

nel 140 to the nozzle 170 where the sample is discharged in continuous stream 430. The fluid is preferably a high-pressure gas, such as air or dry nitrogen gas that is delivered from a source that is in fluid communication with the piston bore. The flow direction of the fluid is generally indicated at 470. In another embodiment, the fluid can be the liquid sample fed into the microfluidic channel 140 to continuously push liquid out through the nozzle.

[0080] It will be appreciated that a protective cover (not shown) can be placed at the distal end 452 of the fluid carrying member 450 to prevent sample from contacting the inner surfaces of the piston bore. The protective cover must be permeable to the fluid that flows through the bore and into the reservoir 160 to transport the sample along the microfluidic channel 140. For example, the protective cover can be in the form of a thin polymeric film that is gas permeable, while at the same time being impermeable to liquid flow. In this manner, the sample can not contact the bore itself. The use of such a protective cover is not required since the injected fluid that flows through the member 450 can push the liquid sample out by applying a force to the air gap between the sample and the surrounding structure.

[0081] A more conventional fluid delivery mechanism can be used with the device 100. In this embodiment, a stopper is inserted into the reservoir 160, with the stopper having a bore formed therethrough which is in communication with the reservoir 160. A capillary is inserted through the bore and the liquid sample is injected into the reservoir through the capillary from a source external to the capillary. In this embodiment, the sample is not stored in the reservoir 160 but rather is delivered to the channel 140 by being injected into the reservoir 160 through the capillary.

[0082] As previously mentioned, the front face of the nozzle array is made electrically conducting by a thin film of metal or conducting polymer. When an electric field of appropriate strength is applied to the nozzle (e.g., as by the arrangement illustrated in FIG. 3), the liquid and the analytes it carries (i.e., the sample) are vaporized as they are discharged through the nozzle opening. Liquids that are suitable for use in electrospray mass spectrometry analysis include but are not limited to acetonitrile, methanol, ammonium acetate, and other volatile liquids. Since the inside diameter of the nozzle is less than about 20 μm , the amount of material flowing out of the nozzle to be vaporized is less than the amount that is typically used in a conventional electrospray operation. Also, the outside of 50 μm creates a strong enough electric field for vaporization with applied voltage below about 6 KV.

[0083] The use of a nebulizing gas to assist in the vaporization process is therefore not needed; however, if nebulizing gas is needed, channels conducting dry nitrogen gas to the nozzle opening may be easily added in a polymer substrate attached to the front of the nozzle array. FIGS. 14-15 are a top plan view and a cross-sectional view, respectively, of a microfluidic nozzle array device 500 in combination with a substrate 510 having gas conduits 520 formed therein for nebulization. The microfluidic nozzle array device 500 can be similar to or identical to any of the exemplary microfluidic array devices disclosed hereinbefore. A gas outlet 522 is formed such that it is concentric with one nozzle 530. The substrate 510 with the nebulizing gas channels can be fabricated by an injection molding

process during the injection molding process that is used to the nozzle array device 500 itself or it can be fabricated first and then later attached to (e.g., bonded) the nozzle array device 500 as a separate component. The substrate 510 can be attached in any number of different ways including but not limited to using an adhesive or meltingly bonding the two members along a boundary zone.

[0084] In some instances, it may not be necessary to have the nozzle array conform to the microtiter plate sample well format. For example, the sample can be fed to the nozzle by the elutant of a high performance liquid phase gas chromatography (HPLC) column. Since the reservoir size in the nozzle array can be formed to arbitrary sizes, it can be formed so that the open end of the reservoir can receive one end of the HPLC column or any plumbing for splitting the HPLC elutant for mass spectrometry analysis. The reservoir side of the nozzle array can also consist of injection molded features for splitting elutant for mass spectrometry analysis. The driving force for the liquid sample analytes to flow through the nozzle opening in this case is the pressure-driven liquid flow of the HPLC. Neither a pressure diaphragm nor an external pressure-inducing mechanism is needed.

[0085] The microfluidic nozzle array devices disclosed herein are also particularly adapted to be used as a nozzle array for optical spectrometry. Since each microfluidic channel in the nozzle array device terminates with a nozzle opening having an inside diameter of 20 μm or less and the substrate of the nozzle array device is formed of a polymeric material which is generally hydrophobic, liquid inside the microfluidic channel does not drip or be discharged out of the nozzle without external force being applied thereto. When light, either ultraviolet or visible, is incident on the reservoir side of the array, the light will come out of the nozzle opening carrying the optical spectroscopic information of the analytes contained within the liquid in the microfluidic channel. The microfluidic channel and the nozzle opening thus provide an optical detection system without the use of optical windows. This is a significant advantage since the microfluidic nozzle array device does not have to be fabricated to incorporate optical windows made of an optical material in its design. This results in reduced structural complexity for the microfluidic nozzle array device and also a reduction in both cost and complexity relative to the fabrication of the microfluidic nozzle array device.

[0086] A 96 microtiter nozzle plate filled with samples can be placed in an ultraviolet reader for a 96 microtiter plate and spectrophotometric information for each sample can be obtained with the reader. A conventional microtiter plate used for UV spectrophotometry must have a sample well bottom made of a special UV transparent material in order to hold the sample inside the well and transmit UV light at the same time or a microtiter plate made of quartz must be used. The use of a microtiter nozzle plate array according to one exemplary embodiment thus allows two detection techniques for the samples in the plate without having to transfer the samples to other additional plates.

[0087] FIG. 16 is a cross-sectional view illustrating how the microfluidic nozzle array device 100 can be used for UV spectrophotometry. FIG. 16 illustrates the microfluidic nozzle array device 100 in partial section showing two