

voltage in the conduit **258** or in the reservoir **232** or via an electrode provided on the reservoir surface (not shown) and isolated from the surrounding surface region and the substrate **200**. A potential voltage may also be applied to the silicon substrate via the electrode **256** on the edge of the silicon substrate **200** the magnitude of which is preferably adjustable for optimization of the electrospray characteristics. The fluid flows through the channel **234** and exits from the nozzle **242** in the form of a Taylor cone **270**, liquid jet **272**, and very fine, highly charged fluidic droplets **274**. **FIG. 6A** shows a cross-sectional view of a 2 nozzle electrospray device generating one electrospray plume from each nozzle for one fluid stream. **FIG. 6B** shows a cross-sectional view of a 2 nozzle electrospray device generating 2 electrospray plumes from each nozzle for one fluid stream.

[0141] The nozzle **242**, shown in **FIGS. 6A-B**, provides the physical asperity to promote the formation of a Taylor cone **270** and efficient electrospray **274** of a fluid **268**. The nozzle **242** also forms a continuation of and serves as an exit orifice of the through-substrate channel **234**. The recessed annular region **240** serves to physically isolate the nozzle **242** from the surface. The present invention allows the optimization of the electric field lines emanating from the fluid **268** exiting the nozzle **242**, for example, through independent control of the potential voltage of the fluid **268** and the potential voltage of the substrate **200** of each nozzle.

[0142] **FIGS. 7A-7D** illustrate 1, 2, 3 and 4 electrospray plumes, respectively, generated from one nozzle **242**. **FIGS. 8A-8B** show video capture pictures of a microfabricated electrospray device of the present invention generating one electrospray plume from one nozzle and two electrospray plumes from one nozzle, respectively. **FIG. 9** shows mass spectral results acquired from a microfabricated electrospray device of the present invention generating from 1 to 4 electrospray plumes from a single nozzle. The applied fluid potential voltage relative to the applied substrate potential voltage controls the number of electrospray plumes generated. **FIG. 9A** shows the total ion chromatogram ("TIC") of a solution containing an analyte at a concentration of 5 μM resulting from electrospray of the fluid from a microfabricated electrospray device of the present invention. The substrate voltage for this example is held at zero V while the fluid voltage is varied to control the number of electrospray plumes exiting the nozzle. **FIG. 9B** shows the selected mass chromatogram for the analyte at m/z 315. In this example, Region I has one electrospray plume exiting the nozzle tip with a fluid voltage of 950V. Region II has two electrospray plumes exiting the nozzle tip with a fluid voltage of 1050V. Region III has three electrospray plumes exiting the nozzle tip with a fluid voltage of 1150 V. Region IV has four electrospray plumes exiting the nozzle tip with a fluid voltage of 1250V. Region V has two electrospray plumes exiting the nozzle tip.

[0143] **FIG. 10A** shows the mass spectrum resulting from Region I with one electrospray plume. **FIG. 10B** shows the mass spectrum resulting from Region II with two electrospray plumes. **FIG. 10C** shows the mass spectrum resulting from Region III with three electrospray plumes. **FIG. 10D** shows the mass spectrum resulting from Region IV with four electrospray plumes exiting the nozzle tip. It is clear from the results that this invention can provide an increase in the analyte response measured by a mass spectrometer proportional to the number of electrospray plumes exiting the

nozzle tip. **FIG. 11** charts the ion intensity for m/z 315 for 1, 2, 3 and 4 electrospray plumes exiting the nozzle tip.

[0144] The electric field at the nozzle tip can be simulated using SIMION™ ion optics software. SIMION™ allows for the simulation of electric field lines for a defined array of electrodes. **FIG. 12A** shows a cross-sectional view of two 20 μm diameter nozzles **242** with a nozzle height of 50 μm and separated by 120 μm center-to-center. A fluid **268** flowing through the nozzles **242** and exiting the nozzle tips in the shape of a hemisphere has a potential voltage of 1000V. The substrate **200** has a potential voltage of zero volts. A simulated third electrode (not shown in the **FIG.** due to the scale of the drawing) is located 5 mm from the nozzle side of the substrate and has a potential voltage of zero volts. This third electrode is generally an ion-sampling orifice of an atmospheric pressure ionization mass spectrometer. This simulates the electric field required for the formation of a Taylor cone rather than the electric field required to maintain an electrospray. **FIG. 12A** shows the equipotential lines **278** in 50 V increments. The closer the equipotential lines **278** are spaced the higher the electric field. The simulated electric field at the fluid tips with these dimensions and potential voltages is 8.2×10^7 V/m. **FIG. 12B** shows an expanded region around the nozzles of **FIG. 12A** to show greater detail of the equipotential lines **278**. **FIG. 12C** shows the equipotential lines **278** around the nozzles **242** with a fluid potential voltage of 1000V, substrate voltage of zero V and a third electrode voltage of 800 V. The electric field at the nozzle tip is 8.0×10^7 V/m indicating that the applied voltage of this third electrode has little effect on the electric field at the nozzle tips. **FIG. 12D** shows the electric field lines **278** around the nozzles **242** with a fluid potential voltage of 1000V, substrate voltage of 800 V and a third electrode voltage of 0 V. The electric field at the nozzle tips is reduced significantly to a value of 2.2×10^7 V/m. This indicates that very fine control of the electric field at the nozzle tips is achieved with this invention by independent control of the applied fluid and substrate voltages and is relatively insensitive to other electrodes placed up to 5 mm from the device. This level of control of the electric field at the closely positioned nozzle tips is of significant importance for electrospray of fluids from nozzles co-planar with the surface of a substrate. Accordingly, a nozzle can be provided having a discrete electric field which is not subject to interference from another closely positioned nozzle.

[0145] The fine control of the electric field allows for precise control of the electrospray of fluids from these nozzles. When electrospraying fluids from this invention, this fine control of the electric field allows for a controlled formation of multiple Taylor cones and electrospray plumes from a single nozzle. By simply increasing the fluid voltage while maintaining the substrate voltage at zero V, the number of electrospray plumes emanating from one nozzle can be stepped from one to four as illustrated in **FIGS. 7 and 8**.

[0146] The high electric field at the nozzle tip applies a force to ions contained within the fluid exiting the nozzle. This force pushes positively-charged ions to the fluid surface when a positive voltage is applied to the fluid relative to the substrate potential voltage. Due to the repulsive force of likely-charged ions, the surface area of the Taylor cone generally defines and limits the total number of ions that can reside on the fluidic surface. It is generally believed that, for electrospray, a gas phase ion for an analyte can most easily