Applied Surface Science
Room: 316 - Session AS+BI+VT-TuM

Ambient Ionization Mass Spectrometry

Moderator: Gerardo Brucker, Granville-Phillips Vacuum Products, Steven Pachuta, 3M Company

8:00am **AS+BI+VT-TuM1 Laser Ablation Electrospray Ionization Mass Spectrometry with Ion Mobility Separation for Cell and Tissue Analysis**, ***Akos Vertes***, *B. Shrestha, H. Li, S.A. Stopka, L. Zhang*, George Washington University **INVITED**

Laser ablation electrospray ionization (LAESI) is a novel ion source that enables the direct analysis of biological samples, including tissues and individual cells. In this ionization method, mid-IR laser ablation is followed by electrospray ionization of the ablated material in the expanding plume. Molecular coverage in complex biological samples is limited, in part, by the large number of components and the absence of a separation step prior to ionization. In addition, isobars, such as structural isomers and conformers, are not distinguished by mass analysis alone. To overcome these limitations, LAESI is combined with ion mobility separation (IMS) before mass spectrometry (MS). In this contribution, we describe the first results with such a LAESI-IMS-MS system for metabolite, lipid and protein analysis, including its application to plant and animal tissues, MS imaging and single cell analysis. The studied systems, among others, comprise mouse brain sections, *Arabidopsis thaliana* leaves and green algae (*Chlamydomonas reinhardtii*) cell pellets. The introduction of IMS resulted in enhanced molecular coverage, reduced interferences, distinction of structural isomers, observation of larger multiply charged ions typically suppressed by singly charged abundant metabolites and phospholipids, and in extended dynamic range.

8:40am **AS+BI+VT-TuM3 Miniature Mass Spectrometry Systems with Ambient Ionization and MS/MS Capabilities**, ***Zheng Ouyang***, *L. Li, Y. Ren, X. Wang, X. Ma, R. Zou, R.G. Cooks, Y. Xia*, Purdue University **INVITED**

As a technique for chemical analysis, mass spectrometry is versatile and provides very specific information. High sensitivity can be achieved when sample matrix effect is properly suppressed. Miniaturization of the mass spectrometry instrument system and simplification of the operation procedure enable the chemical analysis outside the analytical laboratories and/or by personnel without special trainings. The development of these systems goes beyond the miniaturization of the mass analyzers and mass spectrometers. At Purdue, we have taken an approach of combining the ambient ionization for direct sampling and the miniature ion trap mass spectrometer with MS/MS capability. The miniature systems use linear ion traps (LIT) for mass analysis and can perform multi-stage MS/MS, which help to improve the specificity of the analysis using the fragmentation pattern of the target analyst and to eliminate the chemical noise from the complex mixtures. A discontinuous atmospheric pressure interface (DAPI) has been developed to allow coupling of ionization sources at atmospheric pressure with the instruments using miniature pumping systems to support the vacuum. The DAPI opens for about 20 ms for ion introduction and requires a 200 ms delay for pressure drop prior to mass analysis. The complex gas dynamics has been characterized using direct simulation Monte Carlo method and an electro-hydrodynamic simulation method has been developed for predicting the ion trajectory for DAPI instrument design. While mass spectrometers as light as 4 kg have been previously developed with capability of analyzing non-volatile compounds, two complete MS analytical systems have recently developed as the backpack MS for in-field analysis and the Mini 12 desktop system for point-of-care analysis by nurses and physicians. These two systems use ambient ionization for direct sampling analysis. The low temperature plasma (LTP) probe was modified with an in-line configuration for point-and-shoot operation with the backpack MS. New ambient ionization methods have been explored for development consumable sample cartridges for the Mini 12 system, which include the paper spray, extraction spray and the most recent slug flow microextraction nanoESI. IS-coated capillary samplers have been developed for highly quantitative analysis using several microliters of biofluid samples and extremely operation procedures. On-cartridge chemical derivatization has been developed to significantly improve the sensitivity of the target analytes in complex biological samples and on-cartridge assays have also been studied for direct monitoring the enzymatic functions. Direct analysis of the biological tissues have also been explored using Mini 12 and on-line Patenò-Büchi (P-B) reactions facilitated by UV irradiation has also been implemented to identify the locations of C=C bonds in the lipids, which is highly relevant to the biosynthetic pathways and the function of the lipids. The relative ratios of the unsaturated isomers can now be quantified, as the potential biomarkers for diagnosis of diseased tissues.

