The Bonding Technology for Microchannels with Electrode Patterns on the Glass Substrates

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ABSTRACT

This paper presents a simple method to fabricate microchannels with embedded electrodes on glass chips. This technique can be used for the rapid design of microsensors as well as for electric fields applied by electrodes in microfluidics.

Current surface treatment for glass fusion bonding was adjusted to obtain as planar surface as possible. The hydrofluoric acid (HF) smooth pre-treatment process reduces the surface roughness up to 38% compared to that without HF wet cleaning process.

The average resistance drops by about 26% after bonded, whereas the bonding process raises the stability of the resistance by around 32% standard deviation individually. These results provide a foundation for the design of more complex electrodes arrange on the glass-based substrates.

Keywords: electrode, microfluidic, wet etching, fusion bonding, surface roughness

1 INTRODUCTION

Wafer bonding technology, as one of the key fabrication processes, plays a critical role in the BioMEMS device realization. To enhance the bonding strength, several methods of surface preparation were compared for glass ceramics.[1] A process was developed to smooth the walls of the drilled holes with different concentration of hydrofluoric acid (HF).[2] Various UV-curable glues[3,4] were developed for bonging glass at room temperature. The disadvantage is the relatively low upper use temperature of the cured material, typically 150℃, which limits the material to special sealing applications only. Fusion bonding provided an efficient sealing of glass chips can be accomplished. Surface smoothness and microfluidic channels obtained after etching are more relevant factors for the glass bonding procedures. Surface quality could be obtained by modifying the composition of the etch fluid and by executing a series of complicated cleaning steps.[5,6] These cleaning procedures were not suitable for the electrode layer on the glass substrate because of the metals would be released during the surface finishing process. Moreover, detailed investigates on glass to glass fusion bonding with inserted electrode layout are very spare in the literature.

In this study, methods of surface preparation by polishing and chemical etching were evaluated with spectrophotometer and surface profiler. The resistances of each device were compared before and after the fusion bonding process. In this work, fusion bonding technology with metal thin film sputtered on glass substrates was performed. A novel fabrication process for the glass fusion bonding has proposed and the significant improvement of the resistance could be achieved.

2 PROCESS AND METHODS

2.1 Surface treatment

The 0.6mm-thick glass wafers, Corning Pyrex 7740, were used as substrate for etching the channels. The glass surface smoothen processes, which were polished, or etched with diluted HF were compared. It is essential to clean the glass surfaces before bonding. The traditional polish process, chemical-mechanical polishing (CMP), is used to planarize glass. A common problem associated with the CMP processes used in damascene sequences is the generation of microscratches. These scratches and residual slurry particles become defects that were filled in microstructure during CMP processing. In the experiments, some microstructures fractured on the glass surface after the standard CMP technique executed as shown in Fig. 1.

To avoid the defects, we flatten the etched microchannels with a fresh solution of HF:H_2O (1:1.5) at 20℃ for 3 seconds before fusion bonding. The method of fabrication microchannels on a glass

substrate with an embedded electrode is summarized in Fig. 2. The assembled chip could be divided into two parts, namely the microchannels substrate and the electrodes substrate.

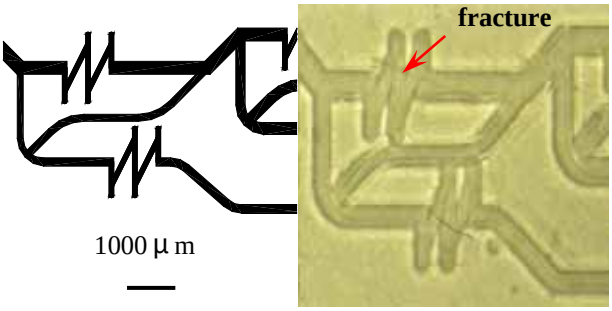

Figure 1 Some damaged microstructures caused by CMP and the fractures clog the channels after bonding.

