A BONDING METHOD BETWEEN POLY(LACTIC ACID) (PLA) AND POLY(METHYL METHACRYLATE) (PMMA) FOR MICROFLUIDIC CHIPS

Pin-Chuan Chen * and Huyen-Lynh Duong
Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan

* Email: pcchen@mail.ntust.edu.tw; Tel.: +886-2-2737-6456

Progress Claims

This article presents a novel method to bond PLA, a 3D-printing material, and PMMA, a popular substrate material for microfluidic applications. With this technique, the tubing connectors can be fabricated by 3D printing and make this PLA/PMMA hybrid microfluidic chip extremely easy to use for experiments. The major challenge of bonding this hybrid chip is the high level surface roughness of PLA substrates with its significant influences on bonding strength [1]. After Ethanol treatment and UV irradiation of this hybrid chip, a post-annealing step was realized to facilitate the bonding. To further analyze the bonding quality leakage test, cross-sectional image by microscope, and pressure bursting test were conducted. The experiment results clearly showed that this method could successfully and rapidly form a strong bond (＞13 bars) between PLA and PMMA substrates.

Background

Nowadays, thermoplastics are used commonly in microfluidic applications. The bonding of PMMA/PLA can offer significant benefits taken advantages from 3D-printing process such as allowing producing incredibly complex products in a short time, while minimizing material waste.

Description of Bonding Procedure

Ethanol solution was distributed uniformly sandwiched between two substrates by spin-coating process (190 rpm, 10 sec). Following the UV irradiation (56 sec), an instantaneous and permanent bonding can be formed between PMMA and PLA. However, the bonding strength is significantly affected by the high level of surface roughness of PLA substrates (range from 4.5 to 6.5μm). It can cause the failure of bonding. To solve this critical issue, we employed a post-annealing strategy (55℃, 30 min) straightforwardly after UV exposure step. Its purpose is help create more contacting points between two bonded substrates because of surface degradation caused by coarsening phenomena [3]. Besides post annealing can help relieve stress and therefore improve the bonding strength. The temperature executed for post-annealing is below the glass transition temperature of PLA (Tg of PLA = 60~65℃), hence there has no significant channel deformation observed. The overall bonding procedure is described in Fig. 1.

After bonding, several experiments were conducted to characterize the bonding quality such as leakage tests, cross-sectional images by microscope, and burst tests.

Experimental Results

a. Comprehensive examination

Following the completion of the bonding experiments, leakage tests and the cross sectional investigation using microscope of bonded chip were conducted, the results of which are presented in Fig. 2. The figure clearly demonstrates the effectiveness of the proposed bonding method for heterogeneous substrates between PMMA/PLA. Figure 2(a) shows the bonded chip, Figure 2(b) shows the enlarged figure of the microchannel, both figures clearly showed that no leakage was observed. Figure 2(c) shows the cross-sectional image of bonded chip.

b. The influence of post-annealing conditions on bonding strength.

Fig.3 illustrates the set up for busting test and Table 1 lists the experiment results of bonding strength. In all of the experiments, the microchannels were fabricated on the PMMA substrates and the cover substrates were PLA. Table 1 clearly shows that the microfluidic chips have sufficient bonding strength above 10 bars.

Word Count: 493

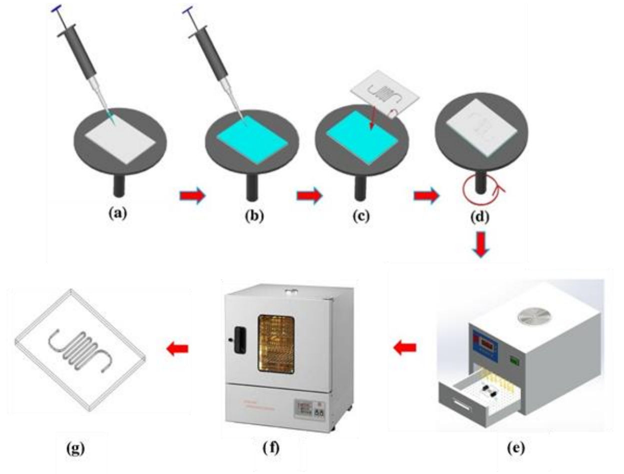

__Figure 1__: Bonding process: (a, b) Pipette used to load ethanol solution on the thermoplastic substrates; (c) PMMA substrate with machined microchannels was brought in contact with the thermoplastic substrate; (d) spin-coating for the distribution of ethanol solution; (e) UV irradiation; (f) post-annealing step for reducing surface roughness; (g) Bonded microfluidic chip used in experiments

