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Angled 3D Glass-to-SiPh adiabatic coupler

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Concept Despite the promise of Silicon Photonics (SiPh) towards next-generation deployments seamlessly combining the on-chip advanced optical functionality with efficient E/O and O/E conversion, their wide penetration across all communication layers is currently hindered by the lack of efficient and scalable optical input-outputs (I/O) that can be realized using standard low-cost assembly equipment. To this end, diffraction-based structures, such as grating couplers, have been lately superseded by in-place coupling solutions employing inverse tapers [1] or metamaterial waveguides [2] in order to achieve coupling to SMFs through spot-size conversion. Nevertheless, those structures suffer from either increased fabrication complexity, including material engineering and undercut waveguide sections, or considerable losses due to poor mode matching. Recently, a very interesting concept was presented by Soganci et al. [3], proposing a compliant polymer interface between SMFs and nanophotonic waveguides, relying on adiabatic coupling. The first experimental demonstration of the interface [4] revealed the necessity of a well-defined, angled adhesive gap so as contain the scattering loss at the chip edge that is degrading the performance. However, considering the coefficient of thermal expansion (CTE) mismatch between the polymer and the SiPh chip, such an accurate control over the adhesive gap will significantly increase the intricacy of the assembly process.

In the current manuscript we propose and simulate, an adiabatic coupling scheme between a 2 degrees angled 3D glass waveguide and a SiPh platform, as shown in Fig. 1. The concept relies on the simultaneous and reverse tapering of the two waveguide cores, that increases the coupling performance and reduces the coupling length, while it alleviates the edge chip scattering loss thanks to the angled approach. The 3D glass waveguide exhibits a mode diameter of about 7um and it relies on the 3D waveguide inscription technology developed by Optoscribe.

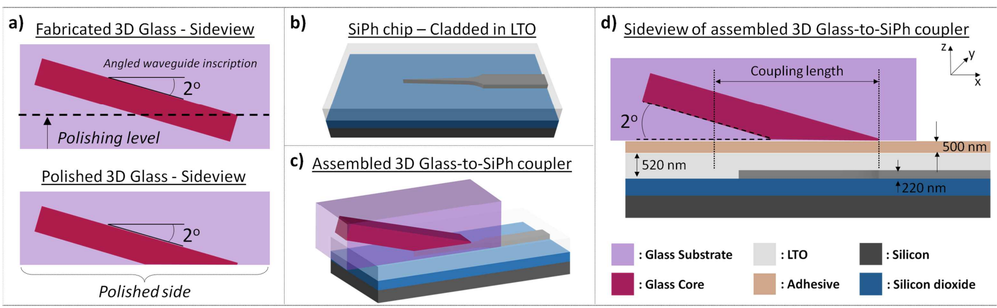

Fig. 6. (a) Angled 3D glass waveguide, (b) SiPh chip, (c) 3D sketch and (d) Sideview of the assembled 3D Glass-to-SiPh coupler

Access to the glass waveguide, prior the assembly, can be achieved by regular polishing (Fig. 1a). The SiPh chip employs 220nm top-Si strip waveguide configuration, with

450nm nominal waveguide width and 520nm LTO cladding (Fig. 1b), whereas a 500nm-thick adhesive gap, separating the two platforms, is also considered. A 3D sketch and a sideview of the assembled structure are shown in Figs. 1c and 1d.

Simulations Coupler's design relies on the calculation of the optimum taper shape that will allow for maximum power coupling within the coupling length that is firmly specified by the angle of the glass waveguide. The ends of the tapering sections of both waveguides are aligned (marker A, Fig 1d) and the assembled structure is backwards divided into fixed-length segments. For each segment, the width of the silicon waveguide is varied and the excited supermodes are calculated, employing Lumerical's Finite Difference Eigenmode solver (FDE). The optimum silicon width is chosen based on the simultaneous fulfillment of the two following criteria: (i) the overlap integral between the fundamental TE supermode of the current and the previous segment should lay within 0.9975 and 0.9999, (ii) the supermode's effective index should be equal or higher than the effective index of the glass mode so to avoid leaky mode excitation. The resulting taper shape is shown in Fig. 2a revealing a rather slow slope from 170nm to 240nm and fast transitions before and after that. The minimum silicon width was 150nm so as to enable standard photolithography and avoid e-beam.

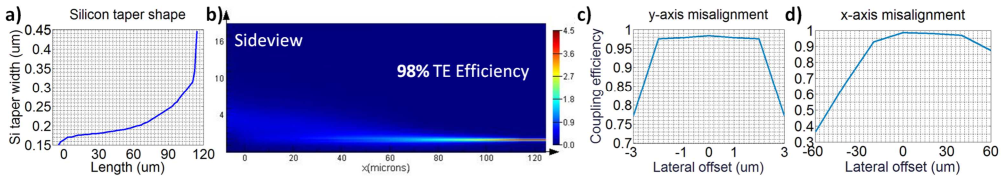

Fig. 2. (a) Silicon taper shape, (b), Sideview of the EME TE propagating field, and effect of the (c) y-axis and (d) x-axis lateral assembly misalignments on the coupling efficiency

The coupler design was then imported into a 3D Eigenmode Expansion (EME) propagation simulation environment under the assumption the 2 degrees angle of the propagating field can be ignored. The overall TE glass-to-silicon coupling efficiency was found to be 98% while the coupling length was as low as 120um. A sideview impression of the TE propagating field is shown in Fig. 2b. The effect of the lateral assembly misalignments on the coupling efficiency was also briefly investigated using the EME solver. The results shown in Fig. 2c and 2d indicate adequate tolerance to lateral misalignments both along the y- and the x-axis, enabling the use of low-cost passive alignment assembly equipment.

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