Fabrication of Su 8 Microfluidic Devices using Low Temperature Bonding

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Introduction

Microfluidic devices have enjoyed attention of many researchers and technological institutes due to their enormous potential applications including pharmaceuticals, biotechnology, the life sciences, defense and public health [1], [2]. Many microfluidic devices are currently fabricated in silicon or glass [3]. Both of these materials are suitable as substrates for microchemical reactors. Moreover, well developed processing techniques for silicon offer opportunity to produce fully integrated structures. However, fabrication of these kinds of devices is still very expensive [2].

A promising material for preparing microfluidics devices is the photo-resist Su 8 developed by IBM. It is a negative, photo definable epoxy-based resist that is compatible with standard silicon processing conditions and can be patterned using a standard lithography technique [4]. The use of Su 8 material for the fabrication of microfluidic devices by photolithographic techniques presents an advantage for easy and low-cost manufacturing of high-aspect-ratio microstructures. Furthermore, Su 8 has good mechanical properties, chemical resistance and it is also a biologically compatible material [5]. Su 8 can be partially pre-baked and bonded with a companion wafer by applying pressure and heat.

This paper describes a method for fabricating microfluidic devices using low-temperature wafer-level adhesive bonding. The fabrication is based on a 4 inches wafer polymer bonding process, using Su 8 polymer epoxy photoresist as a structural material. The uniformity and crosslinking level of the Su 8 in the photolithography process have been optimized to obtain a strong bond without defects and sealed channels.

Adhesive Wafer Bonding

In adhesive bonding, an intermediate adhesive layer (in our case resist Su 8) is used to create a bond between two surfaces to hold them together. The main advantages of adhesive wafer bonding are the insensitivity to surface topography, the low bonding temperatures, the compatibility with standard integrated circuit wafer processing, and the ability to join different types of wafers [6]. This technique is simply and low cost, so suitable for commercial usage.

Fabrication Process for Microfluidic Devices in Su 8

The critical parameter for high-quality bonding is a good thickness uniformity as well as suitable crosslinking level of the Su 8 layer. These two parameters determined our development of a technology for preparing microfluidic devices. Our task was to prepare 100 µm thick Su 8 microfluidic structures on a 4 inch Si wafer, which was afterwards bonded to a glass wafer with an approximately 4 µm thick non-exposed Su 8 layer.

Thickness uniformity can by affected mainly be spincoating and soft bake. Our developed recipe for the spincoater allows fabricating a 100 µm thick Su 8 layer with a thickness uniformity of ±4%. After spincoating, wafers are left to relax on a flat surface approximately for 1 day. During this time the wafers are covered with a glass cover. This technique leads to reflow of the resist and results in final thickness uniformity of ±2.5 – 3.5% across the wafer.

After softbake, edge beads of 40 – 50 µm height are present. These edge beads are removed with acetone. Our experiments show that new edge beads of 6 – 8 µm height arise after drying on a hotplate (temperature above 50°C). For this case all future heating treatment after edge beads removal has to be omitted.

The second critical parameter is the crosslinking level of Su 8 layer. There are two parameters which can affect the crosslinking level of the Su 8 resist; exposure dose and post-exposure bake. Both were optimized in order to obtain suitable crosslinking level. A high crosslinking level leads to bad bond strength and large unbonded areas. On the other hand, a low crosslinking level results in sealing of the channels. Optimized parameters are: exposure dose 400mJ/cm^2 and post-exposure bake 12 min on a hotplate at 95°C.

The crosslinking of Su 8 occurs also during the bake at temperatures above 160°C [7]. This feature of Su 8 was used to obtain a suitable crosslinking level for a 4 µm thick Su 8 layer deposited on glass wafer. Optimized data for baking are: temperature 170 °C and 28 – 30 minutes time.

