Hermetic Room Temperature Glass Welding Technology

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ABSTRACT

An alternative method for joining glass was studied to overcome existing challenges in the industry. The goal was to minimize heat affect, shorten process time, and avoid the use of additive materials but still to obtain excellent mechanical and chemical properties. In this paper, a novel glass welding technique is analysed and its shear strength is compared to adhesive glass-glass bonding. Adhesive bonds were performed with a UV cured glue, often used in glass to glass bonding.

Several benefits of using the novel bonding method for glass were discovered: the bond has improved mechanical properties, welding can be performed at room temperature, and it is a quick, one step process. Additionally, welding has very small heat affected zone (HAZ), and a hermetic homogenous seam can be produced. As a result, this method may be the solution for the challenges raised by the industry.

Keywords: hermetic, glass welding, room temperature, shear strength

1 INTRODUCTION

The miniaturization of components and innovations demand new packaging methods to improve productivity and quality. To meet these requirements, advances in the field of glass micro welding has to be made. Novel technology can be beneficial for several application fields, such as microelectronics, optics, packaging of medical devices, and aero and space industry.

The aim of the study was to find an alternative method for the conventional glass-glass bonding, and overcome challenges addressed by the industry. Fusion welding of glass parts with ultrashort laser is probably one of the most promising bonding methods to replace conventional glass bonding techniques.

Fundamental aspects of glass welding induced by an ultrashort laser has been studied by multiple research groups.[1-6] Other alternatives are e.g. anodic bonding using a Si-film [7] or metal cold welding for glass-silicon wafer bonding applied by Decharat et al. [8] Decharat et al. used metal seals attached to wafers, and underfill to weld two material with different thermal coefficient.

Laser welding is a flexible process and the welding seam itself can be very narrow. This enables the manufacturing of accurate welds around complex structures with minimal safety areas. Laser beam can be focused into a small spot which allows manufacturing of small features. Typical spot size would be approximately 8-25 micrometer depending on the application. Thus multiple lines are usually used to form a wider welded area. Technique can be beneficial in several applications and open new possibilities on the areas where hermetic encapsulation is necessary, temperature sensitive components are involved or use of additive materials is not desirable e.g. clean technology and biotechnology.

Small spot size is often desirable, as finer structures can be made and more importantly heat affected zone can be minimized. However, size of the heat affected zone depends also on the process parameters, such as beam velocity, pulse length, pulse repetition rate, and pulse energy. By optimizing processing parameters, heat affect is minimized and processing time shortened. Wu et al. [3] has studied the effect of the double pulse to the process, and stated that it improves bond strength compared to single pulse welding. However, it will be demonstrated that good or potentially better results can also be achieved with single pulse. Although, accurate comparison is not possible, as materials are not the same.

Since local melting of material can be exploited, no adhesive or additive materials are needed in the novel welding process. Thus, a hermetic welding with excellent mechanical and chemical properties can be produced. Additionally thanks to minimal heat affect and shortened process time, smaller and more accurate features can be manufactured efficiently and at room temperature.

Laser beam heats material locally to a very high temperature, which causes two materials to melt together: melted materials forms bond, and the interface between two materials disappears. Temperature gradient around the weld seam is very high, and the peak temperature in the center of the spot can be several thousand Celsius centigrade [1,4,6]. Although, rest of the material remains at room temperature and unaltered. Due to the small spot size, the depth of focus is short. Therefore, the depth of the melt can be shallow, hence laser welding requires that two glass parts are close to each other. If the cap between two surfaces becomes wider, welding quality will worsen and finally the seam will not be formed. Air gap can also cause that vapor spreads to the interface.

Adequate mechanical strength along with good productivity are important for the applicability. In this paper mechanical strength is discussed and the results of the tests are presented.

2 EXPERIMENTAL

Borosilicate glass, Borofloat 33, was chosen for this study. Samples were made by welding or gluing 1 mm thick glass parts (5x5 mm) to a 5 mm thick glass surface (50x50 mm), see figure 1.

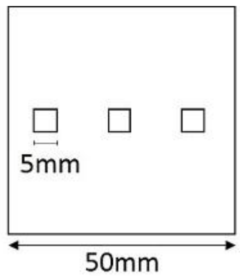

Figure 1. Schematic figure of the test samples.

Adhesive bonds were performed with a UV cured glue Vitralit 7256 (Panacol-Elosol GmbH). It is often used in glass to glass joining and in the field of optics and electronics. Primoceler Felix microwelding machine was used for the welded samples (figure 2).

Figure 2. Primoceler Felix microwelding unit.

The machine has one rotational axis and three linear axes. The positioning accuracy of the axes was measured to be ±1µm according to the standard diagnostic test ISO-230. Samples were placed on a vacuum chuck, which held them in place during the welding process.

