

MICROFLUIDIC ARRAY DEVICES AND METHODS OF MANUFACTURE AND USES THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. patent application Ser. No. 60/341,069, filed Dec. 19, 2001, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to microfluidic devices, and more particularly, to microfluidic array devices that can be used to deliver one or more samples through one or more nozzles that are formed as part of the microfluidic array device. Exemplary manufacturing methods for fabrication of the microfluidic array devices are also disclosed as well as exemplary uses for the microfluidic array devices. For example, the microfluidic array device is suitable for operations designed for lab-on-a-chip functions including analysis of components in the sample fluid by means of optical spectrometry, mass spectrometry, etc.

BACKGROUND

[0003] There has been a growing interest in the development and manufacturing of microscale fluid systems for the acquisition of chemical and biochemical information and as a result of this effort, microfluidics is considered an enabling technology for providing low cost, high versatility devices to operations, such as combinatorial chemistry for drug lead discovery and large-scale protein profiling to name a few. Generally, a microfluidic device (which is also often referred to as a lab-on-a-chip device) is a planar device having one or more micron sized channels formed therein and can also include reservoirs, valves, flow switches, etc. The microfluidic features are designed to carry out complex laboratory functions, such as DNA sequencing.

[0004] In the absence of using microfluidic devices, the above processes and others are carried out in a manner that is very time intensive and thus, costly. For example, large-scale protein profiling is commonly carried out laboriously but pervasively in the biotechnological and pharmaceutical industries. One particular application of microfluidic devices is to provide microfluidic channels that represent the means to separate analytes in a mixture using techniques, such as capillary electrophoresis and liquid chromatography.

[0005] Microfluidic devices have traditionally been fabricated from substantially planar substrates with microfabrication techniques that have been borrowed from the electronics industry, such as photolithography, chemical etching, and laser ablation techniques. When constructing the microfluidic devices in this manner, the microfluidic channels that are formed lie parallel to the surface of one planar surface of the substrate, and the channel is sealed by bonding a second planar substrate to the planar substrate containing the channel. The techniques for detecting materials, such as analytes, that are disposed in the microfluidic channels have for the most part been mainly optical techniques. Fluid transport in the microfluidic devices traditionally entails using electroosmotic, electrokinetic and/or pressure-driven motions of liquid and particles as the means for fluidly transporting such materials.

[0006] While the stacking of multiple layers of planar substrates to form a microfluidic structure having layered microfluidic channels is possible in terms of its fabrication, the prevailing detection technology (optically based detection technology) limits the practicality of fabricating such a structure since parallel operation of multiple layers of the planar substrates containing multiple microfluidic separation channels is not practical due to each microfluidic separation channel requiring its own light source and detector.

[0007] One detection technology that is fast becoming the detection technique of choice in the biotechnology and pharmaceutical industries is mass spectrometry (MS). Mass spectrometry provides more chemical information about the material being tested (e.g., analytes) than other single detection techniques. For example, molecular weight and even chemical composition of the analytes from small drug candidate molecules to large protein molecules can be successfully analyzed by mass spectrometry (MS) and its related technique that is referred to as MS-MS. In MS-MS, a molecule is ionized and analyzed for molecular weight in the first stage of the mass spectrometer, and then the same molecular ion, called the "parent", is fragmented inside the mass spectrometer to produce "daughter" ions that are further analyzed to give the chemical composition of the parent molecule.

[0008] While some progress has been made to interface microfluidic devices with a mass spectrometer, there are still several shortcomings that must be overcome in order to make this interfacing process more practical. For example, one technique that has been discussed involves drilling a small hole, large enough to accommodate a glass or quartz capillary, into the end of the microfluidic channel that is formed by glass substrates and a glass or quartz capillary is then inserted into the drilled hole to act as a nozzle for electrospray ionization. This approach is laborious and is impractical for high throughput operations where many such holes have to be drilled sequentially into the substrates.

[0009] In another technique that has been disclosed, a protrusion termed "electropipette" extends from the edge of the substantially planar substrate. The microfluidic channel in this extended region is formed by two planar substrates as in the microfluidic channels that are formed in the rest of the microfluidic device. The outside dimensions of the tip structure include a thickness that is equal to the thickness of the two planar substrates. It has also been disclosed to fabricate an array of nozzles using microfabrication techniques, such as deep ion reactive etching on a silicon wafer. However, the use of silicon wafers as the substrates greatly limits the ability to individually activate each nozzle because of the potential of dielectric breakdown caused by the high voltage applied to the nozzle to create the electrospray conditions, and the volume behind the nozzle made by deep ion reactive etching is extremely difficult to be accessed by conventional means of liquid handling equipment. Integrating this silicon-based nozzle array to microfluidic devices, which are typically made of glass or polymers, is also extremely difficult. The cost of fabricating the nozzles on silicon is also very high.

[0010] While injection molding has been discussed as a process for forming microfluidic devices, there are a number of limitations that have equally been associated with such discussion of injection moldable microfluidic devices. For