High field asymmetric waveform ion mobility spectrometry combined with mass spectrometry (FAIMS-MS)

Kayleigh L. Arthur, James C. Reynolds, Colin S. Creaser

Centre for Analytical Science, Department of Chemistry, Loughborough University, Leicestershire, LE11 3TU, UK.

FAIMS

What is FAIMS?

- High field asymmetric waveform ion mobility spectrometry (FAIMS) is a gas phase ion separation technique that utilises an oscillating high frequency (RF) periodic waveform at atmospheric pressure.
- Orthogonal separation to chromatography and mass spectrometry (MS).
- FAIMS is also known as differential mobility spectrometry (DMS).

Applications for FAIMS-MS:

- FAIMS can be used to pre-select ions and remove interference prior to mass analysis.
- Ion separation utilising low and high electric field strengths can distinguish structural differences between ions in the gas phase.
- Rapid separation at fast scan rates make FAIMS compatible with high performance liquid chromatography (LC).
- Separation of analytes from complex samples (even isobaric analytes) can be achieved with the application of FAIMS.

How does FAIMS work?

- The rapid separation of gas phase ions is a result of differences in ion mobility in a buffer gas at a high electric relative to a low electric field (Figure 1).

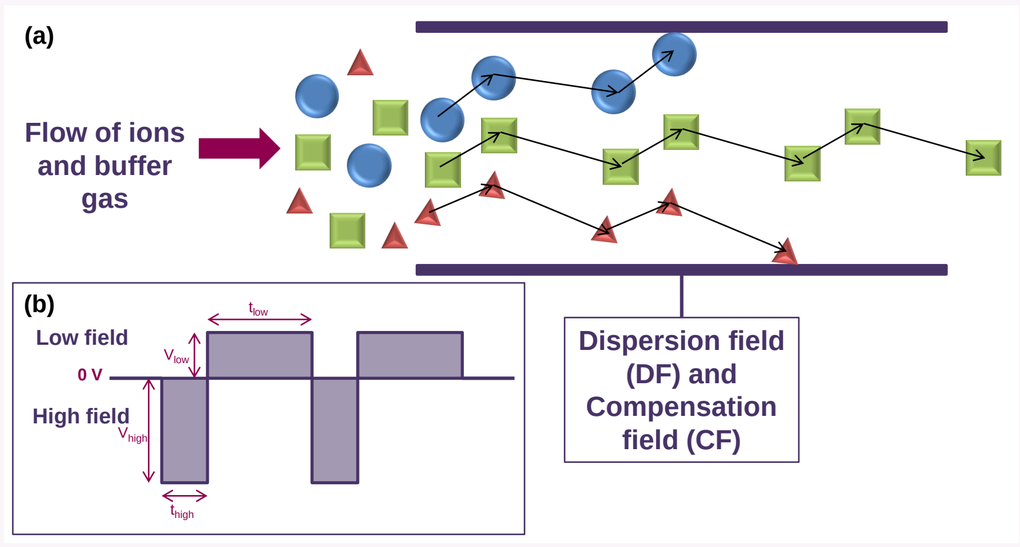

Figure 1: (a) Ion transmission through planar FAIMS electrodes at fixed DF and CF; (b) oscillating asymmetric waveform

FAIMS-MS Instrumentation

Combining FAIMS with MS:

- Prototype ultra-FAIMS chip (Owlstone Ltd.) is located behind the spray shield in a Jet Stream ESI source (Agilent Technologies) in front of the inlet capillary (Figure 2).

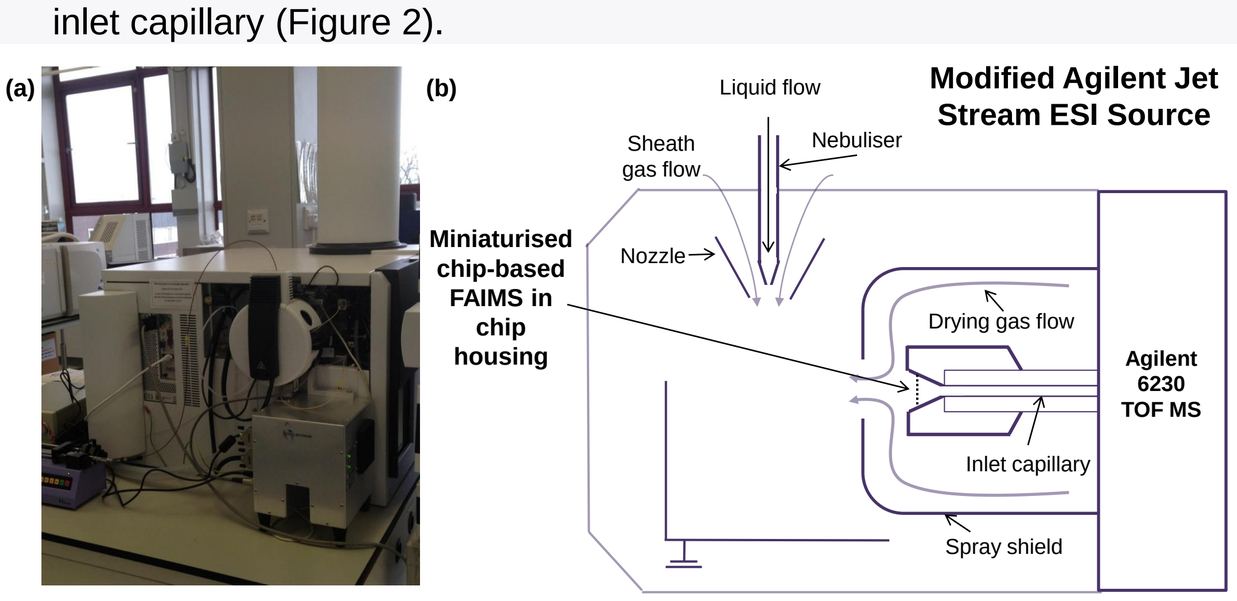

Figure 2: (a) Photograph of FAIMS-MS interface; (b) schematic diagram of the interface of the ion source of the TOF-MS and the chip-based FAIMS device

- Ultra-FAIMS chips have multiple planar separation channels with a 100 µm gap and a 700 µm depth (Figure 3).