9:20am **AS+BI+VT-TuM5 The Importance of Sample Form and Surface Temperature for Analysis by Ambient Plasma Mass Spectrometry (PADI)**, ***Ian Gilmore***, *T.L. Salter, J. Bunch*, National Physical Laboratory, UK

Plasma sources for ambient mass spectrometry are of increasing importance owing to their ability to analyse a wide range of organics including polymers. Some industrially important molecules are not successfully analysed by electrospray based methods and here plasma methods are making an important contribution. For analysis in industry, it is essential to understand the fundamental mechanisms so that predictions can be made of which types of materials can and cannot be detected. In this study, we develop a metrology framework to understand the sensitivity of PADI to different substances and material form. We study in detail, the effect of sample temperature on the signal intensity and show that the intensity is proportional to the vapour pressure. Importantly, we also show the sample form, as a film or powder, has a strong effect of sensitivity. For the analysis of thin films at room temperature and using a low plasma power, a vapour pressure of greater than 10^{-4} Pa is required to achieve a sufficiently good quality spectrum. Using thermal desorption we are able to increase the signal intensity of materials with vapour pressures less than 10^{-4} Pa, in thin film form, by between 4 and 7 orders of magnitude. This is achieved by increasing the temperature of the sample up to a maximum of 200 °C. Thermal desorption can also increase the signal intensity for the analysis of powders. Prospects for imaging PADI and sub-micron imaging ambient mass spectrometry imaging will also be discussed.

9:40am **AS+BI+VT-TuM6 A VAMAS Interlaboratory Study for Desorption Electrospray Ionisation Mass Spectrometry (DESI MS) - Survey of the Measurement Issues**, ***Paulina Rakowska***, *E. Gurdak, F.M. Green, M.P. Seah, T.L. Salter, I.S. Gilmore*, National Physical Laboratory, UK

The DESI technique is celebrating a decade of application since its innovation in 2004. There has been significant progress in understanding its fundamentals and a rapid expansion in the applications, covering a diverse range of science and technologies. For wider uptake in industry, measurements need to be repeatable and constant. It is especially important to test that methods are transferable between different instrument designs and that analytical procedures are clear. This requires the development of a metrological infrastructure. Interlaboratory studies are an effective route to do this. VAMAS provides an excellent mechanism for such evaluation. Under this framework, the National Physical Laboratory (UK) has conducted a DESI interlaboratory comparison. The objectives of this study were to determine the current achievable repeatability and constancy of instruments. The comparison was conducted with the involvement of 20 laboratories from 10 different countries. The instruments used included 7 commercially made DESI sources with the remainder home-built. A variety of mass spectrometers were used including 13 Ion Traps, 4 Orbitraps and 4 Time-of-Flight. Participants were provided with an analytical protocol and two reference samples: a thin layer of Rhodamine B and a double-sided adhesive tape. The studies comprised acquisition of positive ion mass spectra in pre-determined *m/z* ranges. No sample preparation was required. Results for Rhodamine B show that intensity repeatabilities below 20 % may be achieved. However, inadequacies of the spray and sample stage designs lead to repeatabilities that average 50 % with some worse than 80 %. Rhodamine B is an excellent reference sample to check the sample erosion, the sample stage movement and memory effects. The adhesive tape samples show that the absolute intensity repeatability is 31 % with several achieving below 20%. Importantly, the spectral response, given by the relative repeatability, not measurable with Rhodamine B, was reduced to 9 % with a significant number achieving the 5 % expected of more mature analytical methods. The constancy of these spectra from relative intensities gives day-to-day averages of 31 %, over three times worse than the short term repeatability. Significant differences in the spectra from different laboratories arise from different factors. This first interlaboratory study has provided an effective survey of the measurement issues and some important conclusions can be drawn about the possibilities for DESI MS concerning overall practice, reference samples and recommendations for the future. These will be discussed.

