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Transmission of Ions Through Conductance Pathways from Atmospheric Pressure

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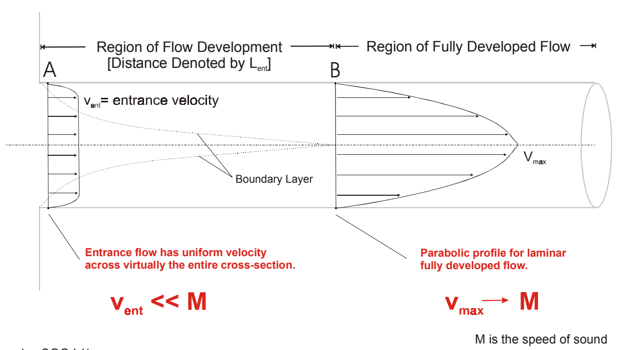
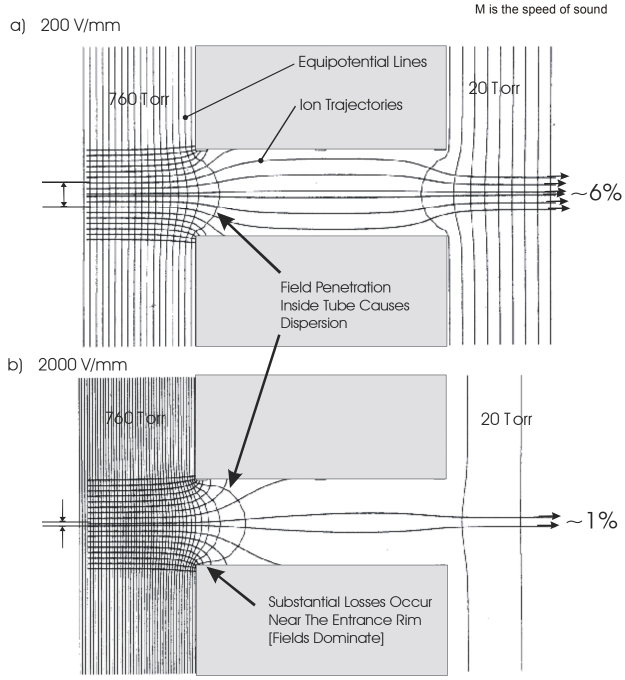
Introduction

There is significant need for improvements in ion transport from atmospheric pressure (AP) ionization sources into lower pressure detectors such as a mass spectrometer. Typical transport efficiencies are in the range of 0.01 %, or 1 ion in 10,000 gets to the detector. The conductance pathway (CP), usually a tube or pinhole aperture is the lowest cross-sectional area along the entire transmission path. It is well established that most of the source current is lost on the surface of the conductance wall or within the conductance pathway. Understanding of the mechanism of loss may help to overcome these inefficiencies and improve sensitivity.

Methods

We evaluated fluid dynamics and ion mobility properties of ions entering the CP in order to more fully characterize and hopefully develop an accurate quantitative model for motion to predict behavior. The goal was to use our knowledge of behavior to develop alternative configurations for CP to improve transmission.





Who wins, field or flow?

Gases at atmospheric pressure accelerate through tube conductance pathways in a manner similar to the diagram at the top left. Of note is the lower velocity flow at the tube entrance where field dispersion is highest. The two examples of field penetration (lower left) show that the majority of ions entering the tube will disperse under the influence of field penetrating into the tube. These simulations where calibrated for reduced mobility for ion motion and the flow was calibrated to about 5% of the speed of sound.

Under typical commercial source conditions where ions are introduced into a field free tube (glass or metal) from a high field source region or optics region, the field wins!

If ions were introduced into the tube from low field, the flow would win!

We define the "effective aperture diameter", $D_{effective}$, as the cross-section of the incident ion beam that actually traverses the conductance pathway. The percentage of the actual diameter of the CP can be quite small. Note that higher focusing fields from the source side decrease the $D_{effective}$. Focusing in high field does not necessarily improve transmission.

How do we increase transmission through conductance pathways (CP)?

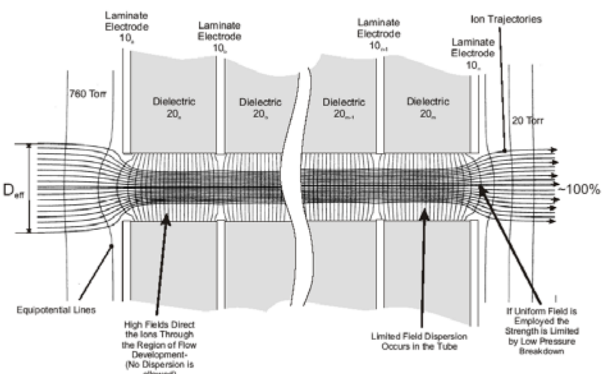
We evaluated a number of alternatives to increase the ion sampling efficiency into CP. Here we present four alternatives that have been developed in our laboratory.

1) The first, we call “laminated tubes”, eliminates the field dispersion in the entrance region of the conductance tube. Laminated tubes can operate with precise control of both field and flow conditions throughout the tube, including uniform fields throughout the entire length or delaying the dispersion until the flow has more fully developed. We have acquire up to 300 nA through 600 um laminates.

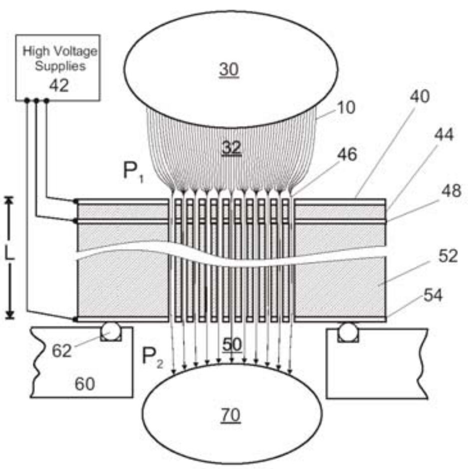
2) The second alternative, we call “ion enrichment aperture” (IEA) arrays, utilizes micro-fabricated arrays of conductance opening with lamination. These have excellent conductance properties in that they allow the ion-sampling cross-section from the source to increase while having precise control of the electric field throughout the CP. Conductance can be minimized while ion transmission maximized!

3) The third alternative for improving transmission through conductance pathway utilized “patterned” IEA arrays. We are able to fabricate atmospheric pressure source optics to concentrate ion transmission cross-section profiles to very precise patterned geometries (e.g. Toroidal Stacks, Poster MPH 120). Using a number of micro-fabrication techniques, including maskless photolithography, we are able to match the conductance opening pattern to the incident ion beam pattern.

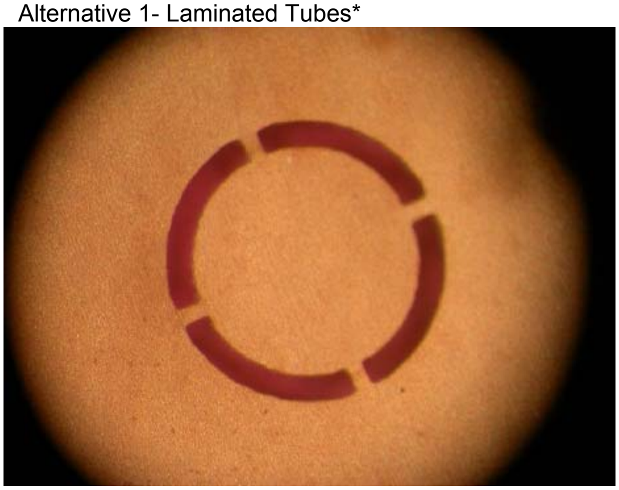
4) The fourth alternative for increasing transmission is to utilize field free focusing at AP to minimize field dispersion inside the CP (e.g. Atmospheric Pressure Quadrupoles [APQ], Poster TPH 102). Utilizing axial multipoles at AP [with sampling at the bottom of the potential well] and viscous flow along the axis has shown promise as an alternative to DC optics.



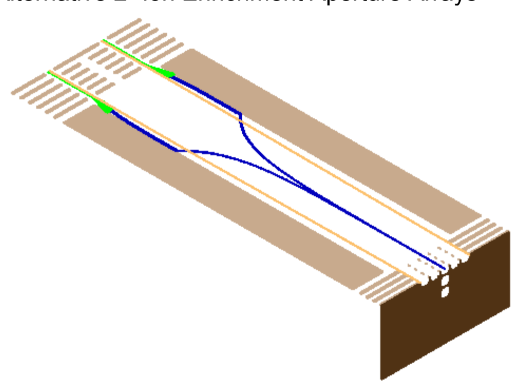
Alternative 1- Laminated Tubes*



Alternative 2- Ion Enrichment Aperture Arrays*



Alternative 3- Patterned Ion Enrichment Aperture Arrays*



Alternative 4- Atmospheric Pressure Quadrupoles*

Conclusions

There are a variety of effective alternatives for improving transmission of ions through CPs.

Acknowledgements

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