

lowermost section of portion **235**. Using this technique, the diameter of the tip section **219** of the pin **216** can be greater than $20\ \mu\text{m}$ since the opening of the nozzle and the outside diameter of the nozzle are no longer defined by the dimensions of the corresponding parts of mold but rather are defined by a combination of mold dimensions, gap dimension and injection pressure. In this manner, the pins **216** do not have to be manufactured to have a tip section **219** on the order of $20\ \mu\text{m}$ in order to form a nozzle opening of the same dimension. Instead, the tip section **219** can have a diameter greater than the diameter of the nozzle opening that is ultimately formed in the nozzle as a result of the injection molding process.

[**0065**] **FIG. 9** illustrates one exemplary method of overshooting the injected resin into the gap **240** formed between the tip section **219** and the tip of the conically shaped lower portion **235**. The nozzle opening **215** is defined by pressure used to inject the molten resin and the dimensions of the gap **240**. By controlling these parameters, the dimensions of the nozzle opening can be controlled.

[**0066**] Injection molding as a manufacturing technology for polymer parts is low-cost at high-volume production. However, there is considerable cost involved in the production of the mold itself, especially for a microfluidic nozzle design which has micron sized features and therefore is a demanding design in terms of producing a mold. If the microfluidic nozzle array device is arranged to have the same pattern as the microtiter plate so that commercial robotic liquid dispensing equipment can be used to fill the reservoirs of the microfluidic channels with samples, then tiling or combining a number of smaller microfluidic nozzle array devices (i.e., subunits) to form a larger structure can be used since the microtiter plates consist of regularly spaced sample input points in a grid pattern. For example, the microfluidic nozzle array devices can be formed and then combined with one another to produce a structure that has the desired number of sample reservoirs (also referred to as sample wells or sample inputs) to receive a desired number of samples. For example, some common microfluidic devices contain 96 sample reservoirs (8×12 grid); 384 sample reservoirs (16×24 grid); and 1536 sample reservoirs (32×48 grid). The tiling can be done by number of known conventional means, including by permanently bonding adjacent tiles together by melt bonding, welding, gluing, etc. In other words, any suitable method or technique for joining polymer structures together can be used. The subunit structures can be formed as individual subunit tiles (see **FIGS. 17-18**) or the subunit structure can be in the form of an elongated strip that includes a number of rows of nozzles. For example, the strip can be formed to include 2 rows of spaced apart nozzles.

[**0067**] Alternatively, the user can be supplied with a base plate that has a number of features formed therein to permit nozzle subunit structures to be inserted into and retained by the base plate. For example, the base plate can contain pre-defined receptacles that receive the nozzle subunit structures in such a way that the nozzle subunit structures are securely held within the base plate and are arranged according to a desired pattern. One or both of the base plate and the nozzle subunit structures can contain interlocking features to provide an interlocking connection between the base plate and the nozzle subunit structures. In this embodiment, the base plate functions as a base on which the final microfluidic

nozzle array device can be constructed by arranging a number of nozzle subunit structures together and then securely holding these subunit structures within the base plate. One exemplary structure for releasably holding the nozzle subunits in an interlocked manner is illustrated in **FIG. 17** and is discussed in greater detail hereinafter in the discussion of Example 3.

[**0068**] There are a number of advantages that are obtained by tiling or otherwise combining a number of nozzle subunit structures into a microfluidic nozzle array device of greater dimension. First, the cost of manufacturing the mold for the smaller nozzle subunit structure is substantially less than the cost of manufacturing a mold for the entire grid of the microfluidic nozzle. Also, the cost of mold replacement is also substantially reduced in the case that only one pin in the mold is damaged. Second, the utility of the nozzle array is made more flexible. If an experiment does not require all of the reservoirs (e.g., 96) of the microfluidic device to be filled, only the needed number of nozzles or a number close thereto can be inserted into the base plate. At the same time, this construction still permits robotic dispensing of samples. For example and according to one exemplary embodiment, one nozzle subunit structure contains 4 reservoirs and therefore, if the experiment only requires 60 reservoirs, then only 15 nozzle subunit structures are inserted into the base plate. In this manner, the potential waste or inefficiency related to each microfluidic device is eliminated or greatly reduced because the number of unused reservoirs is greatly reduced or entirely eliminated.

[**0069**] Third, when the microfluidic nozzle array device is used for electrospray or nanospray in front of a mass spectrometer inlet, a common configuration is to have the nozzle spray "off-axis", i.e., the nozzle sprays in a direction perpendicular to the inlet. Since the nozzle has to be placed in close proximity to the inlet (e.g., typically within an inch), there is often times not enough room in front of the inlet to accommodate the entire microtiter plate. **FIG. 10** illustrates how a tiled microfluidic nozzle array microtiter plate can be used for electrospray in the off-axis configuration. A tiled microfluidic nozzle array **300** arranged in a 96 well microtiter plate format is broken up into strips **302** with two rows of 12 nozzles **310** each. One of the strips **302** is broken away or is otherwise removed from the others and is transferred (as indicated by arrow **320**) to a nozzle mount (not shown) in front of a mass spectrometer inlet **330** of a mass spectrometer **340**. The nozzle mount holds the strip **302** and has at least an x-y translation stage such that each of the nozzles can be placed in an optimal position with respect to the mass spectrometer inlet **330** for spraying of the sample material that is contained within the microfluidic channel associated with the selected nozzle. The direction of the spray is perpendicular to the mass spectrometer inlet **330**. In schematic drawing of **FIG. 10**, the nozzles **310** are positioned below the centerline of the mass spectrometer inlet **330** and the spray is in the direction out of the surface of the drawing figure. It will be appreciated that the strips **302** that are still in tact can be used in future applications either by using the entire structure of joined strips **302** or by detaching one or more strips **302** for use in a given application depending upon the precise application and what the requirements for the application are in terms of the number of nozzles **310** that is needed.