Micro-transfer printing for silicon photonics

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Abstract: We describe our work on heterogeneous photonic integrated circuits realized using micro-transfer printing, a versatile integration approach for the integration of III-V semiconductors, LiNbO3 and silicon photonic/electronic chiplets on Si/SiN photonic integrated circuits.

1. Summary

Silicon photonic integrated circuits leverage the advanced CMOS fabrication infrastructure to realize compact photonic ICs in high volume and at low cost. However, the platform needs to be augmented with features that cannot easily be integrated in silicon, such as laser sources, efficient and ultra-high speed optical modulators, etc. Several approaches are being developed to realize this heterogeneous integration: wafer-scale flip-chip or pick-and-place of laser diodes, die-to-wafer bonding, micro-transfer printing and hetero-epitaxial growth. Micro-transfer printing is an approach that is based on the processing of the to be integrated components on a separate wafer (e.g. a III-V wafer fabricated in a III-V fab), followed by a release process, allowing to pick-up the thin-film components with a stamp and print them on a silicon photonic target wafer with high alignment accuracy (state-of-the-art printing tools allow for an alignment accuracy better than +/- 0.5 micron). After printing, the heterogeneous integration is completed typically by a metallization to connect the devices to the back-end of the silicon photonics circuit. The technique combines some of the advantages of flip-chip integration and die-to-wafer bonding integration. The techique uses a known-good-die concept, where devices are fabricated prior to integration such that they can be wafer-scale tested beforehand, similar to flip-chip. It has the potential to be a high-throughput integration approach as stamps as large as the reticle size (for the highest alignment accuracy) and as large as the wafer size (for lower alignment accuracy needs) can be used, and a printing cycle takes less than 1 minute. This high throughput is similar to a die to wafer bonding approach. Finally, it is a back-end integration technique, similiar to flip-chip integration, requiring no redevelpment of the silicon process flow, similar to flip-chip integration. Current developments focus on establishing the supply chain (i.e. have foundries realize transfer-printable chiplets) and demonstrating high yield printing of reliable opto-electronic components. At the conference we will describe the use of micro-transfer printing to realize InP and GaAs heterogeneously integrated lasers (either widely tunable lasers, single frequency DFB lasers, modelocked lasers or VCSELs) integrated on a photonic integrated circuit. We are also working towards the integration of III-V single photon sources on Sin PICs. Also GaAs, InP, GaSb and Si photodiodes have been integrated using micro-trasnfer printing. Next to that we will discuss our progress in micro-transfer printing of LiNbO3 films on SiN waveguide circuits, both for efficient electro-optic modulation and second harmonic generation.

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