ONE-STEP PLASTIC SURFACE MODIFICATION FOR IRREVERSIBLE SEALING WITH PDMS ELASTOMER AT ROOM TEMPERATURE

M.L. Ha, J. Wu and N.Y. Lee
Gachon University, Korea

ABSTRACT

In this study, we propose one-step chemical modification of plastics for bonding various plastics with poly(dimethylsiloxane) (PDMS) elastomer at room temperature. This was realized by anchoring poly[dimethylsiloxane-co-(3-aminopropyl)methylsiloxane] (amine-PDMS linker), a chemical composed of a PDMS backbone incorporating an amine side group, on the surface of thermoplastics. Following corona treatment of the PDMS-modified plastic and a sheet of PDMS, the two surfaces were placed in contact with each other and heated at 80°C for 1 h. Polycarbonate (PC), poly(ethyleneterephthalate) (PET), poly(vinylchloride) (PVC), and polyimide (PI) were bonded successfully to PDMS, and PC–PC homogeneous assembly was also realized using this method.

KEYWORDS: Plastic Sealing, Amine-Polydimethylsiloxane Linker, Surface Modification, Room Temperature

INTRODUCTION

PDMS–plastic assemblies have a number of advantages over homogeneous assemblies, as they can provide versatile surfaces owing to the innate properties of the partner plastics as well as the elasticity offered by poly(dimethylsiloxane) (PDMS). Many strategies were demonstrated for realizing plastic–PDMS bonding. Sunkara et al. [1] bonded thermoplastics to PDMS by activating the substrates using plasma treatment followed by surface modification with aminopropyltriethoxysilane. Suzuki et al. [2] investigated the use of a sol–gel coating for fabricating plastic–PDMS microfluidic devices. In our previous studies [3,4], we introduced the concept of chemical gluing for bonding PDMS–PDMS and PDMS–plastics by forming a chemically robust amine–epoxy bond at the interface. Although robust and permanent seal was achieved at room temperature, two silane coupling reagents were required, and both surfaces had to be oxidized prior to chemical modification. In this study, we propose one-step chemical modification of plastics for bonding various plastics with PDMS at room temperature mediated by the use of an amine-PDMS linker.

EXPERIMENTAL

Figure 1a and 1b show the chemical structure of the amine-PDMS linker and the schematic for surface modification of polycarbonate (PC) followed by bonding with PDMS respectively.

Figure 1: Schematic representation of the surface modification and bonding process.
RESULTS AND DISCUSSION

Figure 2 shows the results of contact angle measurement at various stages of the chemical modification. “A” represents contact angles of pristine plastics. “B” represents contact angles after corona treatment of the pristine plastics. “C” represents contact angles after amine-PDMS linker coating of the pristine plastics. “D” represents contact angles after corona treatment of the amine-PDMS linker-coated plastics. Regardless of the substrate types, the contact angles drastically decreased to less than 10° after corona treatment on amine-PDMS linker-coated plastics.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDMS</td>
<td>104.70°</td>
<td>&lt;10°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>64.42°</td>
<td>40.37°</td>
<td>95.60°</td>
<td>&lt;10°</td>
</tr>
<tr>
<td>PET</td>
<td>74.71°</td>
<td>38.63°</td>
<td>94.51°</td>
<td>&lt;10°</td>
</tr>
<tr>
<td>PVC</td>
<td>79.31°</td>
<td>50.17°</td>
<td>94.60°</td>
<td>&lt;10°</td>
</tr>
<tr>
<td>PI</td>
<td>73.02°</td>
<td>&lt;10°</td>
<td>96.03°</td>
<td>&lt;10°</td>
</tr>
</tbody>
</table>

Figure 2: Contact angles measured at various stages of chemical modification. Contact angles on pristine and corona-treated PDMS were also measured as references.

Figure 3 shows the results of the bond strength measurement obtained by performing pull tests. As shown in Figure 3, rugged PDMS residues remained on partner plastic surfaces, indicating that a permanent seal was realized between the amine-PDMS linker-coated plastics and PDMS. In the control experiments where the amine-PDMS linker coating step was omitted, plastic and PDMS were immediately separated with no force applied, indicating that no chemical bond was formed in the absence of the linker molecule. PC, PET, PVC, and PI were bonded successfully to PDMS using this method, with bond strengths of PC, PET, and PVC with PDMS measured to be approximately 428.5 ± 17.9, 361.7 ± 31.2, and 430.0 ± 14.9 kPa, respectively, and the bond strength of a PC–PC homogeneous assembly was measured to be approximately 343.9 ± 7.4 kPa.

Figure 3: Bond strengths measured by performing pull tests.
Figure 4a shows the results of delamination tests performed when film-type PC, PET, PVC, and PI were bonded to PDMS. Rugged PDMS residues can be observed on the partner plastic surfaces, demonstrating that a permanent seal was formed between the plastics and the PDMS. Figure 4b shows the results of the leakage test carried out to examine the physical stability of the bonded assembly. This is particularly important for high-throughput fluid injection applications where a large amount of sample needs to be processed, such as environmental samples, or for chromatographic separation purposes.

<table>
<thead>
<tr>
<th>(a) Delamination test</th>
<th>(b) Leakage test</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>PET</td>
</tr>
<tr>
<td>PVC</td>
<td>PI</td>
</tr>
</tbody>
</table>

Figure 4: (a) Results of delamination tests performed on PC, PET, PVC, and PI bonded to PDMS. (b) Result of leakage test performed on PC-PC homogeneous assembly.

CONCLUSION
In this study, a simple and facile strategy for bonding various plastics to PDMS has been demonstrated, mediated by one-step chemical modification at room temperature followed by corona treatment. The use of an amine-PDMS linker dispensed with the need for prior surface oxidation and heating, as the coating procedure was realized by direct reaction between the amine functionality and the plastic at room temperature. Owing to the relatively mild conditions applied, surface morphologies of the plastics could be preserved without channel collapse, and a heterogeneous plastic assembly could be realized while retaining a homogeneous PDMS surface inside the microchannels.

ACKNOWLEDGEMENTS
This work was supported by the Public welfare & Safety research program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2012M3A2A1051681).

REFERENCES

CONTACT
*N.Y.Lee; phone: +82-31-750-8556; nylee@gachon.ac.kr