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FACULTEIT INGENIEURSWETENSCHAPPEN

DVS-BCB Bonded, Hybrid III-V/Si Laser

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I. INTRODUCTION

Silicon photonics is a fast-developing research area, based on the use of silicon and the well-known processing technology from electronics that enables fabrication of passive and some active devices in integrated photonic circuits. Silicon, being transparent at communication wavelengths (1.3 µm and 1.5 µm), has a great potential for high-speed communication photonic devices. However, making a light source in silicon is a very serious challenge, due to its indirect bandgap. One way to solve this problem is to integrate III-V semiconductor materials (providing the light emission) with the SOI (Silicon-On-Insulator) waveguide platform fabricated by standard, low-cost, CMOS processes.

One approach in this hybrid integration is based on evanescent coupling between optical modes in the III-V layer and the SOI waveguide. Several hybrid lasers, based on this principle and emitting at 1.31 µm and 1.55 µm, have been recently demonstrated [1][2][3][4]. These devices were based on a molecular wafer bonding procedure, requiring very clean, contamination-free and smooth bonding surfaces. Therefore, this technique may not be robust enough for industrial scale fabrication where such strict requirements are difficult to meet.

In this paper, we present the design of a hybrid III-V/Silicon evanescent laser and its fabrication procedure based on an adhesive die-to-wafer bonding technique, using a commercially available DVS-BCB[1] polymer, as an alternative to the molecular bonding.

II. HYBRID LASER DESIGN

The layout of the proposed hybrid III-V/silicon evanescent laser is given in Figure 1. The underlying Si rib waveguide is made on a standard SOI platform (1 µm thick buried oxide layer) with waveguide thickness of $H = 500$ nm, rib etch depth of $R = 220$ nm and the waveguide width of $W = 1.2$ µm. The epitaxial III-V structure is bonded on top of the SOI waveguide, using a spin-coated DVS-BCB adhesive layer. The n-type InP spacer layer and the mesa are on top of it. From bottom to top, the mesa comprises a multiple quantum well (MQW) region (8 QWs and 9 barriers, made in InGaAlAs, for λ=1.3 µm), a carrier blocking (CB) layer, a separated confinement heterostructure (SCH) layer, a p-type InP top cladding layer and an ohmic contact.

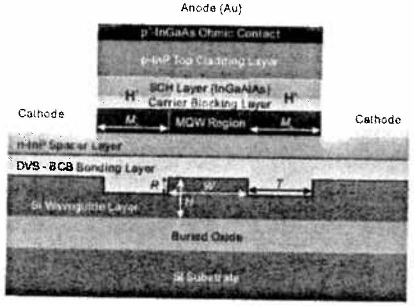

Figure 1. Hybrid laser cross-section

For effective evanescent coupling, distance between the III-V active layers and the SOI waveguide must be sufficiently small (<350 nm), so the bonding layer of BCB must be very thin (<120 nm). Main idea of this design is to make the fundamental hybrid mode mostly confined within the Si waveguide, with only a fraction of its power (sufficient to sustain laser operation) within the MQW layers. In this way, no additional light coupling (taper, for example) is necessary, as the bulk of the optical power is already confined within the Si waveguide. Based on the optical simulations, the optimal design parameters were chosen, enabling to achieve confinement factors for the fundamental mode within Si waveguide and MQW layers of ~70% and ~3%, respectively. Chosen design parameters also provide tolerance to small variations of the BCB layer thickness.

To excite the fundamental optical mode (but not other, higher modes), the current flow through device is confined via proton implantation in the lateral parts of mesa. To enhance device thermal properties, addition of a thermal via is also planned. This is of particular importance due to very poor heat conducting properties of BCB. Thermal simulations confirmed that such via can reduce the device thermal resistance by 30%.

III. DEVICE FABRICATION PROCESS

Fabrication of the hybrid lasers according to this design comprises three phases. In the first phase, SOI and III-V epi wafers are fabricated according to the specific designs in dedicated fabrication facilities. In the next phase, III-V and SOI dies are bonded at the UGent cleanroom, using specially developed BCB bonding procedure, based on the use of a wafer bonding machine. This process creates a BCB bonding layer of specific and uniform thickness, which is important for device properties and yet very difficult to achieve in a manual bonding procedure. In addition, machine bonding is performed in vacuum, excluding a possibility of trapping air bubbles within the BCB bonding layer, which would degrade the bonding quality.

After the bonding is finished, a third fabrication phase follows in which processing of the bonded III-V die is performed. In a series of processing steps (based on photolithography), III-V islands and mesas are formed, both n-type and p-type contacts are formed and proton implantation is performed. Finally, individual devices are diced (or cleaved) and tested.

IV. CONCLUSIONS

A hybrid III-V/Silicon evanescent laser, emitting at λ = 1.3 µm has been designed based on optical and thermal simulations. To enhance its thermal properties and help efficiently remove heat generated during laser operation, a thermal via has been added to the design. Device fabrication process, including a machine-based BCB bonding procedure, has been developed and thin BCB bonding layers, required for evanescent coupling, have been achieved in preliminary tests. In the future work, we will use this process to fabricate hybrid lasers according to this design and characterize them.

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[1] divinyl siloxane-benzocyclobutene