BOROFLOAT® & Glass Wafers: A Union of Inspiration & Quality

The performance requirements for glass wafers used for anodic bonding or as carrier wafers in wafer thinning processes are mainly determined by their ability to perfectly match those of the silicon wafer to which they shall be permanently or temporarily bonded. Well-adapted thermal expansion behaviour is as important as excellent flatness and process robustness. BOROFLOAT® glass wafers provide such outstanding material properties along with exceptionally high UV transmission – a special requirement for high speed laser de-bonding processes.

1. Introduction
BOROFLOAT® – the worldwide first floated borosilicate glass – is one of the most versatile flat glasses available today. The sum of its properties is what makes it unique and has led to the material being adopted across a multitude of diverse applications. Its glass composition is tailored to perfectly match the thermal expansion coefficient of silicon and resist chemical attacks as well as elevated or fluctuating temperatures. Gifted with high grade flat glass characteristics, such as superior flatness, excellent light transmission and outstanding process robustness, it is no surprise that BOROFLOAT® glass has become the ideal wafer substrate glass for anodic bonding and a widely recognized standard material for MEMS processes in general. Indeed it recently generated significant interest in the semiconductor industry as a promising UV-transparent carrier wafer material. Lowering cost and improving the functionality of wafers are two key requirements in supporting the advancement of new technologies. Reduced material usage in form of thinner silicon wafers not only lowers cost but, often more importantly in today’s gadget market, allows for the design of smaller, more lightweight devices with enhanced battery life.

2. The ideal substrate for anodic bonding
Anodic bonding is widely used to combine silicon wafers with borosilicate glass to cap MEMS, other electronic and optical parts or to seal microfluidic devices. A perfect match between the two substrates is essential for good bonding behavior. BOROFLOAT® glass’ unique thermal, mechanical and chemical properties meet the stringent requirements for gap free and long lasting material bonds.

2.1 Thermal properties
Exceptional flatness, an extra-low defect level and a perfect match in thermal expansion are the foremost requirements for a strong and gap-free bond. The picture below shows the thermal expansion behavior of BOROFLOAT® glass over a wide temperature range in comparison to silicon.

Bonding time and temperature play an important role for good bonding behavior and many publications have been released that provide optimized parameters [1], [2], [3] for such processes.


d| Thermal properties
---|---
| Coefficient of Linear Thermal Expansion (C.T.E.) $\alpha_{(20-300 \, ^\circ C)}$ | $3.25 \times 10^{-6} \, K^{-1}$ * |
| Specific heat capacity $c_p_{(20-100 \, ^\circ C)}$ | 0.83 kJ/(kg·K) |
| Thermal conductivity $\lambda_{(90 \, ^\circ C)}$ | 1.2 W/(m·K) |

* According to ISO 7991.

Maximum operating temperatures

| For short-term usage ($\leq 10 \, h$) | 500 °C |
| For long-term usage ($\geq 10 \, h$) | 450 °C |

* The maximum operation temperatures for BOROFLOAT® should be seen in conjunction with RTD (Resistance to Thermal Difference) and RTS (Resistance to Thermal Shock) values. Such values and test methods are available on request.
2.2 Mechanical Properties

Many wafers require microstructures which are often created via ultrasonic drilling, powder blasting or a combination of photolithography and dry etching [4]. Mechanical strength and stability during a process where thousands of accurate features have to be machined are essential in order to produce high precision textured wafers with a consistently perfect surface pattern and accurate size. As shown in the picture below, BOROFLOAT® glass has an exceptional abrasion resistance compared to other alternative substrates.

BOROFLOAT® glass has an exceptional abrasion resistance compared to other alternative substrates.

2.3 Chemical Properties

Outstanding chemical resistance is another critical feature given that wafers are exposed to many chemicals throughout the highly sophisticated etching and chemical mechanical planarization (CMP) processes.

In certain technologies, mask-based chemical etching technologies using an aggressive cocktail of corrosive chemicals are also applied in order to create high definition surface channels where the high chemical durability of BOROFLOAT® 33 is key to deliver perfectly shaped design structures of unmatched accuracy with controlled channel depth.

Resistance to alkalis

Alkal resistance of BOROFLOAT® 33 as a function of temperature (moderate loss of mass).