Before welding, samples were optically contacted. Welding was implemented on the material interface, leaving the surfaces untouched. Layout of the welding seams minimized the effect of optical contact: the entire area of 5x5 mm glass parts were welded. Moreover, seams were positioned perpendicular with respect to shear orientation (figure 3).

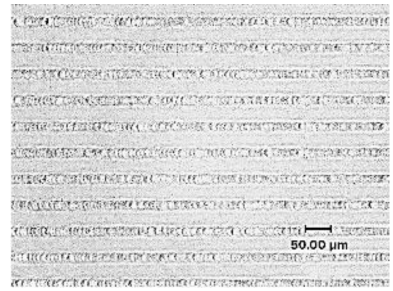

Figure 3. Positioning of the welding seams perpendicular to shear orientation.

A shear test following the standard MIL-STD-883, method 2019.7, was performed at VTT (Technical Research Centre of Finland). The Sebastian Five-A S tester was used. Figure 4 presents the test setup.

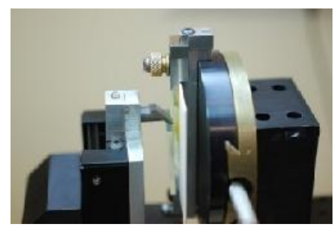

Figure 4. Shear strength equipment [Photo: VTT].

Sample holder is located on the right, and a contact tool, which applies the force to the sample, on the left. Direct shear load was applied to the sample, to one bonded piece at a time (maximum load 100 kg).

3 RESULTS AND DISCUSSION

Samples after testing are presented in the figure 5. The glue was sheared off the bottom glass. On the contrary, in the welded samples the bottom glass fractured before the failure of the welding seam.

Figure 5. Samples after the shear test. Glued on the left, welded on the right.

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The average shear strength value for the adhesive bonded samples was 8 MPa. Lap shear strength given by manufacturer is 5,5 MPa. The same test was repeated for the laser welded test pieces, and average shear strength of 20 MPa was gained, before the borosilicate glass fractured under the weld. Figure 6 presents the results.

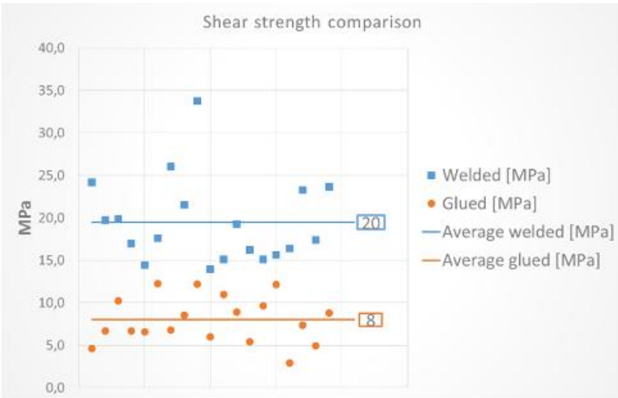

Figure 6. Results of the shear strength test. In the welded samples, the bottom glass fractured before the failure of the welding seam.

Several factors can explain the deviation in the results. Since glass is brittle material, it does not yield in a same way than for example ductile metals. Even the minor flaws in a material can cause crack propagation. In addition, it is challenging to direct the contact tool exactly at the same angle to the specimen. Because adhesive bonding is manual process, some deviation in the results can be caused by slight differences during the bonding process.

All the welds endured the shear test. Optical picture of the weld is presented in the figure 7.

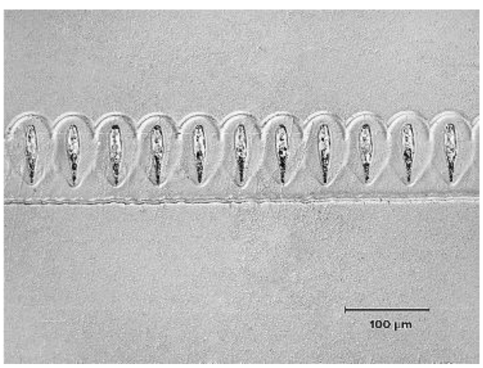

Figure 7. Optical picture of the weld seam (etched 10% HF).

Side view of the seam shows uniform drop shapes through the entire weld. Material interface can be observed as a delicate, continuous line on the wider area of the drop. Results of the shear test and optical pictures verify that homogenous seam and good welding quality are obtained with novel welding technique.

4 CONCLUSIONS

The results indicate that seam properties obtained with novel laser welding method are consistently better than properties with conventional glass bonding techniques. Since heat affected zone is extremely small, temperature sensitive products can be encapsulated. In addition, size of the safety areas can be minimized.

The novel technique does not need any additive material. Additionally, the material surfaces leave untouched and hermetic seal is formed. Consequently, application fields such as clean technology, medical industry, and areas of aero and space technology may benefit this method.

Future investigations to examine the actual shear strength of the weld, until failure of the weld, may be considered.

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