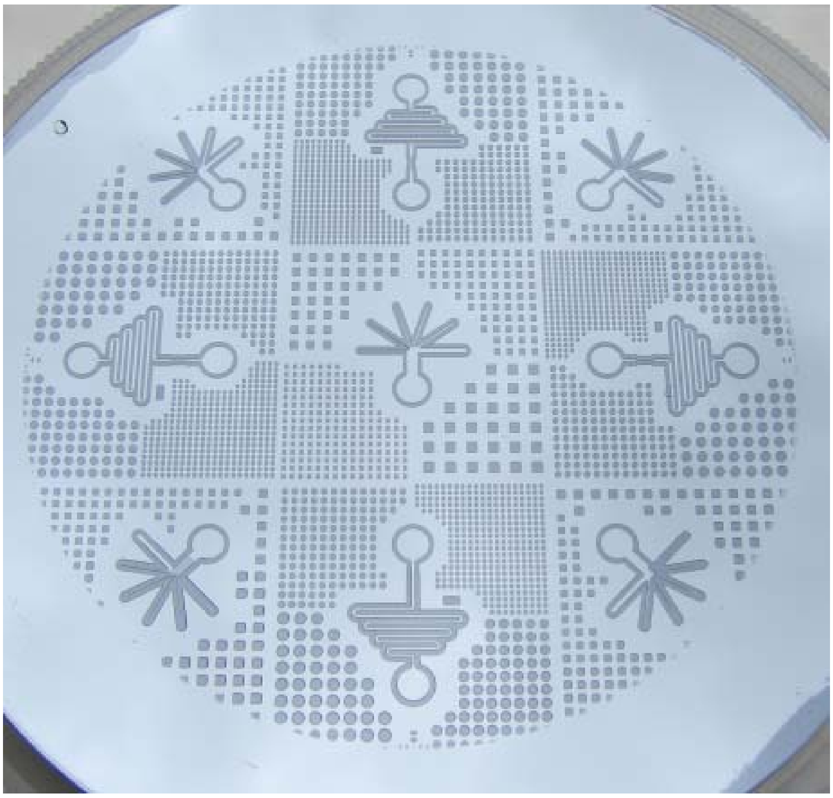

Fig. 1: Bonded 100 µm thick microfluidic structures on a 4 inch wafer without defects and deformation of channels.

Bonding Experiments

Our bonding experiments were realized with an EVG 501 bonder. Wafers were inserted into the bonder chamber on an elastic base holder of approximately 3 inch diameter. This wafer base improves the distribution of the applied bonding force across the wafer. The bonding chamber is evacuated in order to avoid trapping air bubbles in the bond area. Wafers are brought into contact, pressed together and heated to a temperature of 180°C. Heating was realized in 3 steps in order to obtain a uniform heating ramp. A pressure of 1200 N is applied for 10 min. During this time full crosslinking of the Su 8 resist takes place, and permanent contact between the exposed and non-exposed layers is created. Bonding with these parameters results in bonding on all places across the 4 inch wafer without defects and closed channels (Fig.1). Details on bonded structures with channels with widths in the range of 25 µm to 500 µm are presented in the Fig. 2. The bond interface is directly inspected through the transparent glass wafer to identify the status of sealed and unbonded areas.

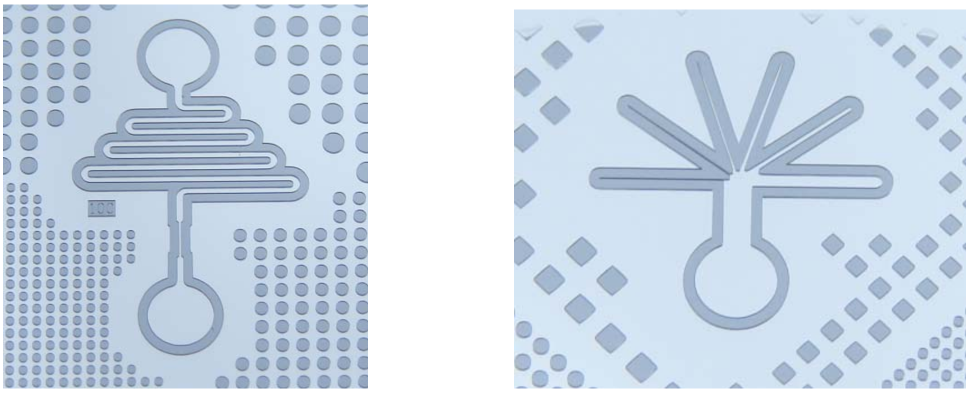

Fig. 2: Detail on bonded structures with channels of 25 – 500 µm width. Structures are bonded without deformation and without sealing of the channels.

Conclusion

We developed a technique for preparing microfluidic devices in Su 8 resist. The final bonding recipe can be used for low-cost mass-production of microfluidic devices. Bond strength was inspected be inserting tweezers between wafers. The bond was strong enough to allow the dicing of devices without detachment or partial release of them. Leakage test results show that this low-temperature wafer bonding process is a viable MEMS fabrication technique for microfluidic applications.

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