2.2 Fabrication

The glass substrates were first carefully cleaned in the solution (H_2SO_4+H_2O_2) at 120℃ for 15 minutes. For the microchannels fabrication procedures, a thin Cr/Au (200Å/2000Å) metal film was deposited by sputtering onto both sides of the substrates. These metallization layers were patterned and used as a hard mask for glass etching process. After that, dipped the substrates into the solution of HF:H_2O (1:1.5) at 20℃ with time controlled. The microchambers (20 μm to 75 μm in depths) were created. As a final step, all of the remaining films on glass surface were removed using appropriate removers individually. The holes of 1mm in diameter were formed by laser drilling.

The electrode pattern of the other substrate was performed by a lift-off process. In the lift-off process, a sacrificial material such as photoresist was first deposited and patterned on the substrate. The electrode layer of Titanium/Platinum (500Å/2000Å) was then deposited on top and the sacrificial material was subsequently removed through exposure to solvent soaking and spraying, leaving behind only the material deposited directly on the substrate.

Before bonding, thoroughly clean the non-metallic substrate with HF diluted solution for 3 seconds and clean the metallic substrate with isopropyl alcohol (IPA) solution for 3 minutes. All of the clean steps followed by a rinse in DI water. After the surface-preparation process has been completed, the diced chip was thermally bonded to the resistance temperature detectors (RTD) sensor and heater chip used a programmable furnace at 680℃ for 8 hours.

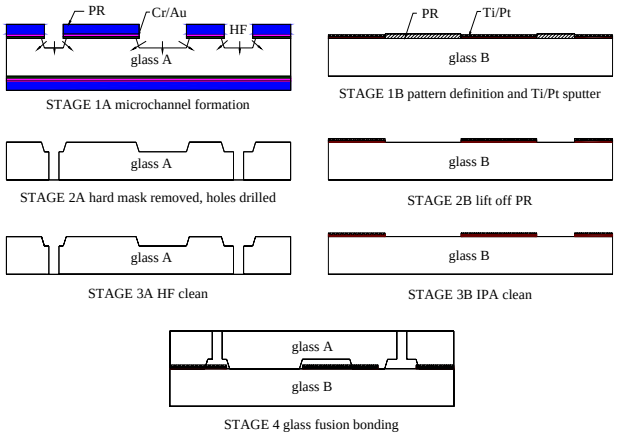

Figure 2 The principal schematic fabrication flow for the microchannels with electrode layer by glass fusion bonding.

2.3 Measurement

Transmission electron microscopy (TEM) images were obtained with a Philips/FEI Tecnai 20 G2 S-Twin transmission electron microscope. Spectra were collected at magnifications of 100000 at 5 kV. These images were captured by a CCD camera with a Diffpack program. Surface roughness measurement was measured with an Alpha-Step 500 surface profiler (Tencor, USA). The morphology of fusion bonding was observed by scanning electron microscope (SEM), Hitachi S-3500H, to examine the cross-section of boned and diced chip. The resistance of heater and sensor was characterized by an electric meter.

3 RESULTS AND DISCUSSIONS

3.1 Surface observation

To present the influence of the surface treatment, glass with and without diluted HF etched were examined to investigate the effect of the cleaning processes. Spectrophotometer images and surface roughness were compared for quantification of the surface microtopography with and without etching chemical treatment. Fig. 3 has shown that glass treat with diluted HF solution provided a smoother surface than the raw one.

For the TEM images, the small white dots with HF treatment appear less than that without HF treatment. This demonstrates that the surface can potentially be increased as smooth as possible after diluted HF cleaning for a while.

We also measure the surface roughness by using a surface profiler to check the planarity. From the results shown in Table 1, it is evident that the wet-smoothing process substantially modified the surface. The wet-smoothing process can be used to reduce the surface roughness to the range of 9Å in average. It appears that the surface roughness by diluted HF wet cleaning is better than that by without chemical treatment. The diluted HF solution can be used to create a smooth surface that the etchant does not further roughen or contaminate the surface.

