

# Direct-Write CMOS-Based Laboratory-On-Chip

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## ABSTRACT

In this paper, we presented a novel microfluidic packaging procedure based on direct-write fabrication process. Microfluidic structures as microchannels and fluidic connections are implemented onto electrically packaged microelectronic system (e.g. wire-bonding, flip-chip) for potential Laboratory-On-Chip applications. The experimental procedure is described and detailed results of this procedure along with the scanning electron microscopic in-channel inspection are demonstrated in the following sections.

**Keywords:** CMOS, Sensor, Direct-Write, LOC, Packaging, Microfluidics.

## 1 INTRODUCTION

LOC results in the miniaturization of analytical procedures and has many advantages for diagnosis of disease (e.g. genetic diagnosis, glucose detection, etc.), environmental monitoring (e.g. the detection of bacteria in water or food), food industries (e.g. the detection of bacteria in food) and chemical analysis ( $\mu$ TAS). To realize an automotive and functional LOC system, the integration of microfluidics and microelectronics is a challenging issue. To date, only a few hybrid systems have been presented including microfluidics and standard microelectronics. A polymer surface micromachining to fabricate the microfluidic channels on a previously processed CMOS integrated circuit was reported for bio-analysis application [1]. Also, a polymer-based microfluidic structure fabricated through hot embossing was demonstrated for cell manipulation and detection [2].

The integration technique presented in this paper is based on direct-write fabrication process (DWFP) [3-7]. In the next section, we describe our novel packaging procedure. Then in section III we demonstrate the experimental results followed by a conclusion.

## 2 NOVEL FLUIDIC PACKAGING PROCEDURE

To fabricate and integrate microchannel onto microelectronic chip along with connection of fluidic fittings, six steps are considered as the fluidic packaging

procedure. Figure 1 shows a typical electrical packaged chip where bonding wires electrically connect microchip die to the package.

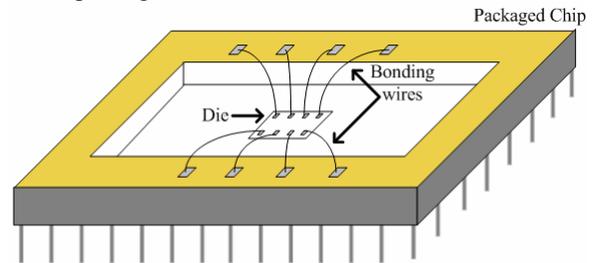


Figure 1: Illustration of a typical packaged chip.

(a) As shown in figure 2a, before the ink deposition, to avoid the damage on the ink filament due to existence of sharp bonding wires, just a few drops of epoxy resin are required to cover the wires whereas not to cover the die. For this, a semi-cured epoxy resin is purred from different sites of package gently.

(b) The trajectory of ink deposition is approximated based on packaged dimensions and the profile of already deposited epoxy. This information is programmed in the microrobot, thereafter, the ink filament deposited on the chip, as shown in figure 2b.

(c) As shown in figure 3a, the fittings are installed close to microchannel using micromanipulator or manually.

(d) To make a fluidic connection between fitting and the channel, it is needed to extrude ink from the fitting to fill the space between them (see figure 3b).

(e) Epoxy resin is coated on the chip to cover die, ink filament and fittings, as shown in figure 3c.

(f) Ink removal in the moderate temperature is the final step of this procedure (Figure 3d). Obviously, this low temperature ( $\sim 75^{\circ}\text{C}$ ) process doesn't damage underneath microelectronic circuitry.

## 3 EXPERIMENTAL RESULTS

In this section, the fabrication results on microelectronic chip are shown along with SEM images of microchannel.

