Wafer-Level Fabrication of Microfluidic Sensors for Impedance Spectroscopy with Integrated Opposing Electrodes

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Summary We present the fabrication of **microfluidic sensors with opposing electrodes for impedance spectroscopy**. The sensors are fabricated by **sandwiching TMMF dry photopolymer between two substrates**, each with one electrode patterned on its fluid-contacting side. In this configuration, **TMMF becomes a permanent part of the microfluidic device and has a twofold purpose: it defines the microfluidic network, *and* it is used as a patterned adhesive for low-temperature full-wafer silicon to glass bonding.** According to the requirements of single cell dispensing, the opposing electrodes are placed between a hydrodynamic flow focusing for aligning the cells in a single file and a dispensing nozzle for printing the detected cells.

Introduction Impedance-based microfluidic sensors measure the dielectric properties of particles flowing in a channel with integrated electrodes. Usually, there are two electrode configurations, i.e. coplanar electrodes *and* opposing electrodes (Fig. 1). It has been shown that the coplanar configuration generates a non-uniform electric field, thus leading to a significant variation in signal strength for identical particles. In contrast, the opposing electrode configuration provides a homogenous electric field and enables a better detection and discrimination of the particles [1]. However, fabricating opposing electrodes is challenging due to the difficulty of patterning electrodes inside microchannels. To address this shortcoming, we apply TMMF dry photopolymer [2]. This material offers a combination of properties such as non-cytotoxicity, capability of tenting over deep trenches as well as high thickness uniformity which make it attractive for numerous BioMEMS applications.

Fabrication The fabrication process is depicted in Fig. 2: A Pt layer was sputtered onto the silicon and glass wafers and patterned by lift-off to form the electrodes. TMMF was applied onto the glass substrate via hot roll lamination (60 °C, 1 m/min, 0.1 MPa). I-line exposure (150 mJ/cm^2) and hotplate PEB (2 min, 70 °C) were applied to initiate a cross-linking of the photopolymer, followed by immersion in PGMEA to remove the unexposed areas and form the microfluidic network. Inlet/outlet access holes were etched in the glass wafer using 50 % HF solution. The opposing electrode configuration was formed by silicon to glass bonding applying a pressure and temperature of 60 N/cm^2 and 90 °C respectively. The dispensing nozzle was opened by through dicing of the glass/TMMF/silicon stack.

Results Fig. 3 shows the electrodes and the patterned dry photopolymer on the glass wafer prior bonding. At that time, the TMMF was not completely cured in order to be able to operate as an adhesive for the bonding process. Fig. 4 shows a single chip. A detailed view of the electrodes facing each other on the opposite sides of a microchannel as well as a cross-section of the dispensing nozzle is shown in Fig. 5 and Fig. 6 respectively. Leaktightness of the assembly was proved by filling the microchannels with water.

Conclusion We have demonstrated the fabrication of opposing electrodes inside microchannels using a low-temperature full-wafer bonding process. The method is of high importance for the accurate operation of impedance-based microfluidic sensors enabling the detection, characterization and sorting of microparticles.

References

[1] Sun et al., IET Nanobiotechnol., 2007, 1, (5), pp. 69–79
[2] http://www.tok.co.jp/en/products/mcb/permanent_prst.html, accessed in April 2011

Word Count: 500

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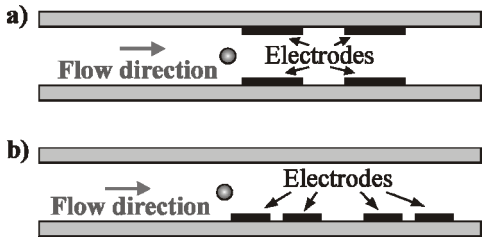

Fig. 1: Schematic of opposing electrode configuration **(a)** and coplanar electrode configuration **(b)**