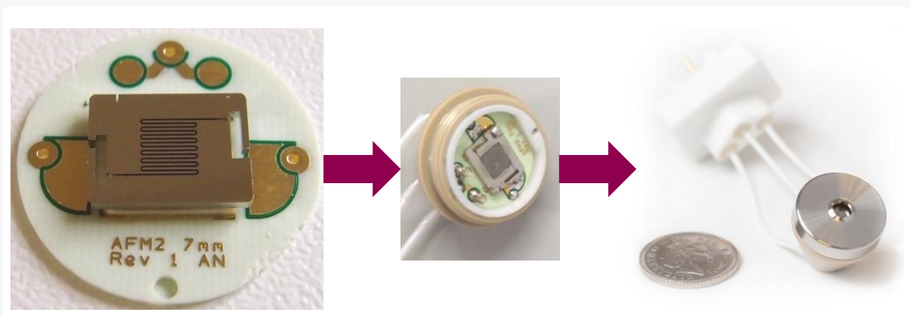

Figure 3: Photographs of FAIMS chip showing the multiple planar channels and the FAIMS chip housing

- Fast scan rates due to high electric field strengths and short ion residence times (50-250 µs) mean that the FAIMS device is compatible with LC as well as MS.
- FAIMS chip is suitable for quantitative analysis.
- Can detect multiple gases simultaneously in sub-second timescales.
- Detection levels below part per billion (ppb).

FAIMS-MS Examples

Structural Analysis using FAIMS:

In +ve ion mode, 3-methylxanthine isobaric singly and doubly charged clusters can be observed. FAIMS-MS can be used to resolve these complexes (Figure 4).

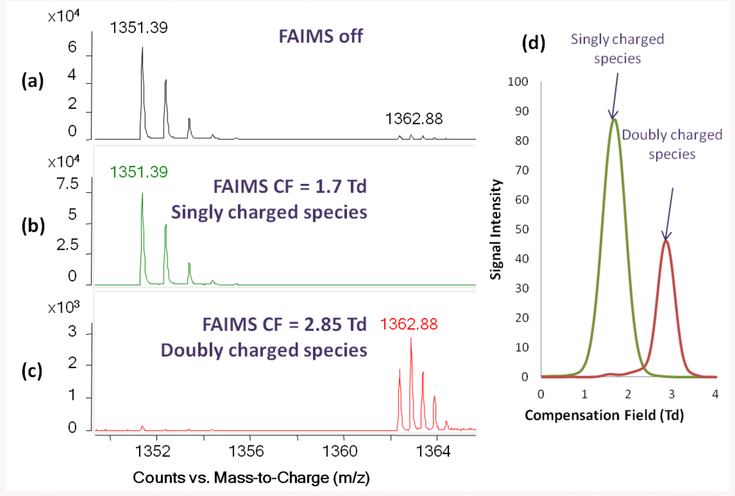

Figure 4: Separation of 3-methylxanthine ($+Na^+$) complexes using FAIMS (DF = 323 Td); (a-c) mass spectra without and with FAIMS applied; (d) FAIMS CF scan at DF = 323 Td

Separation of Isomers using FAIMS:

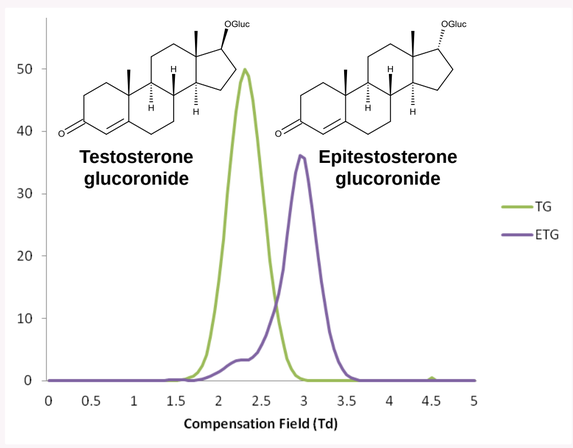

Figure 5: FAIMS-MS separation of glucoronide isomers at a dispersion field of 300 Td

FAIMS-MS allows the separation of testosterone and epitestosterone isomers that are unable to be identified by MS alone. The isomeric glucoronide compounds ($[M+H]^+$ ions at *m/z* 465.24) are resolved using FAIMS-MS in minutes with pre-separation prior to mass analysis (Figure 5).

LC-FAIMS-MS for Metabolite Analysis:

Saliva metabolite analysis can be simplified by removal of background interference from the complex saliva matrix via the incorporation of FAIMS with LC-MS (Figure 6).

Acknowledgements

We'd like to thank Owlstone Ltd. and Loughborough University for financial support and Owlstone Ltd. and Agilent Technologies for instrumentation.

analytical.science@Loughborough
Centre for Analytical Science