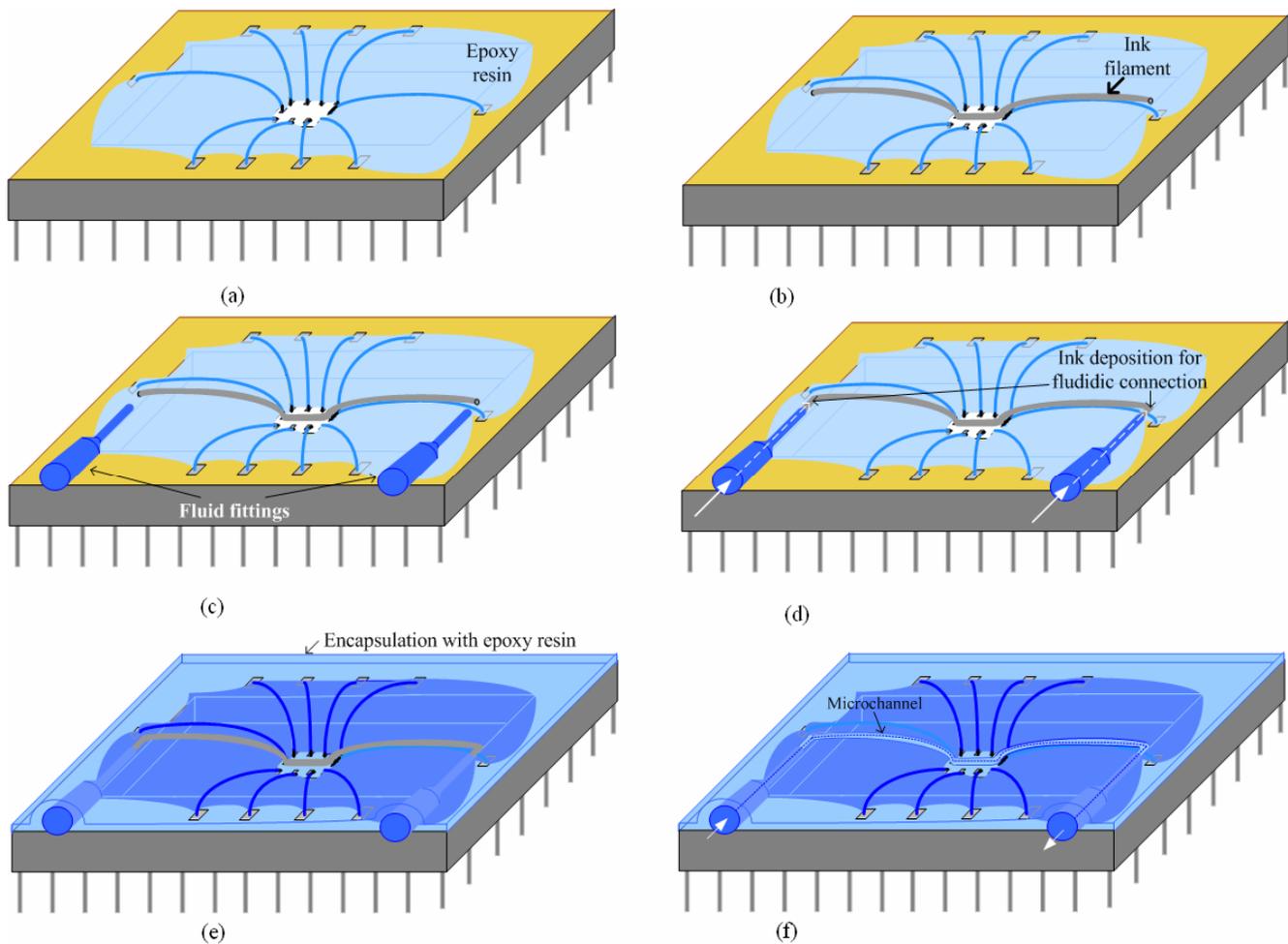


Figure 2: Fluidic packaging procedure from step (a) to (f). (a) first epoxy resin deposition, (b) ink deposition, (c) fitting installation, (d) ink deposition for fluidic connection, (e) second epoxy resin deposition, (f) ink removal.

