

Atmospheric Pressure Focusing

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Introduction

The generation of ions at atmospheric pressure is accomplished by a variety of means; including electrospray, atmospheric pressure chemical ionization (APCI), atmospheric pressure MALDI, and photoionization. A general characteristic of atmospheric ionization sources is their dispersive nature of the ions once produced. Needle/capillary sources such as electrospray and APCI, disperse ions radially from the axis in high electric fields emanating from tubes and nebulizers. Even desorption techniques, such as atmospheric pressure-MALDI, will disperse ions radially in a solid angle from a surface. These dispersive forces can disperse charges and neutral particles or ions over large volumes—5-10 cm in diameter!!

Methods

One solution to collecting and focusing this dispersive plasma is to place a high-transmission element, populated with an array of openings, between the plasma and the sampling aperture or capillary. By doing so one can shape or sculpt and establish electric fields so as to influence the trajectories of ions moving in these electric fields. Three types of high transmission elements (HTE) (1) were considered a High Transmission Surface, a Laminated High Transmission Surface, and a Laminated Toroidal High Transmission Surface. In-house modifications were made to SIMION to account for the viscous forces at atmospheric pressure, and the use of concurrent and counter-current flow of gases.

Results

High-Transmission Surface

Figure 1. shows a SIMION simulation of ions generated in a large volumetric area (to the left) are attracted toward the surface of the element. With the proper electric field-ratio across the surface, generally 1/2 to 1/10, and a low depth aspect of the openings; ions pass unobstructed through the openings and are then focused into small cross-sectional ion beams.

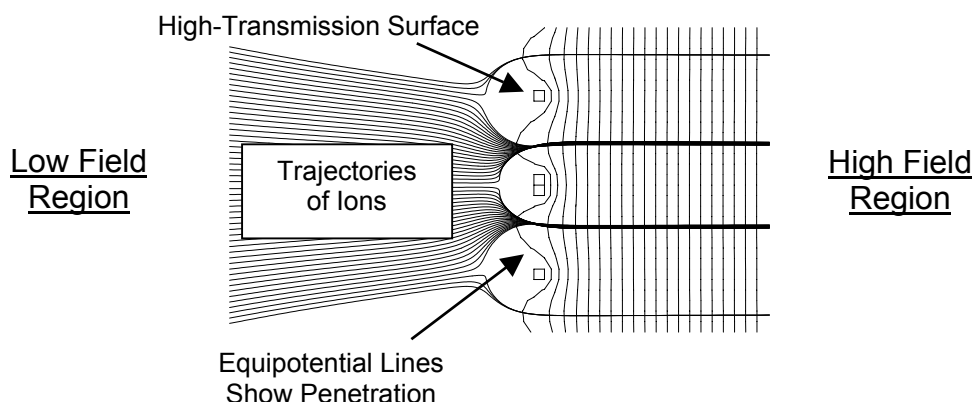


Figure 1. SIMION simulation of a High-Transmission Surface.

In a separate experiment a solution of blue dye (TPM Blue 5EO/5PO, Milliken Corp.) was electrosprayed at a hemispherical shaped High-Transmission Surface (Figure 2). The simulation shows the approximate geometry of the apparatus with needle voltage at +5 kV, high-transmission surface at 0 V, and the collector surface covered with aluminum foil at -12 kV. The photomicroscopy of the collection of blue dye through a high-transmission surface shows a compression ratio of the collected dye of **greater than 5000** (area of the spray/area of collect spot). The dye was collected for 16 hours. Note the indentation of the foil (outlined in white) where the sampling aperture exists.

