Applications of micro-PIXE technique to biological problems

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Elemental mapping of biological tissues has been identified in the early days of nuclear microprobe developments as one of the most promising applications of high-energy focused ion beams. By the improvements of the accelerators, ion lenses and detectors, micro-PIXE became a technique of choice for tissue elemental mapping in the cases, where high elemental sensitivity, high lateral resolution and quantitative nature of the elemental analysis need to be combined for the tissue analysis. Combined with Elastic Backscattering Spectrometry (EBS) and Scanning Transmission Ion Microscopy (STIM), providing light element composition and tissue thickness, micro-PIXE elemental maps could be quantified without a need of reference materials. Micro-PIXE is currently available to complement biomedical research together with several similar techniques, such as micro-X-ray fluorescence (micro-XRF) spectroscopy at synchrotron radiation facilities and table-top method of laser ablation with inductively coupled plasma mass spectrometry (LA-ICP-MS).

Preparation of samples for micro-PIXE analysis on biological tissue or individual cells is a demanding process, which dominantly influences the quality of the results. Shock-freezing, cryotome slicing and freeze-drying of the tissues are most frequently used steps for the tissue preparation. However, the removal of water induces morphology alterations at the subcellular level. A need for preserving the sub-cellular morphology motivated the efforts to keep the tissue in a frozen hydrated state during the analysis. First micro-PIXE measurements on frozen hydrated tissues were reported in 2007 by iThemba group [1]. Several micro-XRF facilities at synchrotrons started to offer such sample handling for external users. We report on instrumental and methodological development of micro-PIXE analysis on frozen hydrated tissue at JSI [2].

After the incorporation of a multicusp ion source at JSI tandem accelerator, high-energy proton beam brightness is increased for one order of magnitude in comparison with earlier used duoplasmatron ion source [3]. This results in the availability of sub-micrometer beam sizes for micro-PIXE and correspondingly the sub-cellular resolution in the tissue mapping.

Several recent applications of micro-PIXE at JSI will be presented, addressing plant physiology [4], nanomedicine [5], nanotoxicology [6], food research [7] and environmental pollution [8].

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