**On-chip fabrication results-** Figure 3 shows a view of microchip after the first step of procedure. It is clear that the epoxy resin is not covered the die on the chip. Also, ink deposited on the die is shown in figure 4. Optical and ultra-violet microscopic images of packaged chip are shown in figures 5a and 5b.

**In-channel inspection-** The main objective of this experience is the observation of inner wall of microchannel. The SEM images of this section are provided after a preparation procedure. To observe the channel, a piece of microchannel was removed using micro-grinding, polishing or sawing techniques.

Focused Ion Beam technique is used as a high precision grinding technique in our experiments. Thereafter, a thin layer of AuPb alloy sputtered on the already grinded specimen. The same preparation procedure was followed to observe the cross section of microchannel.

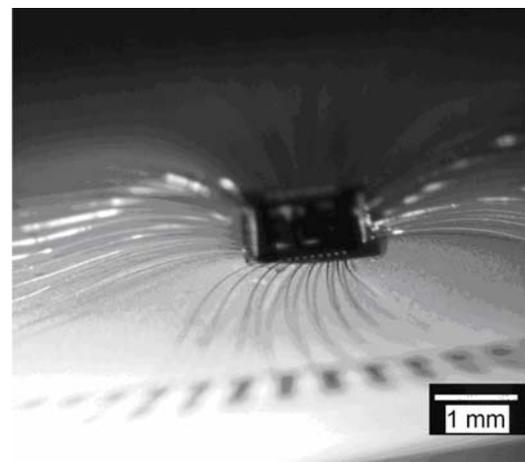


Figure 3: Optical microscope image of microelectronic chip covered by epoxy resin everywhere except the centralized die.

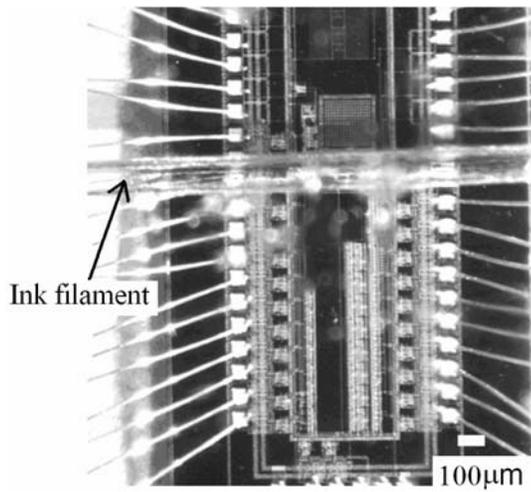
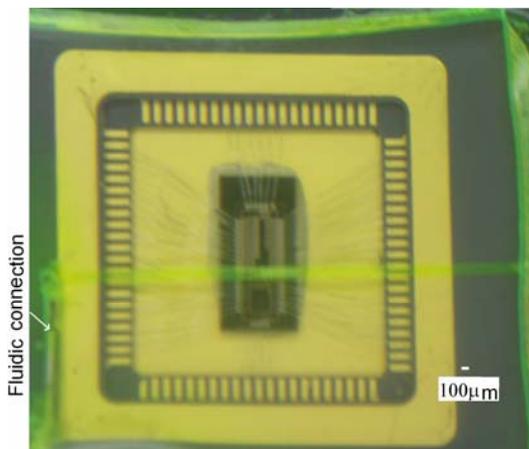
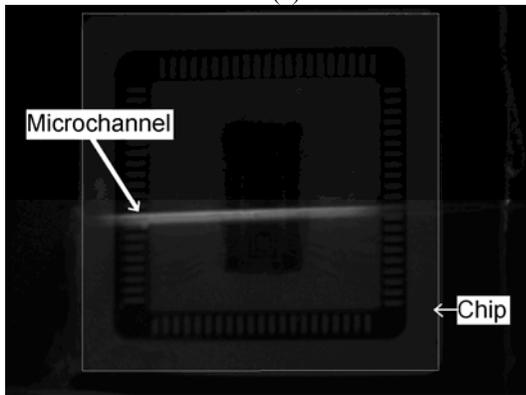


Figure 4: Optical microscope image of an ink filament on the microchip die.



(a)



(b)

Figure 5: Top view of microchannel filled with fluorescence dye on microelectronic chip: (a) optical microscope image, (b) ultra-violet microscope

Also, a semi-circular cross section of microchannel is shown in figure 6. Also figure 7a is zoomed in on the

microchannel and figure 7b is focused inside the channel. Sub-micrometer resolution is clearly observed in figure 7b.

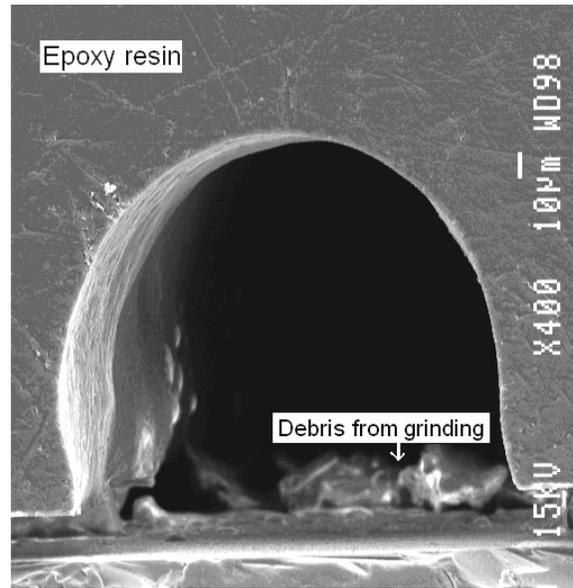
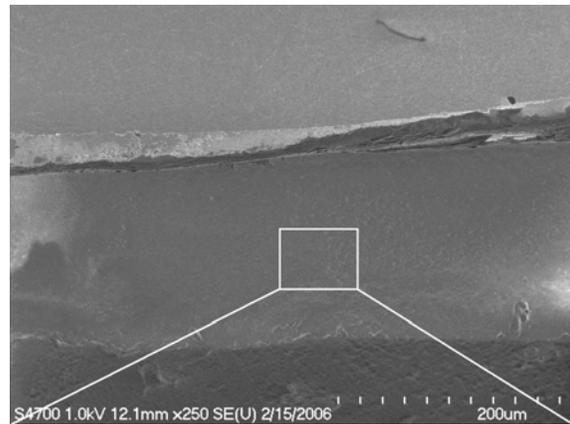
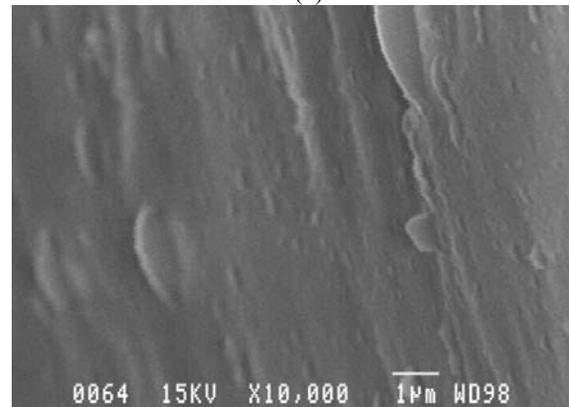


Figure 6: SEM image of a cross section of microchannel.



(a)



(b)

Figure 7: SEM images: (a) upper corner of sample, (b) top view of microchannel, (c) inner surface.

## 4 CONCLUSION

This fluidic packaging procedure is low cost, simple and compatible with standard electrical packaging procedure. This fluidic packaging introduces many new applications to circuit and system field: microelectronic design and fabrication for microfluidics and life science without any laborious post-processing procedures. Also, based on sub-micron resolution uniformity observed in microchannel, the fabrication results of this polymer-based procedure are in good agreement with the required specifications for the cell-based LOC applications.

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