Investigating Different Methods of Bonding Glass Substrates

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For many years, different methods for bonding glass borofloat substrates have been investigated[1], including fusion and various adhesives like cyanoacrylate [1]- **[6]**. This paper investigates the properties of different bonding processes available and presents solutions for bonding plain glass wafers, with investigation into using the same process for bonding glass with microfluidic channels etched in them.

The bonding process must satisfy three requirements to preserve the channels. The first requirement is that the bond has to preserve the colorlessness and transparency of the wafers. No particles may form between the bond and cause the wafers to become opaque. A second requirement is that the material must be non-toxic as the device application will require contact with human tissue or fluids. Lastly, the seal between the wafers has to be sufficient to prevent leakage while still preserving the depth of the microfluidic channels. Given these requirements, three main categories for bonding glass borofloat substrates are considered: adhesive, anodic, and fusion:

Adhesive

Several different adhesives were investigated, including cyanoacrylate, Sylgard 184 (PDMS), Sylgard 839, Duco Cement, Epoxy, and Industrial Strength E600. To successfully bond, each adhesive required a specific application process. For cyanoacrylate, application required rotating the wafer at a speed of 1500 rpm and applying a quarter sized daub at the center of the wafer. Within 20 seconds, the rotation was stopped and the mating glass substrate was pressed onto the drying cyanoacrylate. Acetone was used to remove any unwanted cyanoacrylate.

The second method, required for Duco Cement, Epoxy, and Industrial Strength E600, entailed spreading the adhesive evenly on top one glass substrate with a knife, then pressing the mating glass substrate on top of the drying adhesive. Extra adhesive material was removed with isoproponal.

The third method, used only for the Sylgard compounds, required that the adhesive be cured in a separate mold, then transferred to the glass substrate. Since the layer was only 100 um thick, the material was difficult to remove from the mold. The adhesive would tear in small pieces and proved difficult to mend. If the adhesive was removed properly, it held the two glass substrates well and it was difficult to pull the two bonded wafers apart. More than 10 – 20N hand force was required to break the seal.

With each of the different adhesives used, a good seal was created, but a potential difficulty is for the liquid adhesive to run into the etched channels.

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[1] **Alfi, Oren and Brandon Choi, Glass to Glass Bonding, UCI Symposium**
http://www.urop.uci.edu/symposium/past_symposia/03/abstracts_groups.html

Anodic

Anodic bonding is an electrical and thermal process that typically bonds a silicon wafer to a glass substrate. The wafer and glass substrate are placed between two metal electrodes and heated to 400ºC. By applying a DC potential up to 1kV, an electric field is created causing sodium ions to deplete the surface of the glass and to diffuse into the Silicon. In this state, the glass becomes highly reactive with silicon surface and forms a solid chemical bond.

While this process is well established for silicon-glass bonding, the requirement of this project is to bond two glass substrates. To anodic bond glass, a series of three layers was sputtered onto one glass borofloat substrate: a 100 angstroms layer of Indium-Tin-Oxide, followed by a 100 angstroms of silicon dioxide, and 250 angstroms of silicon [7]. This substrate was then brought into contact with a virgin glass substrate under 10 kPa of pressure and a potential of 100V applied at 55ºC. While this bond worked well because it could not be pealed apart by tweezers nor with the hand, the glass substrates did not remain transparent due to the silver color of the Silicon layer. However, this research shows that anodic bonding can conserve channels in a glass substrate and create a good seal.

Fusion

Fusion bonding the two glass substrates proved to be successful without the issues associated with adhesives or sputtering. The basic fusion bonding process entails pressing two virgin glass substrates together and applying heat for a long duration. 700 μm thick glass borofloat substrates were pressed together by hand until the substrates were fixed by Van der Waals forces. The substrates were transferred to a furnace at atmospheric pressure and placed on top of an unpolished nitride wafer. The nitride wafer prevents the glass from fusing and deforming over the small diameter ceramic base. Silicon and quartz wafers were also tried as the holding base, but were unsuccessful because the borofloat would fuse with them. Glass substrates can be heated up to 600 ºC to allow the material to partially slump and fuse with the opposite substrate, but without melting. Therefore, the borofloat wafers were heated in the furnace for 6 hours at 600ºC.

In several experiments, trapped air bubbles appeared between the two glass substrates. Therefore, additional substrates were bonded under vacuum in an attempt to reduce the number of bubbles. The above process was altered to allow the two borofloat wafers to be pressed together in a vacuum chamber of 1e-2 bars for 2.5 minutes. Once the borofloat wafers were fixed under Van der Waals forces during initial contact, they were transferred to a furnace at atmospheric pressure and heated to 600 ºC for 6 hours.

Once cooled, the wafers were removed from the furnace and investigated under a microscope. The bond was solid with few impurities trapped between the surfaces for the glass substrates as shown in Figure 1 and Figure 2. To decrease impurities on the substrate, it is recommended that a preliminary clean be done in a 1 part hydrogen peroxide to 3 parts Sulfuric acid bath (termed piranha).

In conclusion, bonding glass substrates is possible by the three methods: adhesives, anodic bonding, and fusion bonding. As a result of this research, the only method to meet the above requirements is fusion bonding. Additional experiments on the fusion bonding of glass substrates with etched channels are currently underway and look promising.

Figure 1: Van der Waals forces shown in fused glass substrates (left and right picture) that were pressed together without vacuum.

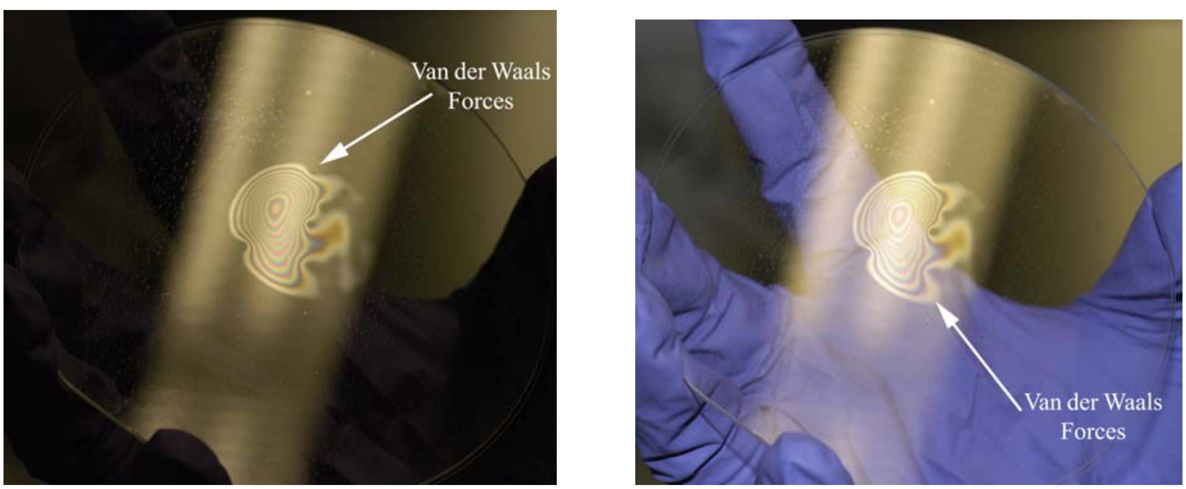

Figure 2: Van der Waals forces shown in fused glass substrates (left and right picture) that were prebonded in 1e-2 vacuum.

Keywords: Bonding, Glass, fusion

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