Experimental study on the bonding of microfluidic chip

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Abstract. In this paper, the ultraviolet radiation curing technology is applied to the processing and manufacturing of microfluidic chips, and a new method of irradiation bonding of photocuring microfluidic chips is studied. Research has shown that by photocuring bonding method, the bonding strength of the photocuring microfluidic chip is high, the bonding speed is fast, the efficiency is high, and since the auxiliary solvent such as adhesive is not needed, the microchannel is not polluted, and the permanent bonding is realized. This new method of photocuring bonding has effectively solved the bonding problem of the microfluidic chip and the photocuring bonding strength satisfies the application requirements.

Introduction
Since the concept of ‘micro-total analysis system’ was introduced in 1990¹, microfluidic chips have played a significant role in analytical chemistry, medical testing and genetic diagnosis. This technique greatly reduces the analytical reagent loss and greatly increases the analysis speed ². The traditional microfluidic chip materials mainly include silicon, glass and polymer ³. Because of their advantages such as more types, lower cost and simpler forming process, the polymeric materials have become the mainstream material for microfluidic chip manufacturing ⁴. The traditional methods for the production of polymer microfluidic chips are mainly hot pressing, injection molding, laser ablation ⁵-⁷. UV radiation curing is an advanced manufacturing technology. It has the characteristics of fast curing, less pollution, energy saving and excellent performance, which meets the requirements of environmental protection and energy saving ⁵. The combination of UV curing technology and injection molding technology forms an ultraviolet curing injection molding technology ⁸. The dimensional accuracy of the product is superior to that of the thermoplastic injection product ¹⁰, and the molding rate can be adjusted according to the process conditions in the experiment. After molding a single microfluidic chip, bonding is required to form a microchannel for detection. The traditional microfluidic chip bonding methods mainly include: hot-pressing method and adhesive method. The hot-pressing method has a higher heating temperature and a higher pressure, which affects the accuracy of the microstructure. For adhesive method, it is necessary to apply adhesive on the surface
of the microfluidic chips to bond the two chips together.

In this paper a new bonding method of UV-curing under pressure to microfluidic chips is studied. This new bonding method is different from traditional bonding methods.

1. The experimental part

1.1. Main raw materials
LE-6702, UV resin, bifunctional polyurethane acrylate, DongtouHengli Printing Materials Co., Ltd.; PUA3, UV resin, tri-functional polyurethane acrylate, DongtouHengli Printing Materials Co., Ltd.; LE-6706, UV resin, hexa-functional polyurethane acrylate, DongtouHengli Printing Materials Co., Ltd.; EOEOEA, Monofunctional Monomer, Ethoxyethoxyethylacrylate, Changshu Hengrong Trading Company; TPGDA, bifunctional monomer, tripropylene glycol diacrylate, Changshu Hengrong Trading Company; TMPTA, trifunctional monomers, trimethylolpropane triacrylate, Changshu Hengrong Trading Company; 1173 photoinitiator, 2-hydroxy-2-methyl-1-phenyl-1-propanone, Changshu Hengrong Trading Company.

1.2. Main equipment
UV Curing Injection Molding Machine (Self-made); Laser Microscope, OLS 4100; Microscope, BX51; Digital Electronic Scale, ME104E, Olympus Industrial Company.

1.3. Experimental steps
1.3.1. Mix the UV-curing resin, monomer, photoinitiator thoroughly according to a certain percentage;
1.3.2. Then put it into the vacuum to remove the entrained bubbles;
1.3.3. Using self-made UV curing injection molding device to form the substrates and cover sheets of microfluidic chips;
1.3.4. Using self-made UV-curing device to bond the microfluidic chips.

2. Research on bonding strength of microfluidic chip
Microfluidic chips are usually divided into substrates and cover piece. The process of stably bonding the substrate and the cover piece under certain conditions is the bonding of the microfluidic chip. The bonded microfluidic chip flow channel has laminar flow features, surface capillary effect, as well as rapid heat transfer and diffusion effects [8,9].
2.1. Bonding process

Figure 2 is a microfluidic chip bonding process schematic.

