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Enabling photonic system integration by applying glass based microelectronic packaging approaches

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Abstract. Advanced hybrid packaging technologies are used to enhance functionality of glass-based substrates featuring electrical, thermal and optical components including laser diodes, modulators, isolators, photonic integrated circuits, beam-splitters and micro lenses. Such glass-based substrates can be either thin glass layers on large panels containing optical waveguides or more mini-bench-like boards. Optical fiber interconnects, plugs, and electrical-optical integration platforms are used for higher level system integration. We discuss thin glass as a suitable base material for ion exchanged waveguide panels and interposers, precise glass structuring for posts and holders, electrical wiring and the related high precision assembly techniques.

1 Introduction

In this work we address photonic systems in the size range of mm to cm focusing on miniaturization, small module integration, and manufacturing. The need is driven by increasing optoelectronic device diversity, progress in micro-optics and the broad range of materials to adress wavelength specific applications requirements.

Photonic packaging has to follow advances in chip and component manufacturing. Apart from vertical cavity surface emitting laser, edge emitting laser and photo diodes, photonic integrated circuits with integrated active and passive optical functionality require platforms for higher level system integration. It turns out that edge coupling is the most promising approach, e.g. for the development of compact laser sources, but issues stemming from low tolerance to optical misalignments and thermal effects of glued interfaces have not yet been fully resolved.

2 Glass Integration Platform

Thin glass has several advantages over other widely used substrate materials, such as silicon and organic materials [1–3]. The specific dielectric properties of glass provide a high integration potential by combining electrical and optical functionalities in a single substrate. Despite being very thin, panels, as well as the machinery to handle and structure them, are continuing to increase in size and decrease in cost. The composition and tempering of glass, to increase its robustness, e.g. in mobile electronic devices, has also progressed remarkably. Considering the thickness of the used glass substrates we distinguish the thin glass layer concept (sub-mm range) from the glass board concept (mm range) which are described in the following.

Thin glass as interposer material will facilitate thinner consumer products, communication and compute devices with increased bandwidth and performance, and high integration in photonic sensors.

Using thicker glass highly stable and miniaturized optical systems on glass boards can be defined - either standalone or embedded into a PCB environment, with or without integrated optical waveguides. Such glass boards host optical and electrical signal distribution, free-space optical elements, and transparent windows with or without additional beam shaping optics, hermetically sealed capping and interfaces to optical fiber interconnects. To create such complex systems, photonic design for packaging, advanced glass structuring technologies and electronic packaging are merged with high-precision assembly.

2.1 Thin glass layer concept for PCB integration

The combination of electrical circuits and optical waveguides in one circuit board enables high speed signal transmission and a high density of integration. In most cases an optical layer, based on glass is laminated into a standard printed circuit board. However, the excellent properties of glass in terms of dimension stability, electrical high frequency and a significantly increasing mechanical strength, also allow so called electro-optical circuit boards to be fully made of glass [4].

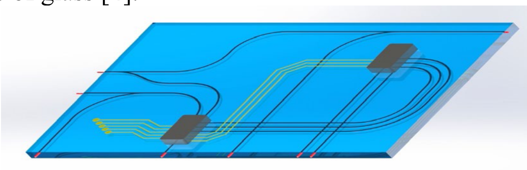

Fig. 1: Schematic drawing of a thin glass layer containing optical waveguides (black) and electrical wiring (yellow) on the top surface.

As shown in Fig. 1, optical waveguides are integrated into the glass, electrical circuits are applied and both optical and electrical components are placed on the board. Such platforms can be realized in single- and double-sided configurations. The application dependent build-up features the flexibility and diversity known from PCB manufacturing. Symmetrical approaches with one central layer only have been developed, but also glass panels with two optical layers on bottom and top side, as well as multilayer boards of stacked or large horizontal glass layer design [4, 5]. The optical waveguides are required to have low propagation loss and can be designed to operate in both single- or multi-mode regime. The process specific gradient index profile is favorable for low signal dispersion communication channels. Waveguides that can fulfill these requirements can be manufactured using an ion-exchange process, in which silver ions replace sodium ions and thus provide a locally increased refractive index.