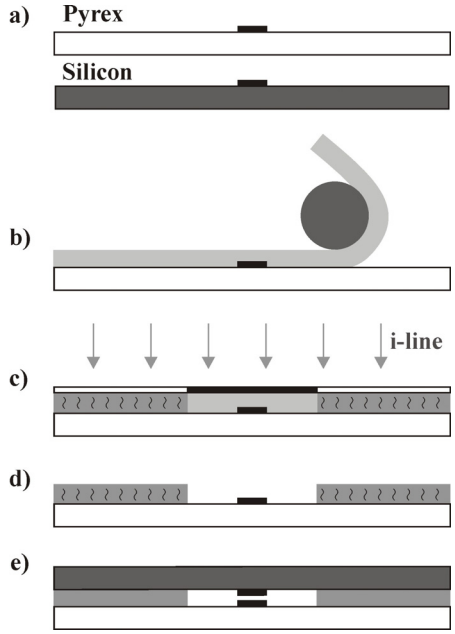

Fig. 2: Fabrication process: (a) Electrode patterning, (b) TMMF lamination, (c) I-line exposure and (d) Development, (e) Glass to silicon bonding

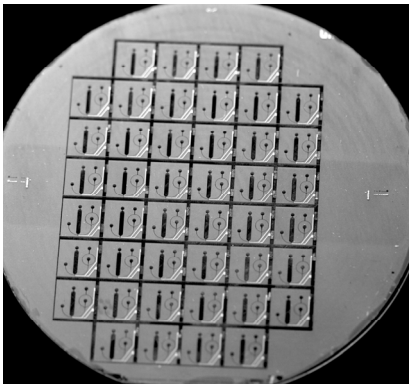

Fig. 3: The glass/TMMF stack prior bonding

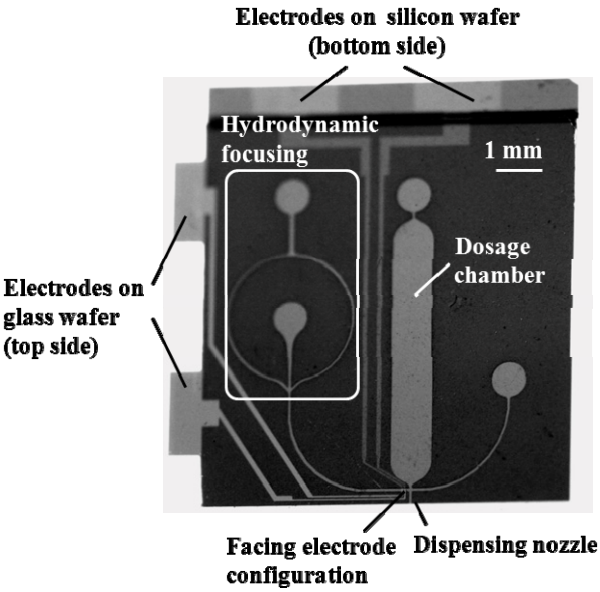

Fig. 4: Microfluidic sensor with opposing electrodes

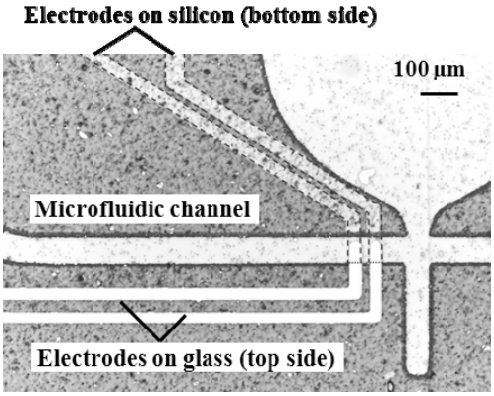

Fig. 5: Detailed view of the measuring cell

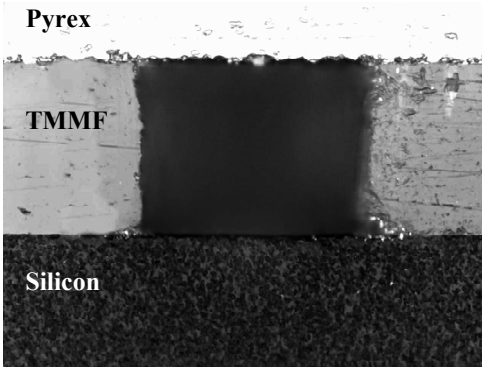

Fig. 6: Cross section of the dispensing nozzle