

[0023] FIG. 6 is a perspective view of an exemplary mold used to manufacture the microfluidic device of FIG. 1;

[0024] FIG. 7 is a cross-sectional view of first and second dies in a closed position that is used to manufacture the microfluidic device of FIG. 4;

[0025] FIG. 8 is a cross-sectional view of first and second dies of the mold illustrating another embodiment where a gap is formed between a pin of the first mold and a nozzle forming feature of the second mold;

[0026] FIG. 9 is a cross-sectional view illustrating a mold arrangement for fabricating a micron sized nozzle opening;

[0027] FIG. 10 is a top plan view of a tile arrangement formed of a number of strips connected to one another with each strip including a nozzle array, wherein one of the strips is removed and placed in close proximity to a mass spectrometer;

[0028] FIG. 11 is a cross-sectional view of one microfluidic channel/nozzle arrangement wherein a sample reservoir is sealed by a member having a polymeric cover sheet which is insertable and movable within the reservoir for discharging the sample through a nozzle opening;

[0029] FIG. 12 is a cross-sectional view of one microfluidic channel/nozzle arrangement wherein a sample reservoir is sealed by a member having an elastic sealing base which is insertable and movable within the reservoir for discharging the sample through a nozzle opening;

[0030] FIG. 13 is a cross-sectional view of one microfluidic channel/nozzle arrangement where a sample reservoir is sealed by a piston device having a bore extending there-through for injecting a fluid into the sample reservoir to cause the sample to be discharged through a nozzle opening;

[0031] FIG. 14 is a top plan view of an exemplary microfluidic nozzle array device;

[0032] FIG. 15 is a cross-sectional view taken along the line 14-14;

[0033] FIG. 16 is a cross-sectional side elevational view illustrating the microfluidic device of FIG. 5 being used in UV spectrophotometry; FIG. 17 is a top plan view of a retaining base for releasably holding a number of microfluidic nozzle subunit structures;

[0034] FIG. 18 is a cross-sectional view taken along the line 18-18 of FIG. 17; and

[0035] FIG. 19 is a top plan view of a retaining base according to another embodiment for releasably holding a number of microfluidic nozzle subunit structures.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0036] Referring first to FIGS. 1-2 in which an exemplary microfluidic device 10 according to one embodiment is illustrated. The microfluidic device 10 has a substrate body 20 that is formed of a polymeric material, as will be described in greater detail hereinafter, and has at least one microfluidic channel 30 that is formed in the substrate body 20. More specifically, the substrate body 20 has a first surface 22 and an opposing second surface 24 with the microfluidic channel 30 being formed between the first and second surfaces 22, 24 such that the microfluidic channel 30

extends the complete thickness of the substrate body 20. The microfluidic channel 30 is thus open at both a first end 32 at the first surface 22 and a second end 34 at the second surface 24. The second end 34 of the microfluidic channel 30 is formed in a protrusion 50 that is formed on the second surface 24 of the substrate body 20. According to one exemplary embodiment, the protrusion 50 has a tapered shape (inward taper) such that it forms a generally conical structure with the open second end 34 preferably being formed at an apex of the conical structure. The tapered protrusion 50 serves as a nozzle that delivers a sample (i.e., a liquid) that is loaded into the microfluidic device 10.

[0037] It will be appreciated that in contrast to traditional microfluidic devices, the microfluidic channel 30 is formed in a perpendicular manner in the substrate body 20 in that the microfluidic channel 30 is preferably formed so that it is substantially perpendicular to the first and second surfaces 22, 24 of the substrate body 20. As illustrated, a predetermined number of microfluidic channels 30 and nozzles 50 can be formed in one substrate body 20. The microfluidic channels 30 can be arranged according to any number of different patterns. For example and as illustrated in the exemplary embodiment of FIGS. 1 and 2, which illustrate a preferred arrangement, a plurality of microfluidic channels/nozzles are arranged in regular arrays having spacing that is identical to or similar to spacing of microtiter plates. For example, if 96 microfluidic channels/nozzles are desired, then the 96 microfluidic channels/nozzles are arranged in an 8x12 grid with spacing of about 9 mm between each microfluidic channel/nozzle structure. For a 384 microtiter array, the microfluidic channels/nozzles are placed in a 16x24 grid with spacing of about 4.5 mm. While not entirely to scale, FIG. 2 generally illustrates a section of a microfluidic channel/nozzle array having spacing of about 4.5 mm.

[0038] According to the present exemplary embodiments, each nozzle 50 is constructed so that its dimensions are measured in microns. The specific configurations of the nozzle 50 and the microfluidic channel 30 are best shown in FIG. 2. As illustrated, the first end 32 of the microfluidic channel 30 is in the form of a reservoir 60 (i.e., an annular cavity) that tapers inwardly to an intermediate channel section 36. The intermediate channel section 36 also has a tapered construction in that it tapers inwardly toward the second end 34 and the nozzle 50 formed at the second surface 24 of the substrate body 20. Thus, the dimensions of the microfluidic channel 30 are greatest at the first end 32, where the reservoir is formed, and are at a minimum at the second end 34 at a tip portion 52 of the nozzle 50. According to one exemplary embodiment, the open second end 34 of the microfluidic channel 30 formed in nozzle 50 has an inside diameter of about 100 μm or less, 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 . The inside diameter of the microfluidic channel 30 opens gradually in a direction away from the nozzle 50 to about several hundred μm as the microfluidic channel 30 traverses through the thickness of the substrate body 20 and eventually the microfluidic channel 30 is formed to a diameter of about 1 mm to define the reservoir at the first end 32. The length of the microfluidic channel 30 can be tailored to a given application depending