High Density Optical Transceiver Packaging using Glass Substrates and Through Glass Vias

Kevin Burt
Samtec Optical Group
Samtec, Inc
New Albany, USA
kevin.burt@satmec.com

Joe Ahadian
Samtec Optical Group
Samtec, Inc
New Albany, USA
joe.ahadian@samtec.com

Chris Bohn,
Samtec Optical Group
Samtec, Inc
New Albany, USA
chris.bohn@samtec.com

John Coronati
Samtec Optical Group
Samtec, Inc
New Albany, USA
john.coronati@samtec.com

Marc Epitaux
Samtec Optical Group
Samtec, Inc
New Albany, USA
marc.epitaux@samtec.com

Adam Owens
Samtec Optical Group
Samtec, Inc
New Albany, USA
adam.owens@samtec.com

Nathan Robertson
Samtec Optical Group
Samtec, Inc
New Albany, USA
nathan.robertson@samtec.com

Sandra Skendzic
Samtec Optical Group
Samtec, Inc
New Albany, USA
sandra.skendzic@samtec.com

***Abstract*— Through glass vias (TGV) are an emerging technology that enables electrical interposers with advantages over organic substrates. These advantages include excellent dimensional stability, a coefficient of thermal expansion (CTE) more closely matched with silicon dies, high thermal stability and high electrical isolation. These are all beneficial to the increased data rates that are required in modern systems. In addition, TGV can be beneficial for optical transceiver packaging design that supports higher data rates as well as higher densities. We describe the benefits of TGV technology in the design of an optical engine capable of supporting 112 Gbps channels with industry-leading density.**

Keywords—Through Glass Vias, Redistribution Layer, Multimode Optical Engine, High Density

I. INTRODUCTION

The continued growth of cloud computing, data centers and AI continue to push the capabilities of optical transceivers by demanding higher bandwidths, lower costs and higher-density packaging. While many companies are working on single-mode base silicon photonics designs, there is still an opportunity[1] for multi-mode based optics that can offer cost-based solutions. These multi-mode devices require new packaging techniques to reduce their size, increase the density and support the higher data rates.

II. THROUGH GLASS VIAS

Similar to the metal vias used in organic PCB, Through Glass Vias (TGV) are simple holes through a glass substrate that are filled with a conductive material to produce electrical connections. TGV produce a significantly higher density, allowing pitches in the range of 80 µm to 150 µm versus a more standard 150 µm to 300 µm of organic PCBs. These pitches are comparable to those of semiconductor die and are a key component in enabling 2.5D and 3D packaging of chips[2]. An example of a glass substrate showing TGC is shown in Fig, 1.

In addition to enabling vertical packaging, TGVs offer the following advantages:

- TGVs are typically shorter and have smaller dimensions compared to wire bonds or flip-chip connections resulting in a lower parasitic capacitance and inductance. These performance improvements are beneficial to high-frequency applications
- TGV allows a direct connection to electronic components on either side of the glass substrate, which minimizes signal reflections that can occur at transition points between different interconnection materials (e.g., wires, solder bumps). TGVs reduce these issues, resulting in cleaner and more reliable signal transmission.
- TGVs can also aid in heat dissipation [3] due to the high density of thermally conductive material in the VIAs. These can provide a direct thermal path away from the chip, reducing the effective operating temperature of the chip.
- TGV substrates are transparent allowing optical signals to be routed directly through the material.
- TGV and the substrates may be hermetic [4] allowing for added protection in harsh or wet environments.

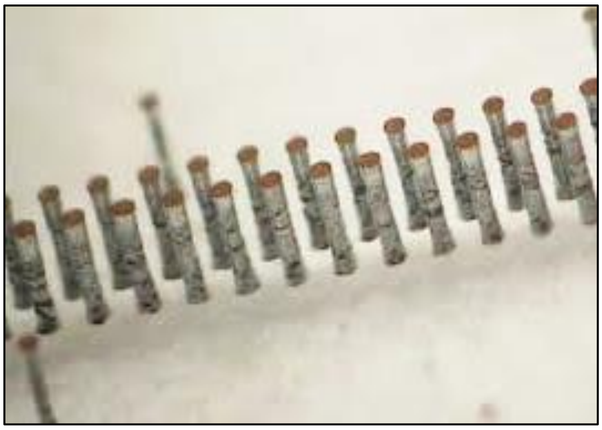

Fig 1. Photograph of TGVs in a Glass Substrate

Modern TGV implementations can include Redistribution Layers (RDLs) similar to those used in organic PCBs. These extend the advantages of TGV to include:

- RDLs can change the pitch of connections to allow for easy integration and connection of different chip packages.
- RDLs can be designed to distribute power and ground connections to the active components. This will help maintain stable power to high-performance/power devices, minimizing the potential for voltage drops across a device.
- RDLs allow for the easy integration of passive components to help with decoupling or power filtering.
- Multilayer RDL structures can further increase the density of 3D packaging by populating more components in a smaller package using both sides of the substrate.

