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µ-Transfer printing of GaSb-based gain elements for integrated external cavity lasers at 2 µm range

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Abstract: Micro transfer printing of GaSb-based gain elements transferred to silicon photonics platform is reported for the first time. Using a distributed Bragg reflector fabricated utilizing silicon-on-insulator technology and the GaSb integrated gain chip, a single frequency external cavity laser emitting at around 1.96 µm is demonstrated.

1. Introduction

Over the past decade, the use of transfer printing (TP) technology for release and transfer of III-V optoelectronic materials to silicon photonics integration platforms has been well developed for InP and GaAs-based materials [1]. At the same time, the need to ensure a broader wavelengths versatility has been recognized as being instrumental for leveraging the advantages of photonic integration to a wider base of applications. To this end, hybrid integration approaches, including µ-TP, provide the flexibility to combine different III-V materials with silicon photonics to access multiple wavelength ranges on a single platform. More recently, the development of hybrid integration of heterostructures covering the 2 µm wavelength range has recently gained attention [2,3]. For example, mid-IR light sources are needed in sensing applications ranging from atmospheric sensing of environmental gasses to biomedical sensors able to detect biomarkers for such as lactate, glucose, or urea. In this respect, the use of GaSb based materials allows the transition to mid-IR wavelengths between 2 and 3 µm and even beyond, as this is where the spectroscopic technologies are usually deployed.

Here we demonstrate a µ-TP process applied for hybrid integration of GaSb material system with 3 µm silicon-on-insulator (SOI) platform. In particular, we present a single frequency external cavity laser emitting at around 2 µm comprising a SOI-based distributed Bragg reflector (DBR) and µ-TP GaSb gain membranes. The gain chip is based on AlGaInAsSb/GaSb-based type-I QW-gain structure ensuring low threshold current and operation voltage.

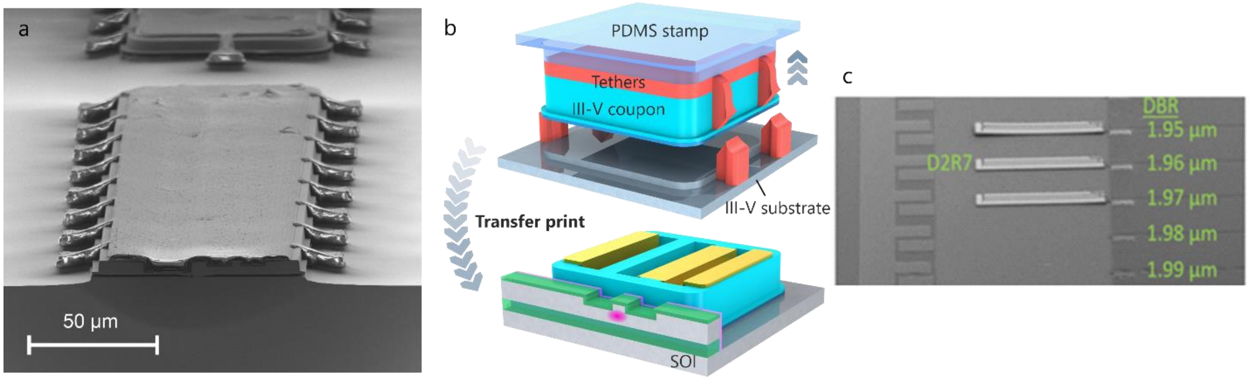

Fig. 1. a) SEM micrograph of partially release etched transfer print coupon suspended with tethers. The release layer is only partially etched here to allow the cleaving of the cross-section sample; b) Illustration of transfer printing of release etched coupon; c) SEM micrograph of transfer printed gain coupons on SOI platform with DBRs.