2.2 Glass board concept and housing

For many photonic applications miniaturized optical benches have to be protected by transparent (hermetic) housings with integrated optical features like lenses, gratings or fiber feed troughs. To configure such micro-optical benches mechanical fixtures made of glass, adapters and posts are structured to not only align various micro-optical or electrical-optical components to the optical axis, but to also include visual and handling features for increased process reliability in automated assembly environments[9]. Especially aspherical or free form optical components often have to be aligned with all six degrees of freedom, often to a precision of less than 500 nm and a few arc seconds.

Fig. 2 shows an example of a rather thicker and stiffer optical bench-like board concept with housing, which includes micro-optic, opto-electronic, and electronic components and connectors. Structured thin metallization on glass that can be electrically bonded enabling co-packaging of surface mounted electronics in the direct vicinity of optical sources or detectors. Component and alignment accuracies are in the 1 to 20 µm range depending on the intended optical performance in free space beams that are split, coupled, combined on the optical board.

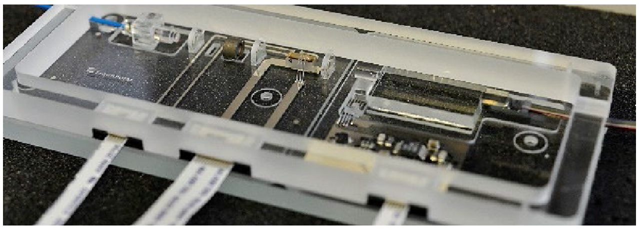

Fig. 2: Glass-based electro-optical micro-bench for optical spectrum analysis including micro-optics (filters, isolators, lenses), assembled by sequential active alignment with temporary fixing of components using integrated vacuum-channels, and metallization (solderable, and wire-bondable) to include electro-optical and electronic features (EOM, TIA, PIC).

Stacking of laser structured thin glass has much potential for cost-effective further development: The assemblies as introduced here can be sealed with glass frames and lids, creating compartments with optical windows for thermally isolated or hermetic operation. Here, the inherent low thermal conductivity and transparency of thin glass are advantageous. Thermal and electrical through glass vias TGV can also be created where needed. In Fig. 3 a multi-chip package made of glass using panel level technologies is shown.

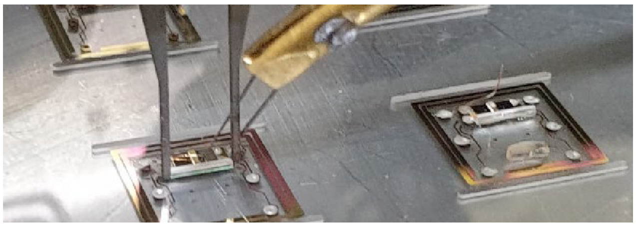

Fig. 3: Automated assembly of small (9x9x0.7) mm^3 laser packages with appropriate lenses and optical edge windows on panel before stacking, hermetic sealing, and subsequent singulation by means of laser structuring.

References

1. M. Töpper *et al., Proc. ECTC*, Las Vegas, NV, Jun. 2010 - Jun. 2010, pp. 66–73.
2. L. Brusberg *et al., Proc. ECTC*, Las Vegas, NV, Jun. 2010 - Jun. 2010, pp. 269–274.
3. M. Neitz *et al.*, *Proc. ECTC)*, Orlando, FL, USA, May. 2017 - Jun. 2017, pp. 538–544.
4. H. Schröder *et al.*, *Proc. ECTC*, Las Vegas, NV, May. 2016 - Jun. 2016, pp. 468–476.
5. L. Brusberg *et al.*, *J. Lightwave Technol.*, vol. 34, no. 10, pp. 2540–2551, 2016
6. T. J. Cullen *et al.*, *Optics Letters*, vol. 10, no. 4, pp. 134–136, 1984.
7. X. Xu *et al., Photon. Res.*, vol. 8, no. 9, p. 1541, 2020
8. J. Beltran Madrigal *et al., Applied Optics*, vol. 55, no. 36, pp. 10263–10268, 2016,
9. W. Lewoczko-Adamczyk, *et al.*, Proc. *ECTC)*, San Diego, CA, May. 2018 - Jun. 2018, pp. 1136–1139.