III-V/Silicon Photonics for Optical Interconnects: Bonding Technology and Integrated Devices

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Abstract: The heterogeneous integration of III-V components and silicon-on-insulator waveguide circuits using DVS-BCB adhesive die-to-wafer bonding is presented. Advances in the fabrication of laser diodes and photodetectors in the bonded epitaxial layer structure are reported.

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1. Heterogeneous III-V/silicon photonics through DVS-BCB adhesive die-to-wafer bonding

Silicon-on-insulator (SOI) is emerging as a promising platform for large scale integrated photonic circuits. This is due to the high omni-directional refractive index contrast and the ability to fabricate the photonic components using standard CMOS technology. Light emission and amplification in silicon is hampered by its indirect band gap. Therefore, the heterogeneous integration of III-V material on top of passive SOI waveguide circuits is proposed to create photonic integrated circuits in which the passive optical functions are implemented on the SOI platform, while active optical functions like light emission and photodetection at telecommunication wavelengths are implemented in the III-V layer. Die-to-wafer bonding of III-V dies onto the processed SOI wafer using DVS-BCB adhesive wafer bonding was developed [1]. DVS-BCB was chosen as bonding agent due to its optical transparency, its excellent planarization properties, its low curing temperature (200-250C), the fact that no outgassing occurs during cure and its high glass transition temperature (>350C), determining the available post-bonding thermal budget for the fabrication of the laser diodes and photodetectors. After bonding of the III-V dies (epitaxial layers down), the InP growth substrate is removed and active devices can be processed in the III-V epitaxial layer structure, lithographically aligned to the SOI waveguide circuits.

2. Laser diodes and photodetectors integrated on top of passive SOI waveguide circuits

Both III-V laser diodes and photodetectors were fabricated in the bonded III-V waveguide layer and coupling to the underlying SOI waveguide circuit was demonstrated [2]. The influence of the self-heating of the laser diodes due to the low thermal conductivity DVS-BCB bonding layer is tackled by integrating a heat sink structure using plated gold contacts. While the first batch of devices are Fabry-Perot laser cavities, advances are being made towards single longitudinal mode light emission from bonded DFB/DBR laser diodes and microdisk lasers. Several types of photodetectors were integrated on top of the SOI waveguide circuit. While a reverse biased laser diode acts as a photodetector with an experimental responsivity of 0.23A/W at 1550nm, the device footprint is relatively large and the fabrication is rather complex. Therefore, a new type of waveguide-coupled metal-semiconductor-metal (MSM) photodetector was designed and fabricated, yielding a responsivity of 1.0A/W at 1550nm on a smaller footprint and with less complex processing [3].

3. References

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