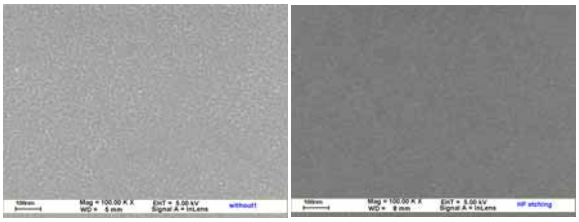

Figure 3 Spectrophotometer images on the glass surface. Left: surface without HF treatment, right: surface smoothing with diluted HF for 3 seconds.

site	Before wet etching (Ra: nm)	After wet etching (Ra: nm)
01	1.23	0.69
02	1.42	0.81
03	1.68	1.18

Table 1 The surface roughness measurement before and after HF smoothing treatment.

3.2 Bonding technology

Two types of glass substrates were tested, one was glass to glass bonding and the other was glass to metal films bonding. For the fusion bonding, the control parameters were temperature, time and applied force. Graphite polished blocks at 100mm × 100mm × 15mm were placed on the top the glass substrates. To prevent the graphite from oxidizing to CO_2, it was necessary to carry out the fusion process in an internal gas (N_2) environment.

Bonding was performed after a pre-seal moisture removal at 150℃. Finally the two glass substrates were joined by means of the fusion bonding technique at 680°C in a programmable oven for 8 hours. The temperature increase rate was controlled at 5°C/min and cooling rate was at 1°C/min.

The results were compared with microscope and SEM. As can be seen in Fig.4(A) and Fig.4(C), the interface between the substrates was clean and no Newton ring was found. A strong interfacial bonding was obtained as shown in Fig.4(B) and Fig.4(D). From these SEM images, it can be seen that the interfaces of the two glass substrates were not observable. Fig. 4 show the excellent glass fusion bonding result can be achieved no matter the electrodes (Ti/Pt) on the glass surface or not.

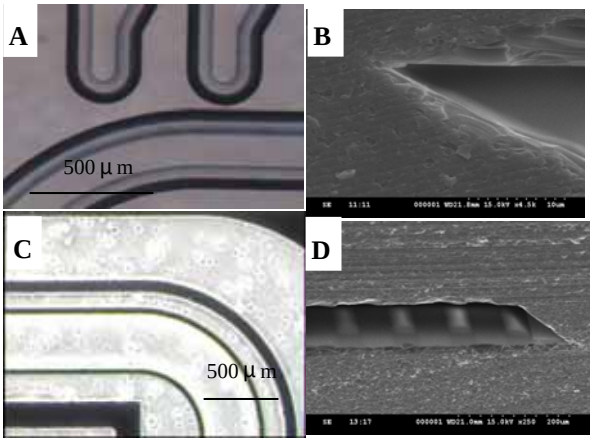

Figure 4 Micrographs of assembled chips. (A) Optical photo of glass to glass fusion bonding, (B) SEM image of a glass channel, (C) Optical photo of glass to Ti/Pt electrodes fusion bonding. (D) SEM image of a sealed channel with electrodes.

3.3 Resistance variation

In order to investigate the resistance variation of the electrodes, a fully integrated glass chip including 4 microfabricated heaters, 4 temperature sensors and one microchambers were constructed as shown in Fig. 5. The chip size of the electrodes substrate, including the bonding pads, is about 30mm ×30mm. The chip size of the etched microstructure is about 25mm × 25mm. The resistance could be measured directly from the connecting pads. The electrical performance after bonded was obtained and compared with before bond.

