Spray Quality Optimization for ESI-MS Applications

Obtaining the best quality electrospray can present a challenge for users of nano-ESI-MS applications. Spray shape and plume characteristics are intimately related to several experimental parameters, including:

- Mobile Phase Flow and Velocity
- Emitter and Tip Inner Diameters (IDs)
- Mobile Phase Composition
- Applied Voltage

In this Technical Note, these parameters are investigated with respect to their influence on spray morphology and quality. Implications for obtaining quality electrospray are delineated for the user.

An Anatomy of Electrospray

Electrospray is generated by applying voltage to an emitter via a tip or junction-style high voltage contact. Immediately following the spray tip (Figure 1A) or end of the emitter is a conical aggregate of moving fluid called the Taylor Cone (Figure 1B). The Taylor Cone then tapers into a fine fluid jet which ultimately radiates into a fan-shaped aerosol called a plume. Vacuum force from the mass spectrometer inlet then draws the plume into the instrument for analysis.

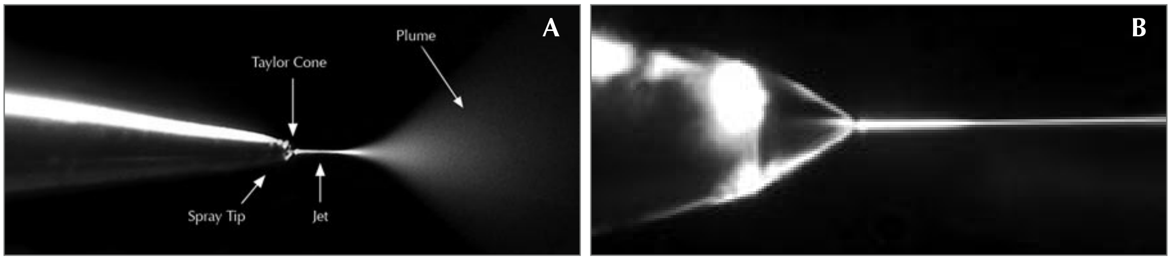
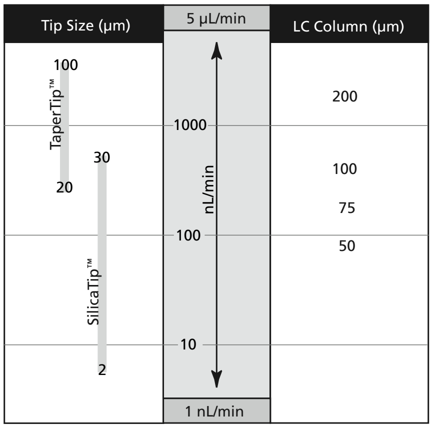


FIGURE 1

Factors Influencing Spray Quality

Emitter and Tip Inner Diameters

Emitter tip inner diameter is directly proportional to sample flow rate. Selecting an optimal tip ID can present a dilemma for the nanoESI analyst: While the smaller tip size generates a low flow rate ideal for small sample volumes, the risk of clog formation increases. As Figure 2 displays, selecting an appropriate tip size can be a difficult though crucial decision.



Mobile Phase Flow and Velocity

Before activating voltage, allow mobile phase to flow and inspect the emitter tip to ensure fluid exits without obstruction. Failure to observe droplet formation using a tip imaging system and/or the presence of high back-pressure in the LC system can indicate an inline clog. Because in-house deionized water can contain particulates which restrict flow and produce clogs, HPLC-grade water is recommended for all applications. To ensure optimal performance, installation of inline filters helps prevent clog formation.

An accurate flow rate measurement technique is described in Technical Note PT-7 “Setup and Measurement of Flow Rate for Online Nanobore LC-MS”. While many LC pumps accommodate flow in the μL/min range, few are specifically designed for the nL/min level. Employing a flow-splitter (Figure 3 between the LC pump and column helps to significantly reduce flow rate to accommodate nanobore LC. A flow-splitter is comprised of a “T” junction where the fused silica LC line from the pump is plumbed immediately opposite the LC line leading to the column. A third fused silica line is plumbed orthogonally to the flow path, providing a second mobile phase outlet (Outlet 2).