Fabricating RDLs requires additional processing of the glass substrate both before and after the TGVs are created and generally uses standard manufacturing processes from both PCB manufacturing and wafer processing. RDLs provide a structured layer of metal traces on the glass substrate, allowing for the efficient routing and distribution of signals across the device.

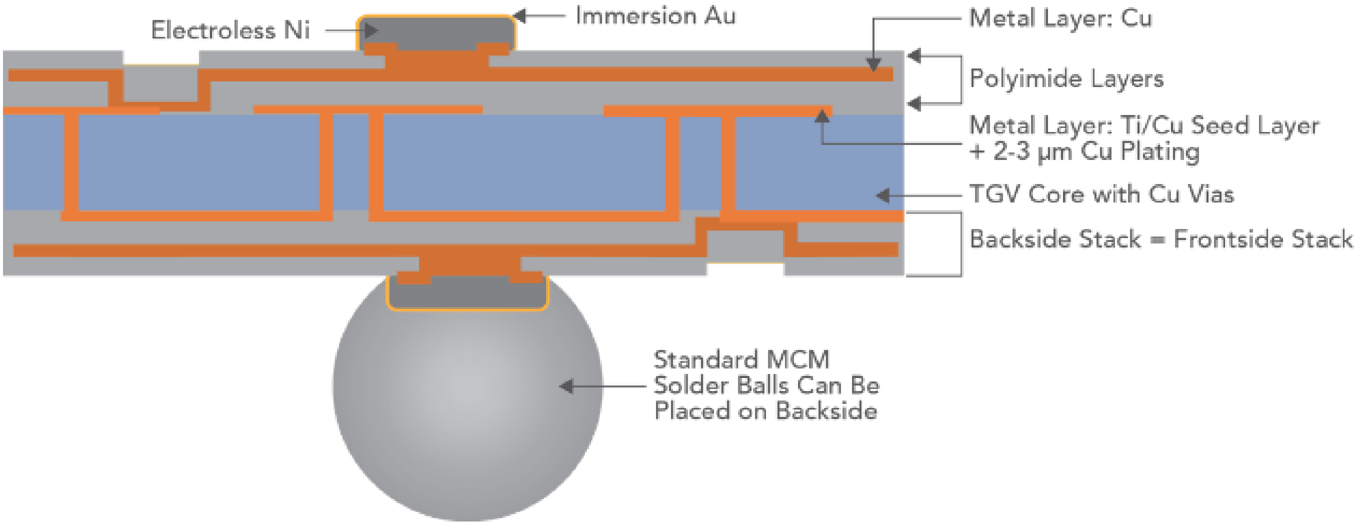

Fig 2. Cross-Sectional Image Showing a Solderable RDL Implementation

III. Optic Transceiver using TGV

The advantages previously listed for TGVs and a glass-based RDL are advantageous for high-speed multi-mode transceivers. Fig 3. shows a photograph of a glass interposer for an 8-channel bidirectional optical transceiver capable of transmitting 450 Gbps.

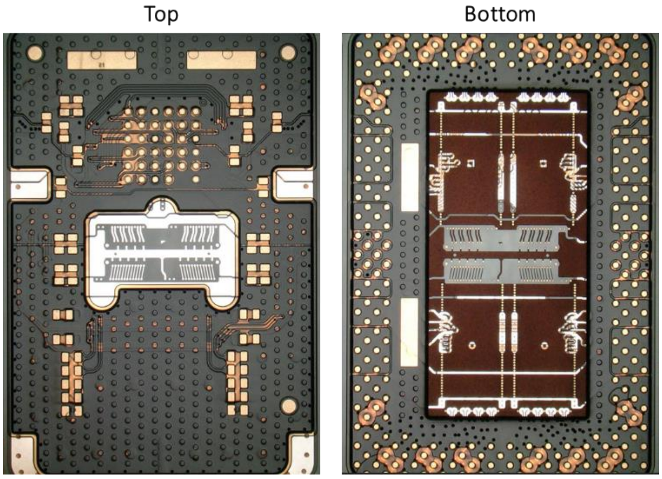

Fig. 3, Photograph Showing the Top and Bottom Sides of an TGV Based Interposer for an Optical Transceiver

Critical components required for the transceiver are attached to glass substrate this board as shown in Fig. 4 and Fig. 5.:

- A microcontroller that automatically configures the device so that it works over temperature and life. It also allows an external user to configure the device to their exact requirements.
- VCSEL arrays that generate the optical signal.
- Multichannel LASER Drivers that convert the input differential voltage into a current suitable for the VCSEL array.
- Photodiode arrays that convert the incoming optical signal into a current.
- Transimpedance Amplifiers (TIA) that convert the current into a differential voltage.
- Lens array that helps focus the optical signals, allowing for high coupling efficiency between the optical arrays and the optical fibers.
- Passive components that provide power filtering for the LASER driver and TIA.