11:00am **AS+BI+VT-TuM10 Mass spectrometry surface analysis outside the vacuum**, ***Justin Wiseman***, *M.E. ElNaggar, J.K. Kennedy, B.L. Laughlin*, Prosolia Inc. **INVITED**

Advances in mass spectrometry in the last 20 years has produced instruments with higher resolving power, smaller footprints, even portable, and the capability of measuring surfaces for molecules in the ambient air; the former truly enabling the latter. Ambient mass spectrometry involves the characterization of samples in their native state in the open air and is exemplified by the development of Desorption Electrospray Ionization (DESI) and Direct Analysis in Real Time (DART). DESI uses high velocity charged droplets produced by a pneumatically-assisted electrospray to effect desorption and ionization of surface-bearing analytes. The applications of the technique are broad and span from the detection of leachables to thin-layer chromatography to imaging of drugs, metabolites and lipids in histological tissue sections, where the lateral spatial resolution has been reported to be as high as 50µm. The flowprobe, also an ambient technique, uses a liquid-microjunction formed at the surface to extract and deliver analytes to the mass spectrometer via an electrospray source. The applications of the flowprobe are also broad and have included microarray sampling, thin-layer chromatography plate analysis, and biological tissue analysis. This presentation will discuss the merits and applications of each of the DESI and flowprobe devices, with emphasis on their application to imaging biological tissue.

11:40am **AS+BI+VT-TuM12 Transporting Ions from Ambient Pressure into Vacuum for Lab-based and Mobile Mass Spectrometers**, ***Mitch Wells***, FLIR Mass Spectrometry **INVITED**

The proliferation of Atmospheric Pressure Ionization (API) sources for mass spectrometry (MS) has expanded the applicability of the MS analysis technique to a wide range of chemical and biological challenges, to the extent that the 2002 Nobel Prize in Chemistry was awarded to John Fenn and Koichi Tanaka for their development of Electrospray Ionization (ESI) and Matrix-assisted Laser Desorption Ionization (MALDI), respectively. Furthermore, recent developments in a specific category of API, referred to as Ambient Ionization (AI), have simplified the applicability of API techniques by removing some or all of the need for sample preparation prior to analysis. AI techniques, such as Desorption Electrospray Ionization (DESI), Direct Analysis in Real Time (DART), and an ever increasing list of additional techniques and variations, allow for direct analysis of an enormous range of sample and matrix types; whole blood, illicit drugs in fingerprints, tissue cross-sections, pharmaceuticals, and forensic samples have all been examined with AI, to name just a relatively few examples.

All API techniques have in common the need to transport ions from atmospheric pressure into the high vacuum of the mass spectrometer - typically $<10^{-5}$ Torr (<1 mPa). Various ion sampling and transport mechanisms are used to transfer ions through differentially-pumped vacuum stages to the mass analyzer. In all cases, significant losses at each stage mean that only a very small fraction (<<1%) of the ions generated from a sample are actually analyzed. The situation is even worse for systems that are intended to be used in mobile or field labs, where space and power are at a premium and large pumping systems are therefore not acceptable.

This talk will briefly review AI techniques to illustrate their value in analytical chemistry (including biological, clinical, and forensic analysis), and will then describe means by which ions are transported from atmosphere into vacuum, with the hope of stimulating dialog with the vacuum community about ways and means that this process could be improved, especially for small, rugged instruments designed for outside-the-lab use.

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