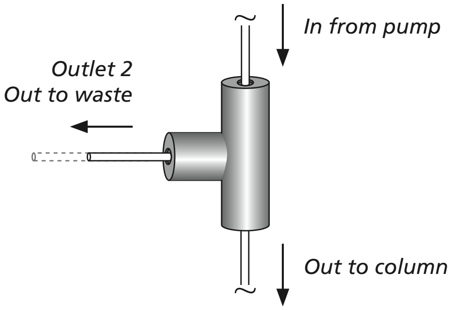


FIGURE 3

In general, the shorter the piece of fused silica utilized for Outlet 2, the greater the flow rate reduction at the tip. Best practice involves starting with a long piece of fused silica for outlet 2, measuring the flow rate at the column tip, and systematically reducing outlet 2 length with an appropriate tool (diamond scribe or SHORTIX™ cutter) to attain the desired flow rate. Installation of an inline microfilter immediately before the flow-splitter and an inline nanofilter between the flow-splitter and column minimizes clogs for this configuration.

Mobile Phase Composition

As a rule of thumb, a mobile phase composition of 30% organic and 70% aqueous is recommended for spray optimization; the aqueous and organic modifiers typically contain 0.1% formic acid or 0.5-1% acetic acid. At low organic concentrations, the plume can appear thin and difficult to visualize, even under high magnification. Increased organic concentrations produce a more distinguishable spray when viewed under magnification.

Applied Voltage

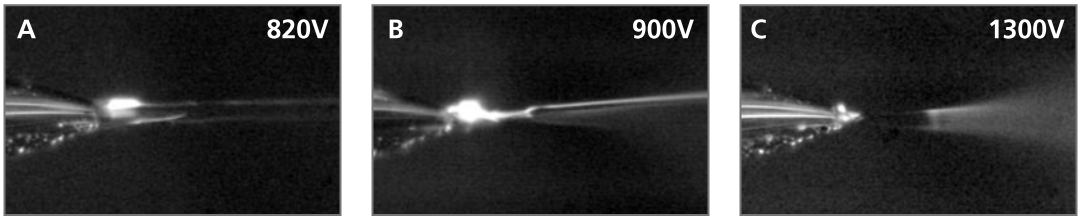
To generate the initial spray, a low starting voltage, such as 0.9kV, is recommended. Because stable sprays often require higher applied voltages, the mobile phase may appear to pulsate or flicker upon exiting the tip. Slowly increasing the applied voltage by 0.1kV increments and noting changes in spray morphology is the most effective technique to attain optimal spray quality.

At very low voltages, a stream of large (ca 5µm) droplets often appears as a thread which oscillates through the center of the plume. This behavior is characteristic of the spindle spray morphology (Figure 4B). As the voltage is slowly increased, the average droplet size decreases to 1µm, and the spindle disappears. The spray then assumes the pulsed cone-jet mode in which a barely visible jet emanates from the emitter tip and forms a trapezoidal plume (Figure 4C). Increasing the voltage to attain the ideal or stable cone-jet morphology produces a clearly distinguishable Taylor Cone and single jet which fans into a round, slightly opaque spray plume (Figure 4D).

When voltage is further increased, the spray can fragment into one or more stable jets which channel the emission into multiple directions. This spray morphology is appropriately named the multi-jet spray mode (Figure 4E). At even higher voltages, the spray assumes a chaotic or ramified jet behavior where the jet undergoes dynamic changes in shape and branching. Multiple spray jets which will form, disappear, and then reappear are not uncommon in this spray mode (Figure 4F).

For increased clarity, photos were collected at 50% organic (MeOH)/1%acetic acid) at 250nL/min.

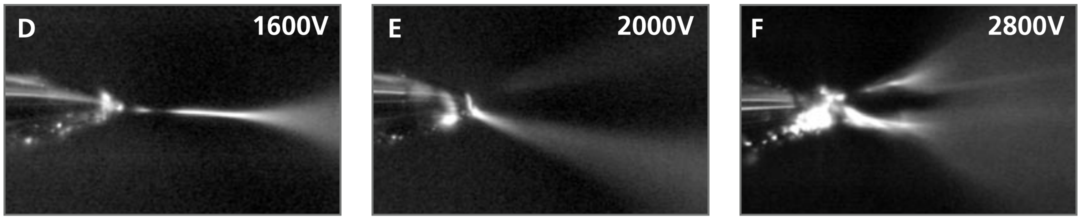
FIGURE 4



Dripping

Spindle
Pulsed spray + large (5 µm) drops

Pulsed Cone-Jet
Pulsed spray + small (1 µm) drops



Stable Cone-Jet

Multijet
Pulsed-chaotic spray

Multi-Jet Ram
Chaotic spray

References

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