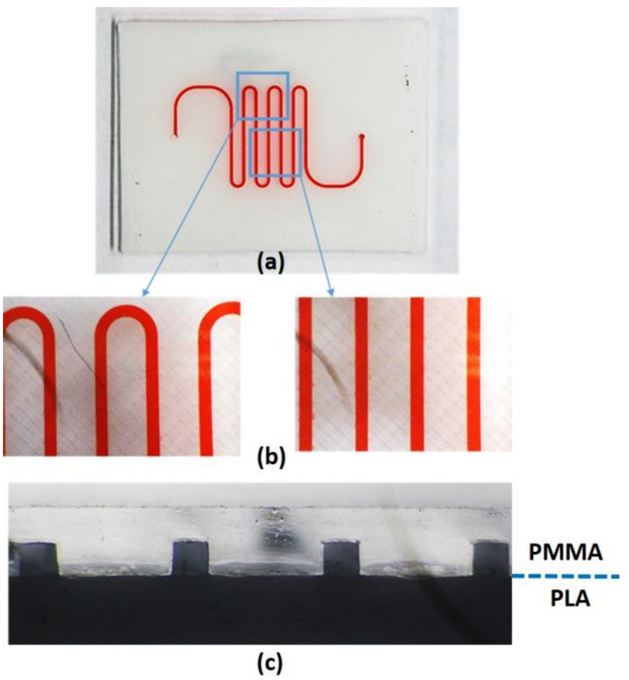

__Figure 2__: Experiment results of leakage tests and cross-sectional investigations using microscope: (a) Bonded chip with red dye solution inside microchannel prepared for leakage test; (b) Microchannels observed under microscope; (c) Cross-sectional image tracked under microscope.

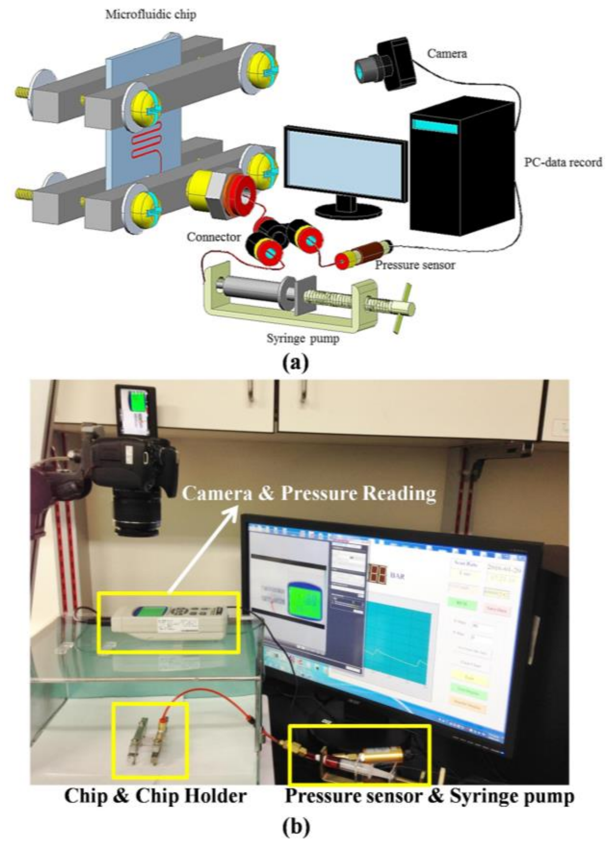

__Figure 3__: (a) System used to measure the burst pressure of the bonded microfluidic chips: The system includes an aluminum chip holder, a syringe pump, a video camera, and a pressure sensor linked to a computer to enable the recording of experiment data; (b) experiment setup.

__Table 1__: Results of burst pressure experiments

Trial	Bonding strength (bar)	Note
(55 degree of Celsius, 30 minutes)		
3	11.1	Leakage happened after 2 months
4	13.52	Channel is still ok.

REFERENCES:

[1] Pin-Chuan Chen, Lynh Huyen Duong, "Novel solvent bonding method for thermoplastic microfluidic chips", *Sensors and Actuators B: Chemical*, Volume 237, December 2016, Pages 556–562.

[2] L.H. Thamdrup, A. Klukowska, A. Kristensen, "Stretching DNA in polymer nanochannels fabricated by thermal imprint in PMMA", *Nanotechnology*, 19 (12) (2008), p. 12530.

[3] Xiaodong Shi, Stuart G. Croll, "Thermal-induced recovery of small deformations and degradation defects on epoxy coating surface", J. *Coat. Technol. Res.*, 7 (1) 73-84, 2010.