example, it has heretofore been discussed that there are limitations on what size dimensions can be formed when an injection molding process is used to form the microfluidic features. Prior to the present applicant, there was a lack of appreciation and understanding that an injection molding process can be used to form a microfluidic device having microfluidic features with dimensions less than 100 μm. As a result, the use of injection molding as a fabrication process was limited since many microfluidic applications require the microfluidic device to have microfluidic features (e.g., channels) that have dimensions less than 100 μm and more particularly, less than 50 μm.

[0011] It would therefore be desirable to provide microfluidic devices, especially microfluidic array devices incorporating nozzles, that overcome the deficiencies of the traditional microfluidic devices and more particularly, the deficiencies that are related to the techniques for fabricating these devices and also to the use of such devices.

## SUMMARY OF THE INVENTION

[0012] The present application generally relates to microfluidic devices. According to one aspect, a microfluidic device is provided and includes a body having a first surface and an opposing second surface. At least one channel is formed through the body such that the channel extends from the first surface to the opposing second surface with the channel having an open reservoir section formed at the first surface. The microfluidic device further includes at least one nozzle that is disposed along the second surface. The nozzle is in fluid communication with one channel such that each channel terminates in a nozzle opening that is formed as part of the nozzle tip. Unlike traditional microfluidic devices, the exemplary microfluidic device has one or more channels that are open at each end and are formed substantially perpendicular to both the first surface and the second surface where the nozzle is formed.

[0013] According to another aspect, the nozzle is conically shaped with the channel extending therethrough and terminating at the nozzle opening. In one exemplary embodiment, the nozzle opening has a diameter equal to or less than 100 μm, preferably equal to or less than 50 μm and more preferably, equal to or less than 20 μm; and an outside diameter of the nozzle, as measured at a tip portion thereof, is less than about 150 μm and preferably is equal to or less than about 100 μm, and more preferably equal to or less than 50 μm. For electrospray type applications, a conductive region is formed on the nozzle, preferably at a tip portion thereof, to permit a voltage to be applied to the tip portion of the nozzle. As the sample fluid is discharged from the nozzle, the electric field that is created by the conductive region serves to vaporize and ionize the sample and form a fine mist containing the sample. This fine mist can then be injected into an inlet port of an analytical instrument, such as a mass spectrometer, to detect and analyze components of the sample and obtain certain information about the components.

[0014] In another aspect of the present application, the microfluidic nozzle array device is formed by an injection molding process that permits the microfluidic nozzle array device to have the above dimensions. A mold is first fabricated with the mold being a negative impression of the channel architecture and nozzle array that are formed as part of the microfluidic nozzle array device. Preferably, the mold is made of a metal material and with at least some portions of the mold being polished to a high degree of finish, i.e., a mirror finish. More specifically, the polishing of a conical portion of the mold that is used to form the nozzle results in the nozzle having a very smooth outer surface and also facilitates the flow of an injected polymer within this nozzle region, thereby increasing the accuracy and the efficiency of the injection molding process. A suitable polymeric material is injected into the mold and is then cured to form the injection molded microfluidic nozzle array device. After the device has sufficiently cooled, the microfluidic nozzle array device is then removed from the mold.

[0015] The exemplary microfluidic nozzle array devices disclosed herein can be used in a number of different applications. For example, the device is particularly well suited for operations designed for lab-on-a-chip functions including the detection of components in the sample fluid by means of UV, visible light and by means of mass spectrometry. Moreover, it will be appreciated that the microfluidic nozzle array device can be used in a wide range of other applications in which similar conventional microfluidic devices have or could be used. For example, the microfluidic nozzle array device can be used for spotting DNA or protein array on a substrate instead of using the conventional capillary wicking methods that are now used. The microfluidic nozzle array device can also be used for spotting the plate for matrix-assisted laser desorption ionization (MALDI), replacing the pipette and capillary spotting methods. In addition, the microfluidic nozzle array device can be in other spray or spotting type applications where it is desired to produce a fine stream of sample fluid.

[0016] These and other features and advantages of the exemplary embodiments disclosed herein will be readily apparent from the following detailed description taken in conjunction with the accompanying drawings, wherein like reference characters represent like elements.

## BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0017] The foregoing and other features of the exemplary embodiments will be more readily apparent from the following detailed description and drawings of illustrative embodiments that are not necessarily drawn to show exact likeness or necessarily to scale in which:

[0018] **FIG. 1** is a top perspective view of a microfluidic device having an array of nozzles incorporated therein according to a first exemplary embodiment,

[0019] **FIG. 2** is a cross-sectional view taken along the line **2-2** of **FIG. 1**;

[0020] **FIG. 3** is a top plan view of the microfluidic device according to **FIG. 1** illustrating placement of electrodes around the nozzles and the connections between the electrodes and electrical contacts formed at one edge of the microfluidic device;

[0021] **FIG. 4** is a top perspective view of a microfluidic device having an array of nozzles incorporated therein according to a second exemplary embodiment;

[0022] **FIG. 5** is a cross-sectional view of the microfluidic device according to **FIG. 4**;