CARBON NANOTUBE-ASSISTED MICROWAVE THERMAL BONDING OF PLASTIC BIOCHIP

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ABSTRACT
A sealed plate is essential for protecting the sample processing inside biochip from the environment and it can be attained through bonding. Bonding technology in silicon and glass are well-developed in the past decades; however, bonding in polymers is still challenging. Issues such as micropattern integrity, contamination and bonding efficiency are important criteria for plastic bonding. In this work, a new bonding method combining the advantages of thermal bonding (homogeneous bonding) and microwave bonding (high fusion efficiency and low energy consumption) has been developed which allows the biochip manufacturing to be more scalable. It features with simple equipment setup, low material and running costs. Given the strong dielectric properties, carbon nanotubes (CNTs) were used as effective microwave absorber in this bonding system. A desirable bonding result has been obtained as shown in this paper.

KEY WORDS
Microtechnology and bioMEMS; Carbon nanotubes; Polymeric bonding; Biochip

1. Introduction
Microfluidic devices have been regarded as the promising technology fostering the Point-of-Care (POC) growth. A distinct prerequisite of microfluidics is its portability and disposability, which are crucial to the health care development in developing world [5,6]. The mounting demand of microfluidics in the health care area, hence, has shifted the manufacturing markets from silicon and glass to polymer. In order to fabricate a plastic biochip, bonding is a critical issue to be addressed to provide a reliable performance. Various bonding methods have been developed such as thermal bonding using low pressure strategy [7], holed pressure equalizing plates [8], and hybrid assembly [9]; adhesive bonding using PDMS [10]; solvent bonding using DMSO and methanol [11]; microwave bonding using a gold thin film [12], and solvent based polyaniline [13]. Although there are plenty of methods for plastic chip bonding, thermal bonding is still the preferential method to be used because it can provide a contamination-free homogenous assembly of the final products. Thermal bonding requires heating up of two polymeric substrates to their glass transition state (Tg) and the substrates are sealed under the ultimate contact by applied pressure. However, it always results in an immense energy loss and a lengthy bonding cycle due to the thermocycling of the hot plates. Herein, we report the use of CNTs for microwave thermal bonding of polycarbonate (PC) substrates which can reduce the energy consumption to improve the bonding efficiency for the industrial application.

2. Methods and results

2.1 Materials and equipments
PC cover, injection molded PC biochip, CNTs with diameter ranged between 20 and 40 nm, and propanol were prepared for the bonding process. Simple equipments such as conventional microwave oven, Teflon holder, glasses and spray gun were prepared for the experiment.

2.2 Sample preparation
Multi-walled CNTs with diameter between 20-40 nm were mixed with propanol to a final concentration 2 mg/ml. CNTs were dispersed in propanol by grinding with mortar and pestle followed by sonication. CNTs were then sprayed uniformly on a bare 0.3-mm-thick PC substrate. The thickness of CNTs was controlled at 64 ± 5 µm. A PC biochip was fabricated by microinjection molding. It contained the microfeatures including microchannels, reservoirs and valves. The microchannels were 90 µm in width and 50 µm in depth. Inlet and outlet holes were drilled before bonding.

2.3 Experimental setup
As shown in Fig. 1, the back side of the sprayed substrate (i.e., surface without CNTs) was in contact with an injection molded plastic biochip. The assembly was clamped between two glasses by a Teflon holder. The whole assembly was sent to a conventional microwave
oven and was exposed to microwave radiation for 2 min 45 sec. The exposure time may vary depending on the thickness of CNTs. After the exposure, the PC biochip was sealed by the plastic cover because of the heat generated by CNTs through heat conduction.

Fig. 1. Setup of the bonding assembly

2.4 Results and discussion

The cross-sectional images of injection molded biochips before and after microwave thermal bonding are shown in Fig. 2 and Fig. 3 respectively. The bonded biochip was cut to examine the cross section of sealed microchannels. The microchannel integrity was retained that no deformation of the microchannels was observed.

Fig. 2. Cross-sectional image of microchannels of the biochip before bonding

Fig. 3. Cross-sectional image of microchannels of the bonded biochip using microwave thermal bonding

In this model, CNTs absorbed electromagnetic radiation and converted it into heat energy [14]. CNTs acted as a heat source to supply heat to the bonding interface through heat conduction. Once the microwave power was off, CNTs stopped generating heat. The whole assembly cooled down rapidly due to the negligible thermal mass. Since the whole bonding process took only a few minutes, the entire part of the microchannels did not subjected to deformation caused by the prolonged high temperature and pressure environment, which is always the case for conventional thermal bonding. The microchannel structures of the sealed biochip remained intact.

3. Conclusion

A new method, microwave thermal bonding, for sealing plastic biochip using CNTs has been successfully demonstrated. The bonding time was hugely reduced from more than half an hour (using conventional thermal bonding) down to several minutes. The equipment and running costs for microwave thermal bonding were relatively small compared to the conventional thermal bonding. The development of microwave thermal bonding facilitates a high throughput production of microfluidic devices. However, further investigation on microwave time duration corresponding to various CNTs thickness could be done to optimize the bond strength to different types of biological analysis, for example, metabolites detection, protein analysis, or DNA amplification.

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References


