An Approach for Fabrication of Polymer-based Bio-analytical Microfluidic Devices

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ABSTRACT

This research performed on the fabrication of thermal bonding of polymer microfluidic devices. Hot embossing process and thermal bonding were both achieved. Fine replication by micro hot embossing using polycarbonate substrate has been modified. Nanoscan machine using optical technique can be used to analyze the fabricated microstructures. Hot embossing results show that the near perfect replication of microstructure has been demonstrated, and the shrink degree of the geometry is less than 3%. The two stage process of thermal bonding was performed. The advantage of this method is to prevent the channel filled with the cover plate. The bond strength of the interface for the micro channel is greater than 17MPa using pull test method. The best results were able to seal the microstructure and drilled hole properly and allow for fluids to flow through channel from one reservoir to another one.

Keywords: polymer chip, micro mold, thermal bonding

1 INTRODUCTION

Microfabricated devices have been used in many areas of chemical and biological science. Various materials were and are used for fabrication of micro bio-analytical devices.[1-2] Common substrates are silicon, glass and quartz fabricated using conventional photolithography techniques. The most issues are the material and process costs and the long time to produce devices. Polymer is well suited as a substrate for bio-application devices due to its high dielectric constant, bio-compatible, low cost and ease of micro fabrication. Coupled with the hydrophobic nature and clear optical properties make it promising material for bio-analytical micro devices. The primary goal is the successful fabrication of micro channels for biochip commonly used in genomics and proteomics. A possible solution is polymer hot embossing and thermal bonding. [3]

Hot embossing is the technique used to fabricate high precision and quality plastics microstructures. Injection molding is normally achieved to make plastics components in industrial production. [4-6] A laboratory hot embossing process which used silicon mold made by MEMS technology has been developed when the polymer-based prototype chip of having bio-analytical function was researched.

The bonding technique for 3D microstructures has been described previously. General bonding technology can be divided into major branches, direct bonding and intermediate layer bonding. [7] For the bonding of polymer chip, there are some methods such as adhesive layer bonding and fusion bonding. Usually fusion bonding technology affects the bonded component yield. Even though adhesive layer bonding, it has the same problem to fill micro channels with intermediate layer. To prevent the problem above, the photo-definable material could be used. Because there are dissimilar materials in microchannels, the physical and chemical properties are a little different from similar materials in microchannels. In this work, fusion bonding for similar materials was performed.

The research is to develop a procedure for hot embossing of the microfluidic devices on PC substrate, and a method for thermal bonding to seal an embossed polymer substrate with a hole-drilled polymer plate.

2 MATERIALS AND METHODS

The masters were produced by three methods including wet anisotropic etching of Si, deep silicon RIE, and nickel electroplated through a photoresist mold. In this work, the micro channels for biochips were fabricated using a 60mm×50mm master, as shown in Fig. 1, which was fabricated from anisotropically KOH wet etched silicon. The master is bonded to a stainless steel support plate. In the embossing system, both master and polymer under vacuum are heated to a temperature above the glass transition point. Then the master is brought into contact with polymer substrate with the constant force applied and held for a certain time. Finally the master and the substrate are cooled down to the temperature less than the glass transition point, and then separated.[8]

Hot embossing condition, such as force, temperature, processing time and procedure, affects the polymer flow behavior and should be discussed. [9] A 500 μm thick polycarbonate (PC) is chosen as the raw substrate material in micro hot embossing. Differential scanning calorimeter is performed to investigate the glass transition temperature (Tg) of PC. The glass transition temperature of PC is around 140-160℃, above which PC exhibits higher fluidity. [10] The glass transition temperature of PC is higher than some polymers, such as PMMA or PS, it is suitable to apply for high temperature cycling requirement. When the temperature is above 160℃, loading force above 2000

Newton (N) and processing time including 120sec and 240sec can be selected as the embossing condition.

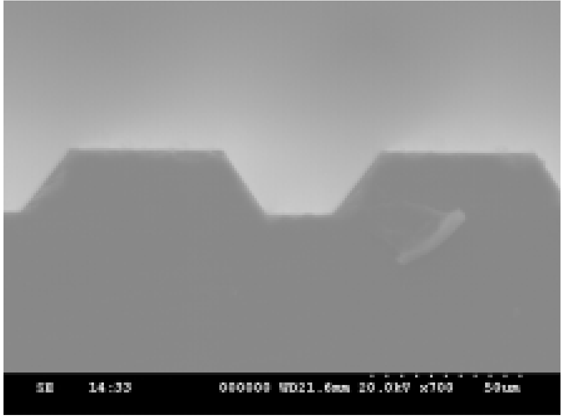

Figure 1: An example of silicon master with micro channels.