The idea behind transfer printing is to form functional device "coupons" on the native III-V wafer and transfer one or multiple coupons in one step on silicon photonics integrated circuit. The III-V structure is epitaxially grown on top of a sacrificial layer, i.e., a release layer. Then specific device features, including electrical contact and waveguides are fabricated using standard semiconductor processing methods. In addition, a separate step to define singular device coupons is needed. For in-plane emitting devices this step forms also the etched facets serving as optical output. After the coupon perimeter is defined, a supporting resist tether structure is applied for the subsequent release etch step where the sacrificial release layer is removed through chemical wet etching. The supporting tethers allow the suspended gain coupon (Fig. 1 a) then to be picked up with a polydimethylsiloxane (PDMS) stamp tool and transferred onto the target silicon photonics platform and aligned with the waveguides there (Fig. 1 b). The main strength of the transfer print method compared to alternative hybrid integration methods is the possibility to transfer multiple devices with a single tool yet requiring alignment between waveguides only once. In turn this leads to faster integration process on wafer level.

2. Device design and experimental results

The realization of the gain coupon requires some specific features diverging from the general design of amplifier chips. First, a process to realize the etched facets is required for optical output. The etched facets are also combined with a thin film optical coating, the design of which depends on the type of the gain device. The main device type in this work is a reflective semiconductor optical amplifier (RSOA), with a 7° tilt on the front facet, combined with an antireflection coating (ARC) applied on wafer level to suppress in-plane cavity effects. In lateral direction the amplifier was defined using a 3 µm wide ridge waveguide (RWG). For the back facet of the RSOA a wafer level high reflection coating (HRC) is also required. Finally, an etched area to define the n-contact pad on the epi-side is necessary.

To analyze the effects arising from these design features, when implemented on the final transfer print coupon, we fabricated different types of laser diodes (LDs) with reflecting front alongside the RSOAs. For example, Fig. 2 a) displays the continuous wave (CW) output power and voltage (LIV) measurements from LD and RSOA devices similar to the actual transfer print devices but fabricated so that it was possible to measure them without the release etch.

Finally, we demonstrate the transfer printing of the RSOA coupon on a plain silicon substrate and on a 3 µm SOI platform with a DBR. Figure 2 b) reveals the CW LIV measurements from a coupon transfer printed on plain silicon and measured with single mode lensed fiber. Comparison between Figures 2 a) and 2 b) shows an increase in the voltage for the transfer printed coupon but no observable reduction in output power. Figure 2 c) presents a single mode spectrum measured from a RSOA coupon integrated on the SOI platform driven in pulsed mode at 90 mA. To the bets of our knowledge, this demonstrates the first µ-TP GaSb gain/laser coupons and functional µ-TP-based hybrid GaSb-laser.

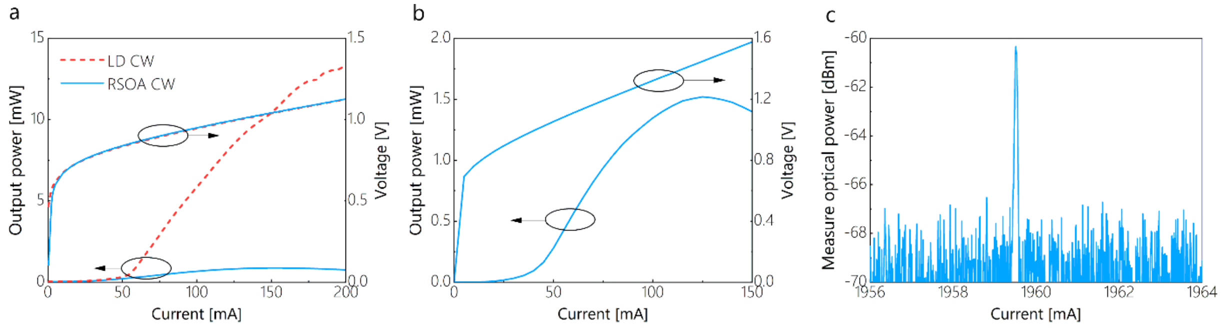

Fig. 2. LIV measurement in CW a) from LD (with an ARC) and RSOA coupons before release etch and b) from transfer printed RSOA coupon. c) Single mode spectrum of a transfer printed RSOA on SOI platform with a DBR.

3. References

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