Resistance to acids

Acid resistance of BOROFLOAT® 33 as a function of temperature (very low loss of mass).
3. Carrier wafers with unmatched light transmission allow for exceptional UV bonding

The incessant trend towards smaller, more lightweight devices with 3D design architecture calls for ultra-thin silicon wafers with very high flatness levels (at present glass wafers with total thickness deviations smaller than a micron are available). To achieve the steadily increasing functionality demanded by the market, higher yield rates are required and this will ultimately necessitate larger wafers at lower cost in the near future. However with larger and thinner wafers, process stability often becomes an issue. One solution is to temporarily bond the silicon wafer to a tooling part called the “carrier wafer” which serves as flat support during silicon wafer thinning. There are many different temporary wafer bonding technologies and as processing time is an essential cost factor in semiconductor wafer production, de-bonding time and achieving a surface cleanliness without imperfections play an important role.

3.1 Optical properties

Laser de-bonding through glass carrier wafers offers the fastest de-bonding time as well as a good price / performance ratio. Deep UV light transmission at the relevant laser wavelength range is crucial for the principal feasibility and efficiency of this type of wafer de-bonding. The laser-activated release will be achieved through irradiation using a 248 nm or 308 nm excimer laser. Extra-low iron BOROFLOAT® glass of desirable 0.5 mm carrier thickness shows over 90 % transmission at 308 nm and still over 35 % for 248 nm, thus significantly outperforming other thin flat glasses.

3.26 3.2 The sum of its properties is what makes it unique

In-line with anodic bonding requirements, a perfect C.T.E. match to silicon is a MUST for all carrier wafers used for temporary bonding processes. Any difference in thermal expansion between the silicon and the glass support wafer would destroy the stringent requirements placed on the finished multifunctional silicon wafer.

Besides thermal and chemical resistance, the process robustness of BOROFLOAT® glass is another important advantage as carrier wafers are to be used over many silicon wafer processing and thinning cycles. They are recycled after each use and excellent abrasion and scratch resistance lengthen the lifetime and lower the cost for carrier wafers.

BOROFLOAT® is the perfect choice for glass wafers that are permanently or temporarily bonded to silicon or other glass wafers. The sum of its properties is what makes it unique in a vast number of wafer-type applications because it allows for economical processing of high quality products with different features.

Comparison of different glass materials

<table>
<thead>
<tr>
<th>SCHOTT BOROFLOAT® 33</th>
<th>SCHOTT AF 32® eco</th>
<th>Corning® EAGLE XG®</th>
<th>Asahi EN-A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Linear Thermal Expansion (C.T.E.) α (λ = 550 nm) x 10^{-6} K^{-1}</td>
<td>3.25</td>
<td>3.2</td>
<td>3.17</td>
</tr>
<tr>
<td>Refractive index n (λ = 550 nm)</td>
<td>1.47</td>
<td>1.51</td>
<td>1.51</td>
</tr>
<tr>
<td>Young’s Modulus (according to DIN 13316) kN/mm²</td>
<td>64</td>
<td>74.8</td>
<td>73.6</td>
</tr>
<tr>
<td>Chemical Durability: 24 h at 95 °C 3% Vol. % HCl</td>
<td>&lt;0.01</td>
<td>1.1</td>
<td>0.79</td>
</tr>
<tr>
<td>24 h at 95 °C 3% Vol. % NaOH</td>
<td>1.1</td>
<td>–</td>
<td>1.83</td>
</tr>
<tr>
<td>20 min. at 23 °C 15 % H2SO4</td>
<td>5.18</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Transmission in UV range of 0.5 mm glass sample (Typical excimer laser wavelength)</td>
<td></td>
<td></td>
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<tr>
<td>248 nm</td>
<td>88 %</td>
<td>62 %</td>
<td>13 %</td>
</tr>
<tr>
<td>308 nm</td>
<td>62 %</td>
<td>88 %</td>
<td>78 %</td>
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</tbody>
</table>

In Fig. 1: UV-Transmission for typical carrier wafer thickness 0.5 mm
4. Outlook

BOROFLOAT® is one of the leading, most well-established glass wafer materials used in the semiconductor industry today. Over the years, it has acquired an outstanding reputation worldwide as a result of its broad adoption across many existing and emerging applications. Indeed the material is often now used as the high quality benchmark against which all other glass types are measured.

The success story of BOROFLOAT® in the semiconductor industry will continue to gain momentum. Having inspired engineers and designers all over the world to break new barriers in technological advancements, SCHOTT remains committed to innovation and continuous improvement to ensure that it provides the highest quality solutions to meet the ever evolving requirements of our customers. Working closely with customers to overcome even the most demanding application requirements, our profound know-how and collaborative spirit ensure that BOROFLOAT® will continue to inspire the semiconductor industry for years to come and set the performance benchmark for advanced flat glass materials everywhere.

BOROFLOAT® - Inspiration through Quality

Literature