh Sockalinghum, Reims University). Both teams have obtained very good results, and one study is ready for publication.

Epilepsy, liver cancer

Studies of biological tissues with subcellular resolution have also been performed by a Polish group, from Cracow. (Drs. Chwiej, Zuzanna Setkowicz and Dr. Szczerbowska-Boruchowska), and by a French group (Dr Le Naour and Prof. Bralet, INSERM, Assistance Publique – Hôpitaux de Paris). They studied, respectively, the postepileptic changes in the distribution of main organotrophic components in selected regions of the rat brain, and the biochemical composition of liver cells in several liver diseases, such as cirrhosis and cancer.

Biocompatible polymers

SMIS has also welcomed a group of users familiar with the previous IR beamline at LURE. This group from Madrid, led by Dr. Ellis (Polymers Institute, Madrid) investigated the nature of the polymeric interphase in a series of advanced polymer materials of scientific, technological and historical interest. Biocompatible polymers developed as cell supports for stem cell-based therapy and tissue regeneration present a great challenge. Novel methods of substrate preparation, such as laser microperforation prior to cell application, are being studied. In particular the monitoring of molecular variations in the polymer at the perforations, which can assist cell adhesion, growth and propagation, is essential[3]. Synchrotron infrared microspectroscopy has provided them with a powerful approach to the understanding of the nature of the structural and chemical modifications in the polymer film around the microperforations (Fig.1).

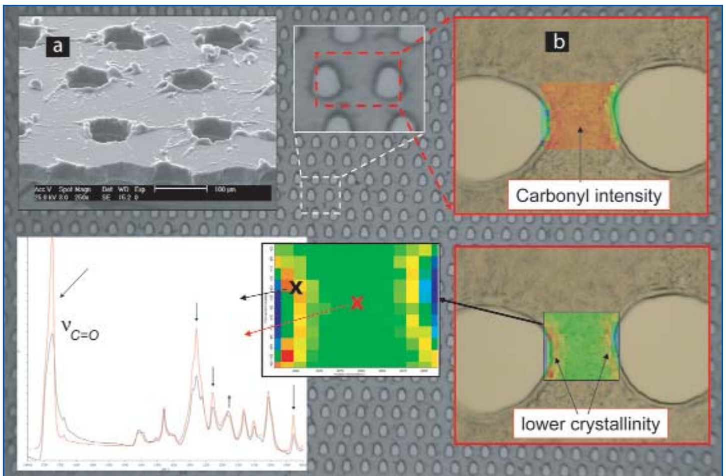

Figure 1 : Analysis of a microperforated biocompatible polymer film (a: electronic microscopy; b: optical microscopy), showing the chemical distribution of carbonyl functional groups and the region where lower crystallinity was observed using the SMIS beamline (courtesy Dr. G. Ellis).

A second microscope...

Recently, the second infrared microscope has been coupled to the synchrotron source, in close collaboration with the Institut Astrophysique Spatiale, in Orsay (Dr. D'Hendecourt, Dr. Borg and colleagues). The two infrared microscopes at the SMIS beamline are now operational and will be continuing to serve the various scientific communities.

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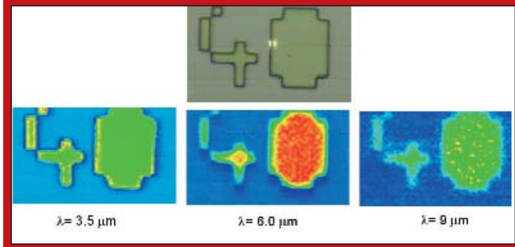
3 F. Serrano, L. López , M. Jadraque, N. Gago, M. Koper, G. Ellis, P. Cano, M. Martín, L. Garrido, Biomaterials, 28, 650 – 660 (2007)

Results of the validation tests of the beamline

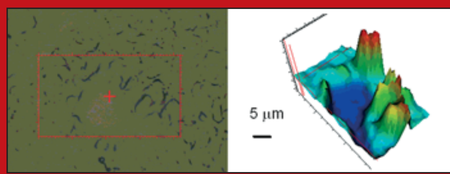
SMIS has satisfactorily completed the validation tests, which were established theoretically for such a beamline. The lateral resolution was checked using a USAF[1] standard target, and well-defined polymer shapes prepared by lithography. To illustrate this performance for the beamline, we have displayed, on the figure below, the visible image of a digit (4) drawn on a polymer resist by lithography. The width of the line is 5 microns precisely.



On the same figure are displayed two chemical images of the polymer, one taken at a wavelength of 3.3 microns, and one at 6 microns. One can clearly see that the structures are well resolved for the 3.3 micron wavelength, and a bit less with the longer wavelength, due to a diffraction effect.

Infrared microscopy has become a highly sought-after analytical tool, particularly in Biology and Biomedicine the recent years[2]. This is thanks to the capability of understanding the biochemical composition of, say, a single cell, with sub-cellular resolution.
Besides this characterization, one is able to record spectra in a cooperative way, and extract from this recording a series of chemical images of all biochemical components.
The hallmark of a synchrotron infrared micro spectroscopic beamline is the ability to record a **high quality spectrum in a very small sample area of 6 microns.** On the SMIS beamline, this has been satisfactorily achieved.

Being able to record high quality spectra with sub cellular resolution results in the recording of chemical images of each of the biochemical components, and with a subcellular resolution. This is illustrated in the figure on the right, showing chemical images of lipids distributed around a blood vessel in a human normal colonic mucosa.



(data from F. Le Naour and M.-P. Bralet)

1 Glass slide with metallic coating of thickness-calibrated lines, which reflects the infrared beam.
2 P. Dumas, G.D. Sockalingum and J. Sulé-Suso, Adding synchrotron radiation to infrared microspectroscopy: what's new in biomedical applications? Trends in Biotechnology 25 (2007) 40-44.