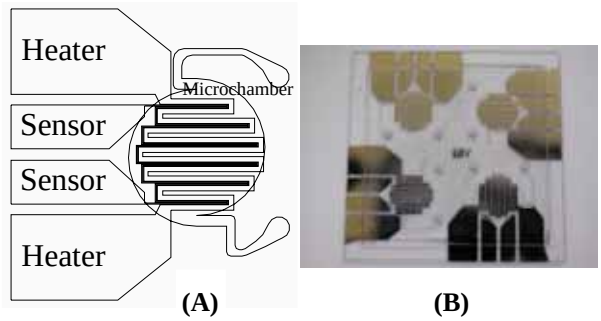

Figure 5 (A) The layout of Ti/Pt pattern for heater and sensor. (B) Photo of the entire assembled chip.

All of the electrodes patterns keep well observed after bonding. The resistances can be individually measured before and after glass fusion bonding. The average resistances of the electrodes including of heater and RTD sensor drop by about 27.8% and 24.3% after chip bonded as shown in Fig. 6 and Fig. 7 individually. However, the standard deviation of heater and sensor drop by 29.6% and 33.6% respectively. The bonding result produces a much smaller standard deviation, which means that the experiment can provide a much better stability of the resistances.

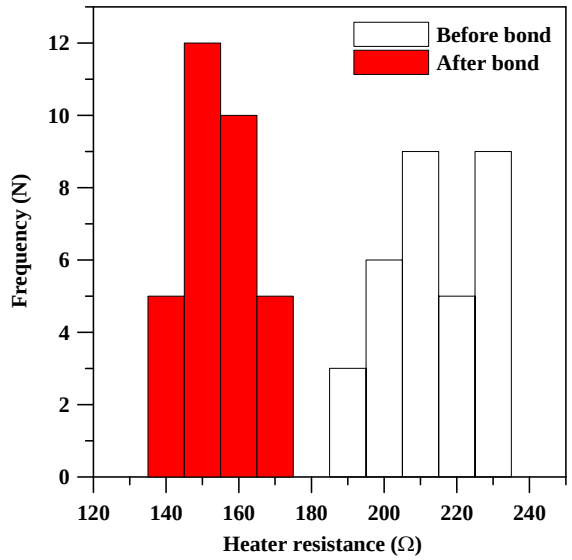

Figure 6 The resistance of heater on the glass substrate compared before bonding and after bonding process.

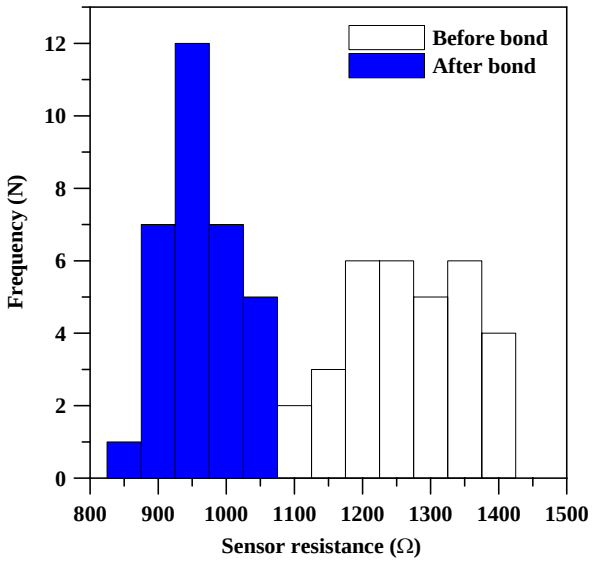

Figure 7 The resistance of sensor on the glass substrate compared before bonding and after bonding process.

4 CONCLUSIONS

A significant improvement of the microchannel with electrode patterns on glass substrates has been demonstrated successfully. We have proved that a post-etched cleaning process can be used to strip the polishing-induced surface layer and improve the surface roughness up to 38% in average.

An integrated biochip including microfabricated heaters, temperature sensors, and microchambers has been constructed. The bonding technology including surface preparation before bonded and resistance variation after bonded were investigated. We believe this technique for glass fusion bonding with electrodes could be very useful for the BioMEMS applications.

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