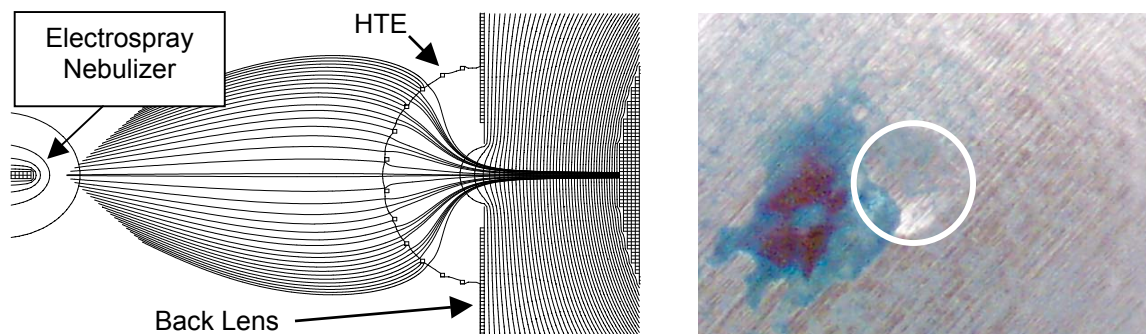


Figure 2. (left) SIMION simulation of an electro spray source and a High-Transmission Surface, showing the trajectories of ions. (right) Collected spot of blue dye, white circle shows outline of 500 μm aperture.

High-Transmission Laminated Surface

Utilizing a laminated surface made up of a thin insulating base sandwiched between two metal laminates, one can control the transmission of charged ions or aerosols through the surface by establishing an electrostatic potential difference between the metal laminates. Figure 3 shows a SIMION simulation of a planar shaped laminated surface with an electrostatic ratio difference of 10/1 across the surface.

Toroidal Laminated Surface

Figure 4. shows a SIMION simulation of a toroidal shaped high transmission surface with an electro spray nebulizer with concurrent and counter current viscous flow incorporated in the surface.

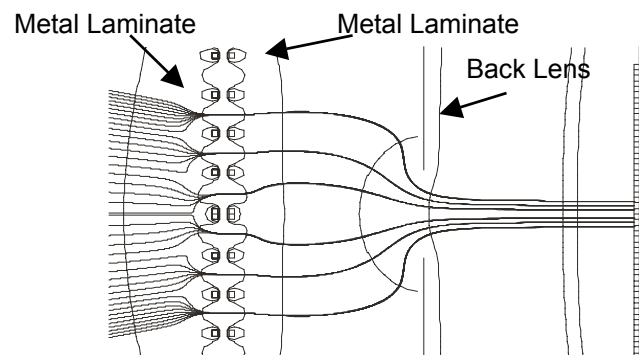


Figure 3. Planar Laminated HTE.

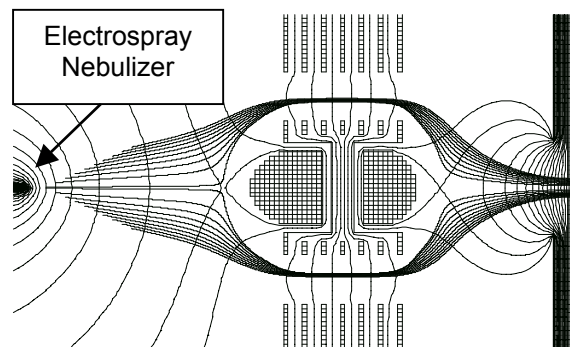


Figure 4. Toroidal Laminated HTE.

Conclusion

By controlling both the electrostatic and viscous forces at atmospheric pressure all points along the trajectory of ions, from the ion generation to ion collection, large dispersive plasma of ions can be focused into small cross-sectional ion beams—as small as 1-2 mm. These beams can be focused at apertures or capillary inlets and then introduced into the vacuum system of mass analyzers. Experimental and simulated results verified that dispersive electro spray ion plasmas can be focused and that ~10-20% of the ion current from an electro spray nebulizer can be delivered into the vacuum system through a glass capillary tube with metalized ends and an aperture.

Acknowledgements

The authors would like to thank the National Institute of Health for Financial support through the SBIR Program (grant # R43 RR143396-1) and David Fries and the staff at the University of South Florida for the use of their labs and manufacturing facilities.

References

1. United States Patents are pending. See: Sheehan, E.W., Willoughby, R.C., "Apparatus and method for focusing ions and charged particles at atmospheric pressure", US Patent 6,744,041 (June 1, 2004).