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GUEST EDITORIAL

Special Section Guest Editorial: Packaging Challenges of Photonic Integrated Circuits

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The rapid evolution of photonic integrated circuits (PICs) has propelled innovation across various applications, from telecommunications to data centers and sensing technologies. Substantial investments in PIC technologies have primarily focused on enhancing the performance of the PIC chip itself. However, despite significant strides in chip-level advancements, the packaging and assembly processes have emerged as critical bottlenecks, impeding the seamless commercialization of full-system solutions.

This special section highlights the interdisciplinary challenges inherent in PIC packaging, shedding light on the complexities involved in integrating advanced packaging materials, precision optical assembly, PIC testing and thermal management.

As passive and active components tend to be integrated with an increased density, thermal management becomes crucial to achieve adequate cooling and to avoid issues with thermal cross-talk. Coenen et al. reported on the thermal modeling of three-dimensional integrated, silicon photonic–electronic transceivers. Flip-chip bonding of photonic to electric ICs on micrometer scale is needed, when performance requests low electrical parasitics, respectively high frequency operation. A comparison of transceiver performance before and after PIC integration reveals strong effects on thermal efficiency and cross talk, which are investigated as functions of the 3D interconnection. Verification by experiments and simulation of favorable thermal designs is presented, particularly taking micro bumps, Cu lines, underfiller, and substrate undercuts into account.

Gupta et al. discuss a novel method to integrate micro-thermoelectric coolers (micro-TEC) in a glass substrate which can serve as an advanced interposer for co-packaging photonics and electronics. These coolers can be applied for temperature control or temperature stabilization and consist of vias half-filled with p- and n-type thermoelectric materials and half-filled with copper. A detailed finite-element simulation was performed to study the effect of several parameters on the cooling performance. It was found that optimizing the via diameter, height, and pitch can greatly affect the cooling performance. Although the current cooling capacity is still inferior to that of free-standing micro-TEC devices, further improvements can be expected when expanding the technology to multilayer glass substrates.

Getting light efficiently in and out of a PIC is another crucial and widely researched topic. This special section has two papers related to the use of microlenses to facilitate coupling between fiber (arrays) and a PIC. Wakeel et al. developed a scalable assembly method for thick optical components, such as microlens blocks, using micro-transfer printing. Although until now transfer printing has mainly been used for thin elements, the authors successfully applied the technology for thick components and demonstrated accurate placement and bonding of lens blocks (accuracy around 1 μm) aligned with grating couplers on a PIC. Missinne et al. reported on the use of a micro-ball lens to allow coupling from the PIC back side so that the device side remains accessible for sensing. Besides, the authors described the whole packaging process that

was required to transform a small PIC into a functional temperature sensor probe compatible with commercial readout equipment.

A final paper, from Howard, Sukovaty, and Brown, reports on scattering elements that can serve as elegant optical test points for monitoring guided light's polarization in optical waveguides. These elements are characterized by negligible loss and compatibility with foundry processes. Experimental validation is also reported. Some designs demonstrated very good polarization extinction values, reaching up to 146. Such elements can for example be used to monitor the fiber alignment more easily in the process of fiber-to-PIC attachment.

We thank the authors for contributing to this special section, which covers several important topics related to packaging of PIC. We hope this special section reveals that considering packaging aspects is crucial in transforming PICs into working products and that it inspires researchers to increasingly invest in novel packaging-related developments.