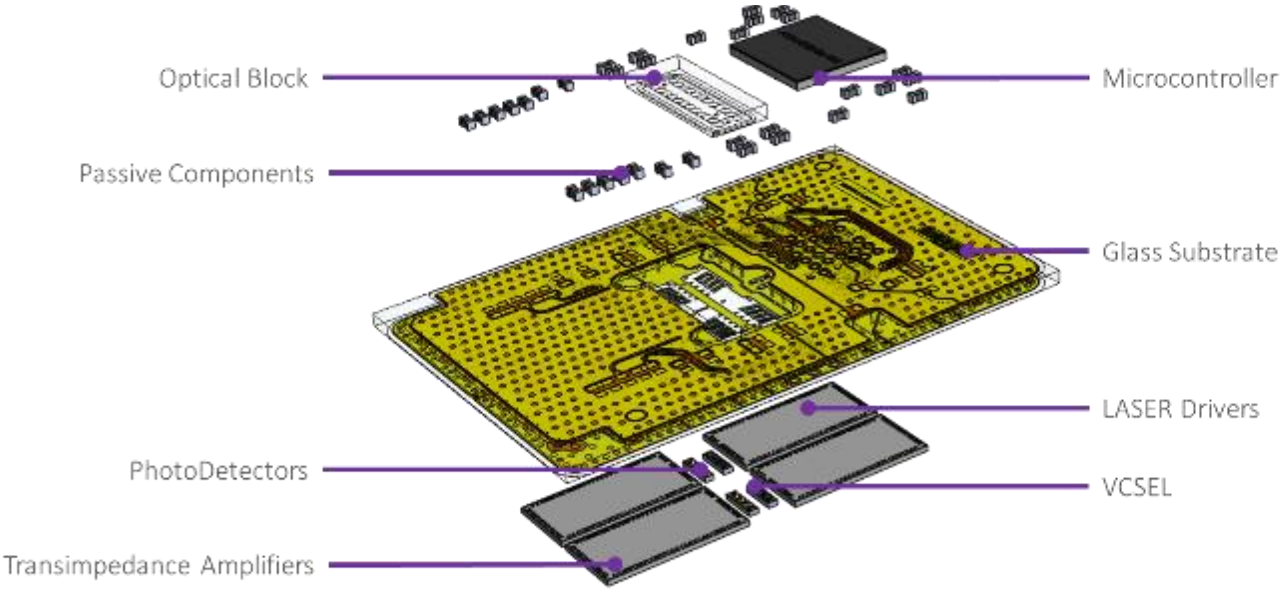

Fig. 4. Exploded CAD view of the Components Attached to the Glass Interposer

Because the glass substrate uses TGVs and RDLs, it allows:

- The optical chips to be bonded upside-down to the underside of the board with short traces between them. Since there is no need to have wirebonds providing connections to and from the chips, this reduces the crosstalk between channels.
- The optical output from the laser (and input to the photodetectors) is transmitted through the interposer. Because this window is intrinsically part of the substrate, it means that no additional space is required for attaching a window to the interposer/PCB.
- A simple 1-dimensional routing of the high-speed data connections to the LASER driver and the TIA without needing to go through VIAs.
- Underfill/sealing of the optical components, protecting them from extreme environments or moisture.
- Power filtering (function of the passive components) to be placed extremely close to the critical components that need clean power supplies (LASER driver and TIA).

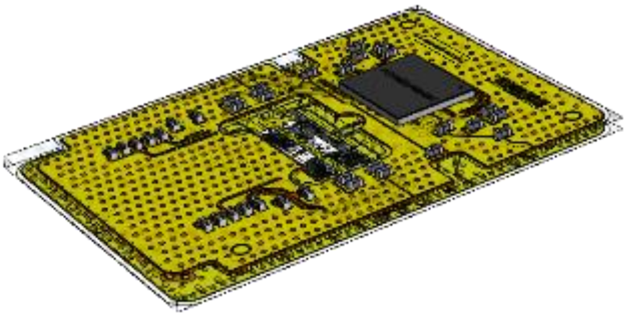

Fig. 5. CAD view of a Completed Glass Interposer

The optical path through the window is vertical. To minimize the size of the finished transceiver, it is necessary to change this to a horizontal path. To achieve this, an optical block is used to reflect the light to the horizontal plane as well as to ensure a maximum coupling efficiency to and from the optical fibers. A computer rendering of this optical block is shown in Fig 6.

The optical block is attached to the glass interposer using epoxy and allows a fiber pigtail with an industry-standard 24 fiber MT optical connector to be connected to it.

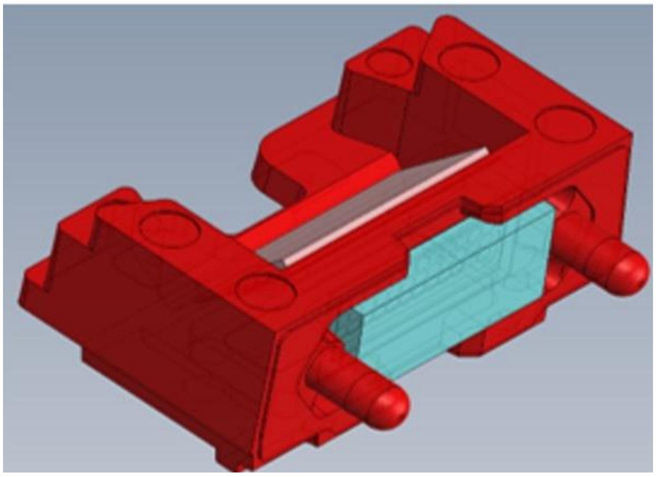

Fig. 6: CAD view of the Optical Lens

Fig 7. Shows an exploded view of a near-package optical transceiver designed around this TGV interposer. The TGV optical engine and the top half of a ring connector are soldered to an organic substrate, which adds robustness as well as easy power/data connectivity. The finished size of this optical transceiver is less than 20 mm x 30 mm x 6 mm. Figure 8 shows an alternative integration of a dual glass substrate optical engine which is considerably smaller than industry standard form factors.

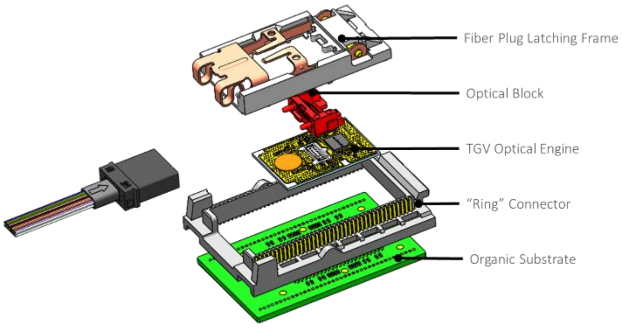

Fig. 7. Exploded CAD View of an Optical Transceiver Using TGV

Fig. 8: Size Comparison of a TGV-Based Optical Transceiver Versus Industry Standard.

IV. PERFORMANCE

The 56 Gbps optical and electrical performance of the optical transceiver was evaluated using eye diagrams. Sample eye diagrams for a single channel are shown in Fig. 9. Wide open eyes were achieved on all channels. Further evaluation is planned.

V. CONCLUSIONS

We demonstrated the packaging of a multi-mode optical transceiver that uses a TGV interposer with an RDL. This transceiver has good performance at 56 Gbps and significantly increases the bandwidth density compared to industry-standard form-factors with an equivalent bandwidth.

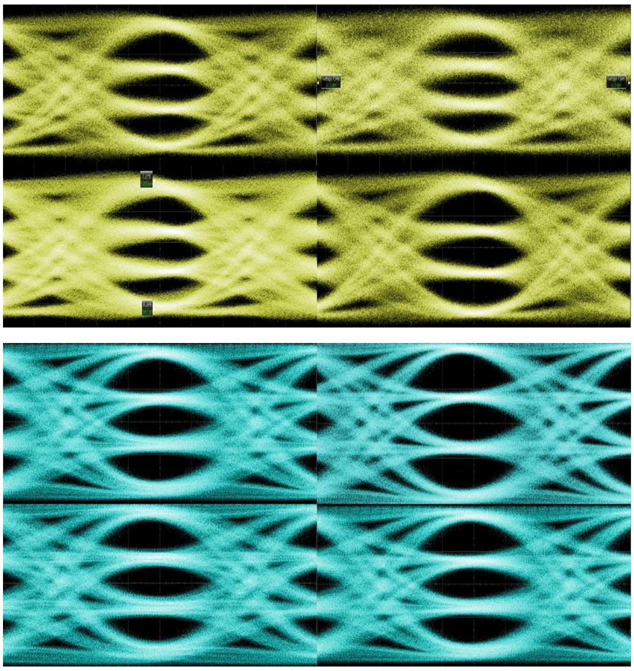

Fig 9. Optical (Top) and Electrical (Bottom) Eye Diagrams

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