Different from other researchers, it's that thermal bonding was performed using two-stage process. The main reason to perform two-stage process is to prevent from micro channels filled due to higher temperature or to seal not properly due to lower temperature. The first stage is pre-bonding procedure using the hot-embosser as a heating and force source to perform bond the polymer wafers and to prevent from the micro channel filled by cover plate, so that the two wafers were combined together without the void between two wafers. The second stage is annealing process, which is to put the pre-bond wafer at the oven. The heating process mainly helps the interface between the channel plate and the cover plate seal stronger, not damages the structure of the micro device.

3 RESULTS AND DISCUSSION

The experimental setup of the hot embossing process is described at section two. The parameters of embossing process affect the processing condition of the hot embossing. The processing force ranging from 2000N to 20000N and the temperature set at the value, which is above 150°C and below 180°C, didn't get the better replication. When the temperature is maintained at 180°C, the micro channels structure transferred from the master looks no deformation as the processing force from 2000N to 20000N. The applied force helps the plastics material flowing into mold inserts. As the temperature higher, the viscosity and surface tension of polymer decrease. This may explain that the processing temperature is more dominant than the applied force. To get an accurate replication with micro features, the best process condition is that the temperature is raised to about 180°C, and a force of 20000 Newton is applied for 120sec. Figure 2 shows the embossed micro channels on PC substrate. The geometry of micro channel was measured with nanoscan, which doesn't damage the microstructure. The shrinkage of microstructure is 2.4% at the width and 1.9% at the depth.

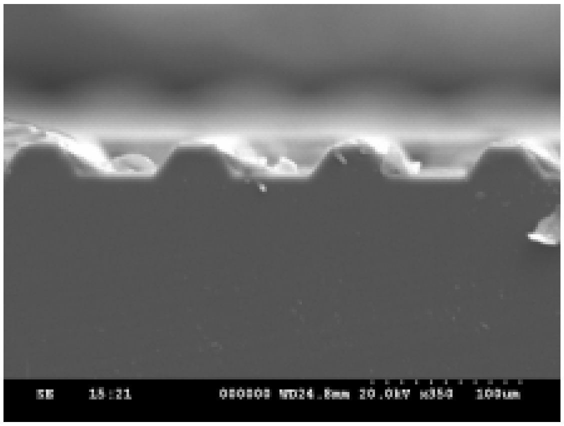

Figure 2: Micro channels transferred from silicon mold.

Microfluidic devices for PC substrates successfully pre-bond at a temperature of 150°C, force of 30000 Newton and time of 10 minutes. It is found that longer pre-bonding time (>10mins) and larger force (>30000N) didn't help the device seal properly. The second stage is annealing process, which is to put the pre-bond polymer device into the oven. This heating process mainly provides energy to bind the interface between the channel plate and the cover plate for sealing stronger, not damaging the micro device structure. In the annealing process, it doesn't need any force. The best condition is set up at an oven temperature 200°C and time larger than 4hrs. Figure 3 shows the SEM photograph of the micro channel after thermal bonding. The defects on the phptograph were resulted from the sample pre-treatment before using SEM. Bond strength could be measured by ROMULUS III. The bond strength is greater than 17MPa after thermal bonding time 4 hours. It was seen that the microstructure of micro channel didn't be filled with the cover plate. The cover plate didn't seem to be deformed.

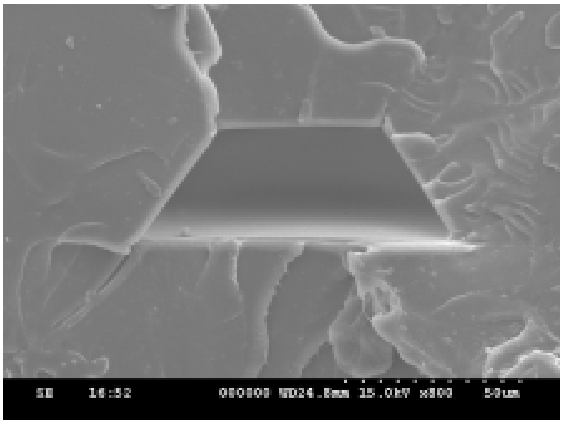

Figure 3: The SEM photograph of the micro channel after thermal bonding.

4 CONCLUSIONS

It reported that the best process condition to get an accurate replication is that the temperature is raised to about 180°C, and a force of 20000 Newton is held for 120sec. The shrinkage of microstructure is 2.4% at the width and 1.9% at the depth. The pre-bond temperature isn't larger than glass transition temperature to prevent the channels from being filled by the drilled-hole plate, and the annealing temperature is larger than glass transition temperature for increasing the activation energy of the interface to let the fusion bond react rapidly. The pre-bonding process would be successful; so that the annealing process could help the polymer molecules in the interface have a stronger bond. The bond strength of the micro channel is greater than 17MPa. The results show that the fabrication method of polymer-based biochip could be performed successfully. The electroosmotic flow and flow field in PC microfluidic chip was determined using the current monitoring method and μPIV. It helps us to understand the surface characteristics in order to develop bio-analytical micro devices.

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