UV ADHESIVE BONDING TECHNIQUES IN ROOM TEMPERATURE FOR PLASTIC LAB-ON-A-CHIPS

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ABSTRACT

In this paper, a new UV adhesive bonding technique for the rapid and low-cost bonding of plastic biochips at room temperature has been developed and characterized. The spreading characteristics of biocompatible UV adhesive have been explored to optimize screen-printing around microchannels to achieve excellent sealing of microfluidic structures. We also have investigated the effect of surface modification on the bond strength of the UV adhesive. The results show that hydrophilic surface treatment enhances the bond strength, whereas hydrophobic treatment drastically reduces the bond strength.

KEYWORDS: UV adhesive bonding, spreading characteristics, surface modification, bond strength

INTRODUCTION

UV adhesive bonding techniques, for microfluidic applications, have been adopted for glass substrates [1]. Thermoplastic fusion bonding can generate very robust bonds for plastic substrates but is inherently a high temperature technique [2]. However, this may not be suitable for bonding of plastic substrates that have a temperature sensitive biomaterial, such as enzyme layer or protein array. We have developed and characterized a room temperature UV adhesive (Loctite 321™) assembly technique for such bonding applications. In addition, using screen-printing technique the cycle time for UV adhesive bonding is very short compared to fusion bonding techniques. Furthermore, certain grades of the UV adhesive are very suitable for BioMEMS applications with good biocompatibility as shown in Table 1 [3].

Table 1. ISO-10993 biocompatibility criteria satisfied by UV adhesive Loctite 321™

<table>
<thead>
<tr>
<th>ISO Test</th>
<th>Criteria</th>
<th>Met?</th>
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<tbody>
<tr>
<td>10993-4</td>
<td>Hemocompatibility/in vitro hemocompatibility assay</td>
<td>Yes</td>
</tr>
<tr>
<td>10993-5</td>
<td>Cytotoxicity</td>
<td>Yes</td>
</tr>
<tr>
<td>10993-6</td>
<td>Implantation test</td>
<td>Yes</td>
</tr>
<tr>
<td>10993-10</td>
<td>Intracutaneous injection</td>
<td>Yes</td>
</tr>
<tr>
<td>10993-11</td>
<td>Acute systemic injection</td>
<td>Yes</td>
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</table>
OPTIMAL DESIGN OF SCREEN-PRINTING MASK FOR UV ADSHIVS

Figure 1 shows a schematic sketch of the developed process. The UV adhesive is screen-printed on one side of the plastic substrate that has the microchannels already formed. A blank plastic substrate is used to seal the channels. The two-piece assembly is sandwiched in a UV transparent jig, pressurized and then exposed to UV light.

During the bonding process, there is considerable lateral spread of the screen-printed UV adhesive patterns, which could be a major drawback of this approach. The schematic sketch in Figure 2 shows the typical spreading patterns of regular geometric shapes that we want to characterize. In Figure 2, the gray regions enclosed by solid line indicate the screen-printed UV adhesive pattern, whereas the dotted lines indicate the spreading boundary after bonding.

This data is essential to design an optimized screen-printing mask such that the UV adhesive will seal all the edges of the microchannels without blocking the channel or leaving unsealed gaps. Using a combination of the basic patterns in Figure 2 one can design an optimized screen-printing mask for a micro-channel. Figure 3 shows a schematic of an optimized screen-printing mask and the resultant sealing pattern. UV adhesive is applied in an optimized screen-print pattern (black regions). Applying pressure after covering with an unpatterned wafer spreads out the

Figure 1. Schematic sketch showing a basic principle of using UV adhesive by screen printing.

Figure 2. UV adhesive spreading pattern due to application of pressure: (a) circular pattern; (b) rectangular pattern; and (c) L-shaped pattern.

Figure 3. An example of an optimum screen printing mask design for complete sealing of microfluidic structures using spreading characteristics.
UV adhesive and perfectly seals the microfluidic channel.

Microphotographs of UV adhesive patterns after bonding are shown in Figure 4. The area of the patterns was computed by image analysis software (Scion Image™) and can be compared to the original dimensions to evaluate the exact spreading characteristics of the various geometrical patterns.

Figure 4. Microphotographs for spread characterization: (a) circle; (b) rectangle; and (c) L-shaped UV adhesive patterns.

Figure 5 clearly shows that the area of the spread-out pattern is linearly related to the original screen-printed UV adhesive patterns. This data can be used to extrapolate the shape of UV adhesive screen-printed pattern so that optimum sealing of microchannels is achieved.

**EFFECT OF SURFACE MODIFICATION**

The surface condition of the plastic substrate has a significant effect on the bond strength in case of thermoplastic fusion bonding [2], so we have investigated the bonding strength in terms of the substrate surface condition. The surface of the plastic substrates is modified using Argon plasma, for hydrophilic treatment and a combined argon and carbon tetrafluoride (Ar/CF₄) plasma for hydrophobic treatment. Oxygen plasma is not used to create hydrophilic substrate since it is very hard to control contact angles between 30° and 90°. The results of the surface modification are shown in Figure 6.

Figure 6. Contact angle modification by plasma: (a); (b); (c) hydrophilic by Ar plasma; (d) native COC; (e); and (f) hydrophobic by Ar/CF₄ plasma.
For bond strength analysis the bonded samples were clamped firmly in a debonding stress measurement machine, which is used for measuring the normal bond strength.

Figure 7 shows the normal bond strength measurement results with maximum bond strength at ~40°. In order to obtain contact angles less than 30°, it is necessary to use high power plasma. This may result in micro-cracks on the surface, which would lead to a lower contact area between the UV adhesive and the substrate as shown in Figure 8. Also, adhesive bond strength increases as surface energy of the plastic substrate increases [4]. A CF4 plasma replaces the surface C-H/C=C bonds with C-F bonds [2], thereby reducing the free surface energy. This may explain the significant drop in bond strength after hydrophobic surface treatment as shown in Figure 7.

CONCLUSION

We have characterized key aspects of UV adhesive bonding techniques in terms of the spreading of UV adhesive patterns and bond strength in this work. The characterization results developed in this work would be of great use for developing a robust UV bonding protocol with an optimized process for generating screen printing masks. The characterization results obtained in this work can be immediately applied for biochip fabrication that requires a reliable low temperature bonding process.

Acknowledgement

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Reference: