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Optical Pitch Transformer Chiplet for Glass Interposer: Concept and Feasibility Study

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***Abstract*—We propose the use of optical-pitch-transformer chiplets, which can be micro-transfer-printed onto glass interposers for beachfront density enhancement. Simulation shows that SiN taper coupling to glass waveguide behaves differently depending on functionality as an emitter or a receiver.**

Keywords— Heterogeneous platform; packaging technology.

I. INTRODUCTION

Packaging and integration of Si-PIC systems remain an under-studied field, with majority of the activities focusing only on achieving the best fibre-to-PIC coupling efficiency [1], either through design improvements or machine enhancements. We opine that attention should also be paid to the next stage of photonic systems integration [2, 3] that involves a) higher density of components with different functionalities within a package and b) the possibility of wafer/panel level integration of such systems. For example, beachfront density of PIC has been an area of interest due to its potential to reduce the overall size of PIC component [4]. However, to increase beachfront density of PIC, fibre array unit (FAU) must shrink in sizes too. Although there have been development works that goes down to 80 µm v-groove pitch, 127 µm pitch remains the smallest that most supplier would supply with confidence.

II. CONCEPT AND APPROACH

Fig. 1 shows the concept of an optical pitch transformer (patent pending), which can be fabricated separately on a source wafer, released from bulk substrate and then micro-transfer-printed onto a glass or silicon interposer. One end of the chiplet can have waveguide pitches matching that of PIC, while the other end matching that on the interposer or FAU and microlens array (MLA). The thickness of the chiplet can be varied with multiple layers of waveguides incorporated, eliminating the need for additional cavity formation on interposer for electrical interconnects. The interposer would have straight passive optical waveguides, such as polymer waveguides [5] or ion-exchanged waveguides [6] incorporated onto it with pitches matching that of standard FAU or MLA components. The interposer would also have typical electrical interconnects (not shown) such as bond pads with under bump metallization (UBM) on top and bottom surfaces, redistribution lines and layers (RDL) and through vias (TGV or TSV). Low temperature transient liquid phase bonding (TLP) such as [7] can also be used as electrical interconnects between PIC and interposer.

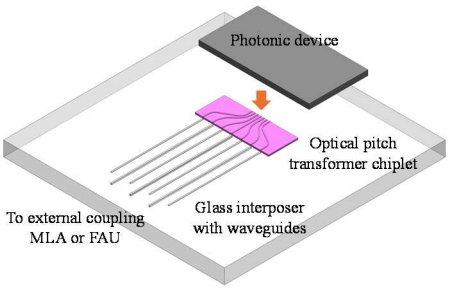


Fig. 1. 3D illustration of the optical pitch transformer concept.

III. SIMULATION AND ANALYSIS

The current configuration assumes a) silicon waveguide and taper on the PIC, b) silicon nitride waveguide and taper on the optical chiplet, and c) ion-exchanged waveguide embedded in the glass interposer. There is a layer of adhesive between the PIC and optical chiplet and between optical chiplet and glass interposer, which can be spin-coated and patterned. The optical transmission from the PIC to interposer would occur evanescently through the chiplet.

To better understand the coupling behaviors at 1550 nm wavelength, we first ran EME for basic parameters sweeping and then FDTD simulations for its ability to differentiate directionality [8]. Coupling studies between Si and SiN are widely available in the literatures; thus, we look only at the coupling effect between SiN and ion-exchanged waveguides here. We study the behavior of 1mm long SiN taper as an emitter (coupling into ion-exchanged waveguide) and receiver (coupling from ion-exchange waveguide) incorporating lateral misalignment, adhesive layer thickness and refractive index differences. We fixed the SiN thickness to 0.2 µm and its taper length to 1 mm to limit the computational requirements of FDTD. We assume standard material parameters of both Si and SiN, while for ion-exchanged waveguide, we adopted those from [9, 10].

A. Effect of SiN taper size

We first explored the taper width design using EME, assuming no oxide below SiN layer and 1 µm adhesive thickness, before subsequently increasing the oxide thickness. Results showed that a taper width of 0.45 µm provides the best coupling efficiency, and while no oxide below SiN provides the best coupling efficiency, we believe that having at least 0.1 µm oxide is beneficial to prevent the layer from being damaged due to post processing and handling.

B. *Behavior of SiN taper as transmitter and receiver*

Next, we move on to FDTD simulation using the best-case scenario from EME to evaluate the SiN taper's coupling performance, either as an emitter or as a receiver. We can see that SiN taper is sensitive to lateral misalignment when it functions both as an emitter and receiver. However, coupling from ion-exchanged waveguide into SiN taper (as a receiver) incurs higher losses compared to the former. For example, considering the case with 0.5 µm adhesive thickness and refractive index of 1.5. With perfect alignment (y-position = 0), coupling loss of a SiN emitter is 1.34 dB but is 1.91 dB as a receiver. Increasing the adhesive layer from 0.5 µm to 1µm further increases the coupling loss by almost two times regardless of functionality. Thus, from the simulation results, SiN taper will likely have to be designed from a functionality perspective instead of a common design for both emitter and receiver.

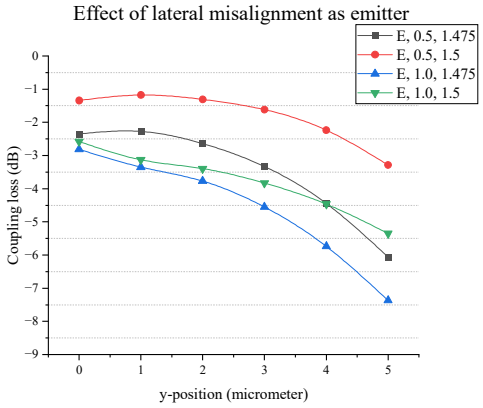


Fig. 2. Effect of lateral misalignment as an emitter, showing that losses increase as the SiN taper moves away from the centre of the ion-exchange waveguide.

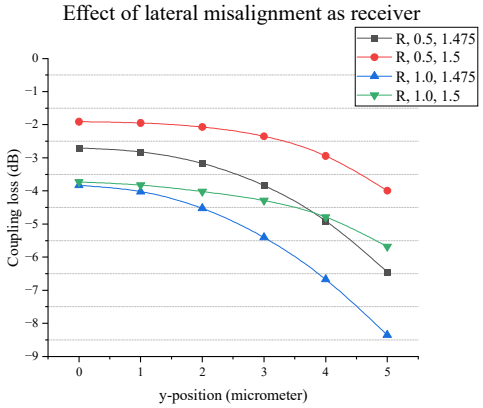


Fig. 3. Effect of lateral misalignment as a receiver, following similar trend as emitter but with higher losses.

IV. CONCLUSION

We proposed the concept of optical pitch transformer chiplet for photonics integration platform and explored the coupling feasibility to ion-exchanged waveguide. While the current simulation results were limited to 1mm coupling length due to available computational resources, EME simulations showed that the coupling efficiencies will increase with longer length. FDTD results showed that SiN inverted taper behaves differently depending on its functionality, and two separate taper designs may be needed as emitter and receiver respectively.

ACKNOWLEDGMENT

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REFERENCES

[1] R. Marchetti, C. Lacava, L. Carroll, K. Gradkowski, P. Minzioni, "Coupling strategies for silicon photonics integrated chips," Photon. Res. 7, 201-239 (2019), doi: 10.1364/PRJ.7.000201

[2] H. Y. Hwang and P. O'Brien, "Photonic Chiplet Integration on Optical Interposer: Can Hybrid Bonding Realize Passive Optical Coupling?" 2024 Photonics & Electromagnetics Research Symposium (PIERS), Chengdu, China, 2024, pp. 1-7, doi: 10.1109/PIERS62282.2024.10618259.

[3] S. Wakeel, P. E. Morrissey, H. Hwang, P. O'Brien, "Demonstration of Micro-transfer Printing Thick Optical Components on Glass and Silicon Wafers.," The 25th European Conference on Integrated Optics. ECIO 2024. Springer Proceedings in Physics, vol 402. Springer, Cham., doi: 10.1007/978-3-031-63378-2_14.

[4] H. Y. Hwang et al., "128 × 128 silicon photonic MEMS switch package using glass interposer and pitch reducing fibre array," 2017 IEEE 19th Electronics Packaging Technology Conference (EPTC), Singapore, 2017, pp. 1-4, doi: 10.1109/EPTC.2017.8277436.

[5] R. Dangel et al., "Polymer Waveguides Enabling Scalable Low-Loss Adiabatic Optical Coupling for Silicon Photonics," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 24, no. 4, pp. 1-11, July-Aug. 2018, Art no. 8200211, doi: 10.1109/JSTQE.2018.2812603.

[6] J-E. Broquin, S. Honkanen, "Integrated Photonics on Glass: A Review of the Ion-Exchange Technology Achievements," Applied Sciences. 2021; 11(10):4472, doi: 10.3390/app11104472.

[7] J. B. Lee, H. Y. Hwang, M. W. Rhee, MW. "Reliability Investigation of Cu/In TLP Bonding," J. Electron. Mater. 44, 435–441 (2015), doi: 10.1007/s11664-014-3373-1.

[8] H. Y. Hwang, "Integrated Silicon Photonics Packaging," Chapter 5, Ph.D. Thesis, University College Cork, 2019. https://cora.ucc.ie/items/ee90f8c0-a684-48cf-9e24-3b6171bdd808.

[9] L. Brusberg et al., "Glass Substrate With Integrated Waveguides for Surface Mount Photonic Packaging," in Journal of Lightwave Technology, vol. 39, no. 4, pp. 912-919, 15 Feb.15, 2021, doi: 10.1109/JLT.2020.3033295.

[10] L. Brusberg, M. J. Dejneka, C. A. Okoro, D. J. McEnroe, A. R. Zakharian and C. C. Terwilliger, "Ultra Low-Loss Ion-Exchange Waveguides in Optimized Alkali Glass for Co-Packaged Optics," 2024 IEEE 74th Electronic Components and Technology Conference (ECTC), Denver, CO, USA, 2024, pp. 85-89, doi: 10.1109/ECTC51529.2024.00023.