A Novel Resistive Glass Atmospheric Pressure Ion Mobility Spectrometer

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Overview

- -Designed and developed a monolithic atmospheric pressure nanoelectrospray ion mobility spectrometer (IMS)
- *Combines advantages of ESI soft ionization and speed of IMS analysis *If combined with MS, provides high peak capacity and improved resolution for analysis of
- complex environmental samples
- *Increased homogeneity of electric fields in drift region increases resolution *Improved signal-to-noise ratio associated with Hadamard multiplexing

Introduction

IMS is a rapid gas phase technique which separates compounds based on their molecular cross-section and m/z. It can be used in standalone mode or in combination with liquid chromatography (LC), with the aim of increasing overall peak capacity. IMS is used in applications such as the detection of chemical warfare agents, screening of pharmaceuticals, metabolomics, and proteomics



Conventional ion mobility spectrometers utilize a drift region built with a stack of ring electrodes. This is known to produce radial variation in the electric fields, leading to deterioration in resolving power. A new high-resolution monolithic nanoelectrospray ion mobility spectrometer which attempts to minimize such variations is described here.

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Methods

This current prototype uses resistive glass monolithic desolvation and drift regions, and Faraday cup detection. The resistive glass used here (Burle Industries Inc.) is formulated with proprietary technology which produces reduced lead silicate glasses with thin film metallization contact points. The electric field produced by the resistive glass is highly homogeneous throughout the drift region. The length of the desolvation region is 110 mm and the length of the desolvation region is 250 mm. The IMS electronics include an FUG 20 kV high voltage power supply (HCL 14-2000), a National Instruments NI-6111 ADC, a National Instruments NI-5411 arbitrary waveform signal generator (for generating conventional and Hadamard gating sequences and controlled by in-house coded software), and a 100 kHz amplifier sensitive in the 1 pA to 1 nA range. The current gates used in the prototype are conventional Bradbury Nielsen-type grids, which can be pulsed up at frequencies as high as 120 kHz, with pulse widths down to 1 microsecond.

Instrumentation: Resistive Glass IMS





Timing Schemes & Software Software for IMS ion gate, IMS data acquisition and TOF-MS repeller pulsing was written using the LabView 7.0 programming environment. The IMS and HT-IMS schemes utilize a National Instruments NI-6111 analog to digital converter and a NI-5411 signal generator. The HT-IMS-TOF scheme utilizes a NI-5411 signal generator, a NI-6602 counter board and a FAST ComTec P7887 4 GHz multiple Prestligh P7887 event time digitizer atic of Waveform Ge Arbitrary Waveform Ion Gate Signal Generate

Results: Characterization of IMS Prototype



Effects of temperature (155, 125, 95, and 65 °C) on drift time and signal intensity of the solvent and reserpine species. Conditions: 80.0 fmol analyzed, 400 µs ion gate pulse, 10,300 V drift voltage, 15,000 V nanoESI voltage, N2 drift gas 0.5 L-min



Radial ion density profiles within the resistive glass drift tube measured using various sized detector plates and a corona discharge source. Conditions: 6,800 V drift voltage, 10,000 V tungsten filament, 25 °C, He drift gas 1.7 L-min-1



Data Acquisition for IMS and HT-IMS Modes

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Drift Time (ms) Effects of N₂ drift gas flow rates (0.4, 0.77, 1.10 and 1.40 L-min¹ on elution time and signal intensity of the solvent and reserpin species. Conditions: 40.0 fmol analyzed, 200 μs ion gate pulse, 10,300 V drift voltage, 15,000 V nanoESI voltage, 25 °C, N₂ drift gas

Resolving Power at Various Ion Gate Pulses



peak), reserpine (2nd peak) and a reserpine dimer (3rd peak) at 400 μ s, 200 μ s and 100 μ s ion gate widths. Conditions: 31.0, 15.5 and 7.8 fmol analyzed, 12,000 V drift voltage, 15,000 V nanoESI, 25 °C, N₂ drift gas 0.6 L-min

Analysis of Model Siderophore using IMS & LC



+0.1% acetic acid), 42.0 fmol deferoxamine mesylate (DFOB) and 44.0 fmol Fe(III)-DFOB. Conditions: 400 μ s ion gate pulse 10,300 V drift voltage, 15,000 V nanoESI 25 °C, N₂ drift gas 0.6 L·min

Average analysis time 0.2-0.5 min (100 ms per sweep, 100-300 sweeps averaged per spectrum)

Waters Symmetry C-18 colu Average analysis time 24 min (16 min separation, 8 min column equilibration

IMS-TOF MS

Time (min)

LC Analysis

Data Courtesy of Kathy Barbeau

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- DFOB

Hadamard Multiplexing

In the HT-IMS and HT-IMS-TOF configuration an encoding sequence is applied to the ion beam by means of a Bradbury-Nielson ion gate which rapidly shutters the ion beam on and off. The rapid on/off modulation of the ion beam creates ion packets of assorted sizes. The detected signal is a convolution of the ion mobility and/or timeof-flight spectra corresponding to these different packets. Using knowledge of the applied sequence, the signal is deconvoluted to yield the ion mobility or time-of-flight spectrum using the inverse of the applied Hadamard transform



Conclusions

We have demonstrated the feasibility of obtaining ion mobility spectra with a spectrometer constructed using a monolithic piece of resistive glass. We have characterized the ion distribution within the drift tube and have investigated and optimized instrumental parameters to maximize resolving power. Work currently underway involves coupling the IMS to a TOF-MS and applying Hadamard multiplexing to increase the SNR and duty cycle of our instrument





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