Development of a new orthogonal ion injection method coupled to dual ion funnel source for highly sensitive and high-throughput MS analysis

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Overview

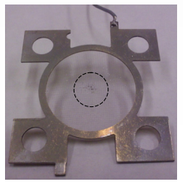
- Ion funnels work well in the ~1-40 Torr range and are well suited for transferring ions from an atmospheric pressure ion source into a mass spectrometer.
- Ion funnels have been successfully used with both ESI and MALDI sources.
- However, ion funnels utilizing an inline ion injection method can lead to contamination of mass spectrometer elements.
- Here we describe the implementation of a new ion injection method that considerably reduced the contamination of the ion funnel elements as well as down stream mass spectrometer components.

Introduction

Electrospray ionization (ESI) sources that consist of ion funnels conventionally utilize an inline capillary to introduce ions into the mass spectrometer (MS). This method can cause contamination of the mass spectrometer elements, resulting in unstable signals and eventually leading to complete signal loss. Employment of a jet-disrupter in the ion funnel has reduced the contamination of the mass spectrometer elements down the line; however, the jet disrupter itself can get contaminated, leading to signal deterioration.

With these considerations in mind, we developed a novel orthogonal method of introducing ions into a high pressure ion funnel. The new method described here can be used with multicapillary inlets with much higher gas loads for significantly enhanced ion utilization.

When the contamination is significant, it is possible to visually identify the contaminants on the funnel lenses as shown in the figure.

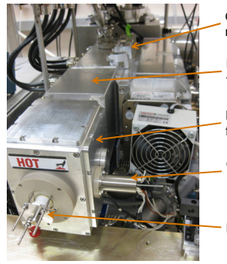


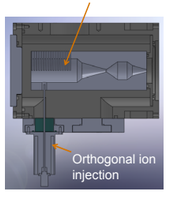
Methods

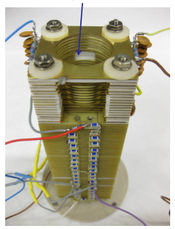
Samples were prepared in a water : methanol : acetic acid (49.5 : 49.5 : 1% by volume) solution. Neurotensin solution was prepared at a concentration of 500 nM. A mixture of eight peptides were prepared with a concentration of 1 µM. Orthogonal injection method was carried out at a flow rate of 80 nL/min while the inline ion injection method was carried out at a flow rate of 100 nL/min.

Instrumentation

For this study, a quadrupole time-of-flight mass spectrometer was used. This instrument consists of two ion funnel chambers that can be operated at two different pressures. The high pressure funnel can be operated at pressures up to about 20-30 Torr. The low pressure funnel is usually operated at 1-2 Torr range.







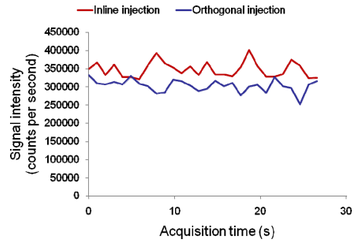
For this study, a PCB ion funnel was modified by adding an extension consisting of 17 brass lenses. Three of those brass lenses have small pieces removed from one side to allow the insertion of the inlet capillary into the funnel. On the opposite side of the insertion window, the spacers between lenses have been removed to allow the liquid droplets from the ESI source to move out of the funnel.

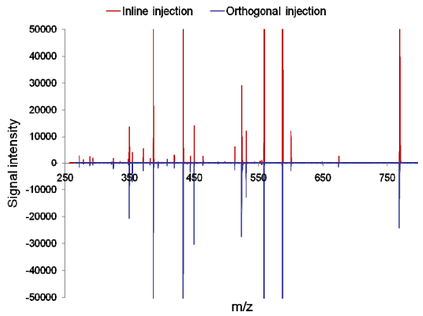
The length of the extension is 2.65 cm while the length of the PCB portion is 9.7 cm. The extension region is wired to have both DC and RF potentials. The DC field gradient for the extension region can be independently varied from the PCB section.

