Ambient Laser Desorption Ionization – instrumentation and applications

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Prof. Zoltan Takats has obtained his M.Sc. degree in Chemistry from the Eotvos Lorand University, Budapest, in 1998. He has carried out his Ph.D. research at the Chemical Research Centre of the Hungarian Academy of Sciences and at Purdue University. He has obtained his Ph.D.degree in analytical chemistry in 2003. He has been doing mass spectrometry-related research for more than 15 years, with a primary focus on the development of novel atmospheric pressure ionization methods. He is the primary inventor of electrosonic spray ionization, desorption electrospray ionization, jet desorption ionization and rapid evaporative ionization mass spectrometry methods. Besides pursuing a scientific career, he has been deeply involved in the introduction of mass spectrometry-based neonatal screening programme in Hungary and served as the head of one of the national screening laboratories. Following a couple of years spent at Justus-Liebig-Universität in Gießen, Germany, he currently works as Professor of Analytical Chemistry at Department of Surgery and Cancer, Faculty of Medicine, Imperial College London. Present research interests include the application of ambient ionization methods in surgical metabonomics and development of mass spectrometric imaging techniques for the rapid phenotyping of cancer patients.

Abstract:

Laser desorption ionization was introduced in the early 1970s and was subsequently used for MS imaging. In contrast to the versatility of the approach, the LAMMA (laser microprobe mass analyser) technique did not become popular in the broader analytical community and the original laser desorption was quickly superseded by the significantly more sensitive MALDI which also allowed the analysis of arbitrary molecular species regardless of their chemical nature or molecular weight.

Atmospheric pressure laser desorption ionization received attention from 2010 as a potential method for the in-vivo analysis of biological tissues, as an alternative (or alternative way of implementation) for the rapid evaporative ionization mass spectrometry (REIMS). The electric current used for tissue aerosolization in case of REIMS exerts a purely thermal effect on tissues, which can also be achieved by low-fluence infrared laser irradiation. The inherent problems with ambient laser desorption ionization are identical to those with REIMS; low sensitivity and contamination of the instrument by large aerosol particles. These phenomena can also be perceived that the ALDI process generates an aerosol with sub-optimal particle size distribution and majority of analyte molecules end up as contaminants instead of undergoing ionization.

In order to enhance ionization efficiency and minimize the precipitation of organic debris in the ion optics, we have devised a special atmospheric interface setup featuring a heated declustering element. The heated metal part is positioned in the free jet expansion region

following the first conductance limit of the atmospheric interface. Our hypothesis was that particles accelerated by the free jet expansion will undergo surface induced dissociation, which is further enhanced by the heat transfer between the heated surface and the particles. The novel atmospheric interface setup was tested using model aerosols and aerosols obtained by the laser ablation of tissues using 337 nm UV laser and 2.94 μm and 10.6μm wavelength infrared lasers for ablation. The concept solved instrument contamination problems and provided a factor of 20-50 signal enhancement. The dramatic ionization efficiency difference observed between model aerosols and aerosols obtained by tissue ablation suggested that the analyte (largely complex lipid) content of tissue originated aerosols exceeded the upper limit of the dynamic range of the method, which hypothesis was supported by calibration experiments. In order to further enhance the ionization efficiency, we have developed an atmospheric interface setup which mixes organic solvent with the sample aerosol, resulting in significantly lower in-droplet concentration. Various organic solvents were tested and significant signal enhancement was found in case of aliphatic alcohols. Infusion of isopropanol into the interface gave an additional 20 times enhancement and also provided a means to infuse internal calibrants into the instrument.

The system comprising a CO_2 laser has successfully been tested for the analysis of bacterial cells, human cell cultures and human tissues. The novel setup gives comparable results to electrosurgical REIMS, with 3-5x better signal-to-noise ratios, resulting in better classification performance.