![Figure 2 Schema of UV curing microfluidic chip bonding](image)

Two kinds of bonding methods are experimentally studied, which are UV-curing bonding under pressure and bonding just under pressure.

2.1.1. Bonding just under pressure method

First, clean the surface of the UV-cured substrate and the cover chip, and put them in order in the mold cavity, then apply the bonding pressure. The bonding pressure respectively set to 0.3MPa, 0.4MPa, 0.5MPa.

2.1.2. UV-curing bonding under pressure method

Using UV-curing equipment, first, clean the surface of the UV-cured substrate and the cover chip, and put them in order in the mold cavity, then apply the bonding pressure at the same time UV irradiation, UV intensity is set to 2500mw/cm² and the pressure is set to 0.3MPa, 0.4MPa, 0.5MPa, respectively.

2.2. Bonding strength test

The average bond strength of microfluidic chips obtained by different bonding methods is characterized by the following calculation results:

\[ \sigma_b = \frac{F}{A} \] (1)

In formula (1) \( \sigma_b \) is the chip bonding strength; \( F \) is the pulling force required when the chip is peeled; \( A \) is the bonding area.

With a universal tensile tester, the chip is pulled at a speed of 2 mm / min, the tensile force is measured when the substrate is separated from the cover piece, and the average bond strength is calculated by the formula (1).

The bonding quality of the microfluidic chips has an important influence on the performance of the chip. If bubbles are formed on the bonding surface, it will reduce the quality of the chip and affect the detection accuracy.

3. Results and discussion

3.1. The bonding strength of the microfluidic chip using the in-mold direct pressure bonding method

Figure 3 is a diagram of the relationship between the bonding pressure and the bonding strength of microfluidic chips using in-mold direct pressure bonding method. Under the condition of bonding just...
under pressure, after the microfluidic chip bonded for a period of time, partial separation was easy to occur at the compacted position.

![Figure 3. The relationship between the bonding pressure and the bonding strength](image)

Figure 3. The relationship between the bonding pressure and the bonding strength

As it can be seen from Figure 3, when the microfluidic chip was bonded just under pressure, the bonding strength is low, and the bonding strength does not change significantly with the increase of the bonding pressure during the bonding.

3.2. Bonding strength of microfluidic chips using UV-curing under pressure method

Figure 4 is a diagram showing the relationship between the bonding pressure and the bonding strength of the microfluidic chip bonded by UV irradiation under pressure. It can be seen from Fig.4, the bonding strength of the microfluidic chip bonded by UV-curing under pressure is much greater than that of bonded just under pressure.

For the microfluidic chips bonded by UV curing under pressure, there is no separation at the compacted position of the UV-coupled microfluidic chip, and the bonding bubble defects is very few, which will not block or contaminate the flow channel. The bonding process is relatively quickly.

3.3. The effects of bonding time on the bonding strength of microfluidic chips

Figure 5 is a diagram showing the effects of bonding time on the bonding strength of microfluidic chips.

![Figure 5. The effect of bonding time on bonding strength](image)

Figure 5. The effect of bonding time on bonding strength

As shown in figure 5, when the bonding pressure is 0.3 MPa, 0.4 MPa and 0.5 MPa respectively, the chip bonding strength under UV irradiation for 5 minutes is 0.240 MPa, 0.269 MPa and 0.271 MPa. Compared to the bonding strength under UV irradiation for 1 minute, the bonding strength changes little. Due to the fast photocuring reaction speed, further improvement of irradiation intensity and
irradiation time has little effect on chip bonding strength.

4. Conclusion
In this paper a new bonding method of UV-curing under pressure to manufacture microfluidic chips is studied. This new bonding method is different from traditional bonding methods.

For microfluidic chips, the bonding strength of the UV-curing microfluidic chip bonded under pressure is much greater than that bonded just under pressure. The method of adhesive bonding produces a large amount of air bubbles, which can easily contaminate and block the microchannels. Using the method of UV-curing under pressure, the bonding speed is fast, the efficiency is high, and since the auxiliary solvent such as adhesive is not needed, the microchannel is not polluted, and the permanent bonding is realized. This new method effectively solves the bonding problem of the microfluidic chip.

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