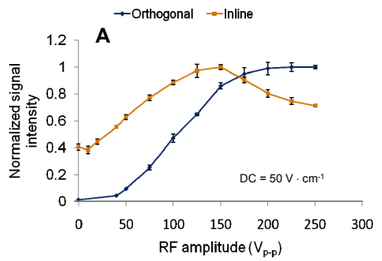
To facilitate direct comparison between inline and orthogonal ion injection methods, the instrument was configured to have both inlets simultaneously. The high pressure ion funnel was operated at 8-10 Torr range while the low pressure ion funnel was operated at 1.5 Torr.

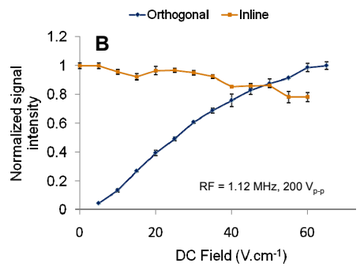
Results

Direct comparison between inline and orthogonal injection methods showed that this method is almost as efficient as the inline method. The average TIC current for an eight peptide mixture using orthogonal injection was 87% compared to the inline injection method. However, close inspection of individual peptides showed variable results where some peptides gave more intense signals for orthogonal injection.

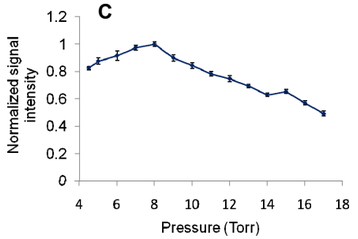


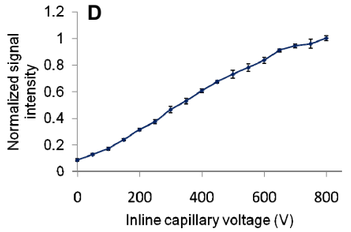






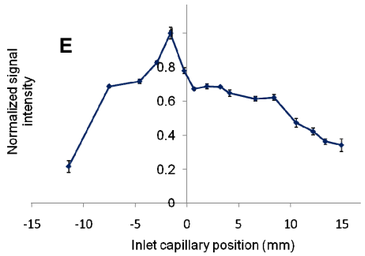
For the orthogonal injection method lowering the RF amplitude significantly reduced the signal transmission **(A)**. This suggests that the ion and droplet transmission for inline injection is affected by the directional gas flow through the funnel while for orthogonal injection the gas flow through the funnel is minimum. The same phenomenon is observed for the DC field gradient across the extension region **(B)**.





Signal transmission is highest between 4-10 Torr region for the set of conditions used in this study **(C)**. The inlet capillary was kept at 0.88 mm inside the funnel aperture. The inline capillary effectually works as a repeller plate to push the ions into the funnel **(D)**. Therefore, when the voltage on that capillary is lowered, the signal transmission was reduced.

The signal was highest when the capillary is very close to the aperture of the funnel lens. For the data shown in plot E, the best signal was obtained when the capillary was 1.56 mm away from the funnel inner diameter. For this system the two lenses on the sides of the capillary were kept at the same RF phase.



Conclusions

- Multicapillary inlets have been successfully used to improve the sensitivity of the mass spectrometer for high-throughput analysis. When multicapillary inlets are used with conventional designs, contamination of the mass spectrometer elements are more pronounced due to the higher gas load.
- We developed a new orthogonal ion injection method that can be coupled to high pressure or low pressure ion funnel systems.
- The ions are diverted into the funnel using strong DC and RF fields while the liquid droplets are moved out of the funnel due to the directional gas flow.
- This method achieved ion signal intensities similar to a conventional inline ion injection method (~90%).

Acknowledgements

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References

1. Patent: US 7459693B2, *Ion guide for mass spectrometers*, Park MA, Kim T, Stacey C, Berg C.
2. Patent: US 7495212B2, *Ion guide for mass spectrometers*, Kim T, Park MA.

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