A NOVEL MICRODISPENSER ARRAY FOR ACCURATE OFF-CHIP DISPENSING FOR MICROARRAY APPLICATIONS

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ABSTRACT
In this work we have designed, fabricated and characterized a novel off-chip dispensing scheme using fixed-volume metering dispensers and in-plane nozzle array. The dispenser array can simultaneously dispense four droplets of 50 nL (or 100 nL) with less than 3% variation between successive dispensing cycles. The dispensed volume can be easily programmed by changing the dispenser chip. This is the first array-type dispenser developed on a plastic substrate and can be readily adapted to mass production techniques.

KEYWORDS: Off-chip dispensing, fixed-volume metering, microarray, disposable dispenser chip

INTRODUCTION
The rapid development of microarrays has been one of the prominent success stories of µTAS devices. Microarrays offer a number of significant advantages such as ultra-low sample/reagent consumption, rapid reaction times, and easy detection etc. Typically, most microarrays are generated by using a "spotting head", which could be a contact or non-contact type dispenser arrangement [1]. Contact type dispensers rely on transferring a pre-defined volume based in the pin design and non-contact dispensers will dispense discrete droplets on demand. However, most non-contact dispensers operate in the low µL - nL regime. The dispenser array developed in this work can be operated in across a broad spectrum of volume ranges by scaling the dispenser design. Furthermore, a key advantage of the present design is the low cost of the dispenser array thus making it possible to replace dispenser heads to avoid cross-contamination.

MICRODISPENSER ARRAY
We have previously reported the development of a fixed-volume metering microdispenser module for dispensing exact volumes of liquid [2]. The fixed-volume metering microdispenser shows excellent accuracy and precision characteristics. In this work we have coupled an optimized in-plane nozzle array to the dispenser to achieve off-chip dispensing. Figure 1(a) shows a schematic sketch of the microdispenser array and Figures 1(b)-(e) show the sequence of operation for one of the dispensers in the array. The dispensed volume is set by the volume defined by the reservoir.
Figure 1. Fixed volume metering microdispenser array for off chip dispensing: (a) schematic sketch and (b)-(d) operation sequence.

Initially, the liquid fills up the reservoirs where it is locked in by a passive valve. Then a low pressure (~0.2 psi) pulse of air is applied via the air-inlet, which splits the liquid column just before the reservoir and slowly dispenses a precise volume of liquid. The liquid is dispensed into a holding channel that is coupled to in-plane nozzle geometry. Then a high pressure pulse (~10 psi) is applied at the air-inlet. This accelerates the dispensed plug towards the nozzle. The nozzle geometry further increases the flow velocity and the liquid is ejected from the chip.

Figure 2 shows a schematic sketch of dynamic pressure actuation applied at the air-inlet. The initial low pressure is required to ensure that there is no fluidic residue within the dispensing reservoir. Since, the dynamic contact angle is a function of flow velocity, the eject velocity is determined as the minimum velocity required to eject the fluid without creating significant fluidic residues.

MICROFLUIDIC SIMULATION

The dispenser geometry with the coupled in-plane nozzles was simulated to determine the optimum shape of the nozzle and the minimum eject velocity to achieve perfect dispensing action. All the simulations were conducted using the CFD ACEUTM module from CFD Research Corporation. The simulation results are shown in Figure 3. As
Figure 3(a) clearly shows, without a nozzle structure the dispensed liquid will not be ejected off-chip but will stick to the sidewalls of the chip. For low-speed ejections with a nozzle structure, the dispensed liquid stream is not clearly defined and poor positional control is achieved. The simulation results predict that for a 50 µm (width) x 100 µm (height) nozzle, an eject velocity of > 80 µL/min will achieve good dispensing action as shown in Figure 3(c).

**FABRICATION**

The dispenser array is defined on a COC (cyclic olefin copolymer) substrate by injection molding techniques. The plastic wafer is diced at the nozzle array line. The structure is sealed with a blank COC wafer. Figure 4 shows SEM microphotographs of the injection molded device and the bonded nozzle array.

**RESULTS**

The assembled dispenser array chip was connected to two pressure sources via active valves. The timing sequence for the valves was generated by a LabVIEW control system. One of the pressure sources was used to generate the desired initial low pressure for slow ejection to the holding channel as shown in Figure 5(b) and 5(c). Following, the controlled dispensing to the holding channel, a high pressure pulse was applied to eject the liquid off chip as shown in Figure 5(d). Figure 5(e) shows a magnified view of the dispensed droplets. We are currently optimizing the dispenser design and pressure system control characteristics to avoid the satellite droplets as seen in Figure 5(e). The formation of satellite droplets was not consistent and the characterization results for the dispenser were obtained from the cases where no satellite droplet formation occurred. The dispenser array was used to dispense discrete volumes of liquid on another blank COC substrate. Since COC is a naturally hydrophobic material with contact angle ~ 90°, volume of the dispensed droplet can be
calculated by measuring the diameter of the droplet. Figure 6 explains the measurement concept and also shows the measurement results for individual dispensers in the array.

As the results of Figure 7 clearly show, the two developed dispenser arrays of 50 nL and 100 nL respectively, have very good repeatability characteristics. The variation within dispensed volumes is less than 3% for both volumes.

CONCLUSION

The dispenser array developed in this work presents distinct advantages such as (a) high accuracy, (b) scalable volumes, (c) easy actuation and control scheme, (d) mass producible, and (e) low cost. Furthermore, we have demonstrated simultaneous dispensing of four liquid droplets in an array. The dispenser array can successfully provide a high accuracy, low cost dispensing solution for microarray applications.

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Reference: