Recent Progress on GaSb-based Photonic Integrated Circuits

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Despite significant technological achievements in InP-photonic ICs with sampled-grating distributed Bragg reflector (SG-DBR) laser tuning technology near 1.55 µm over the past few decades, such platform in the short-wave infrared (SWIR) or mid-infrared (MIR) regimes has not yet reached its full potential. By employing an InGaAsSb/AlGaAsSb/GaSb gain material and necessary processing steps, we aim to develop photonic integrated circuits (PICs) technology in the GaSb material system. The proposed concept for an agile tunable PIC transmitter is shown in Fig. 1. The SG-DBR lasers are the tunable component and each is limited ~6.5% of the center wavelength in order to obtain a good side-mode suppression ratio using a simple cavity geometry; therefore, multiple SG-DBR lasers will be heterogeneously integrated together to cover the entire tuning range. Tunable light output from the SG-DBR cavity will be amplified in the semiconductor optical amplifier (SOA) to increase power to ~10 mW.

As can be seen in Fig. 1, the wavelength range from 2.2-2.8 µm can be covered with only four chips using broad bandwidth of the gain materials. Second, we integrate each chip with the desired phase modulator. Light will then be coupled from the GaSb PICs to the SOI combiner planar lightwave circuit (PLC). We suggest a simple non-dispersive 4 × 1 combiner as illustrated in Fig. 1. This combiner could be accomplished by the indicated "y-branch" structures or by 2 × 1 multi-mode interference (MMI) structures. Alternative to the non-dispersive combiner, a wavelength selective 4 × 1 MMI can also be thought of.

For the phase modulators, we propose current injection into the passive waveguide regions. The modulation depth is expected to be approximately π radians of phase modulation for a current input of 5 mA with a typical modulator length ~100 µm. The modulation is almost independent of modulator length for current densities in the 0.2-2 kA/cm^2 range. Higher bandwidths are possible by using reverse biased *p-n* junctions, also using the same passive regions of the platform.

The offset quantum-well (OQW) integration platform is chosen for processing SG-DBR lasers and compatible PICs because it requires a relatively simple process. A schematic cross-section of the layer structure of a GaSb-based offset quantum-well (OQW) integration platform is illustrated in Fig. 2(a). After growing the base structures, passive regions were formed by removing the multiple-QW active region from the base structure prior to the regrowth. Atomic steps were observed after MBE regrowth in both active and passive areas with and without MQWs, respectively. The film exhibits atomically smooth surface morphology with root-mean-square (RMS) roughness value of <0.3 nm, as shown in Fig. 2(b)-(c). The presented concepts and encouraging materials growth results pave the way for the realization of transmitter PICs covering a large SWIR wavelength range using GaSb-technology.

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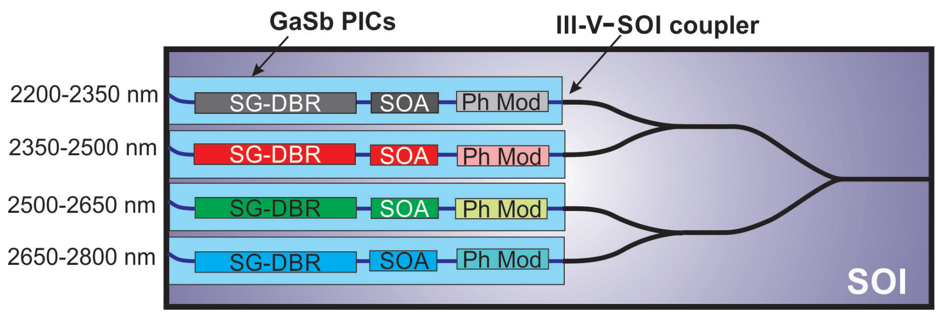

Figure 1: Hypothetical tunable laser design for 2.2–2.8 µm based upon GaSb Photonic ICs. GaSb chip lengths would be about 4 mm.

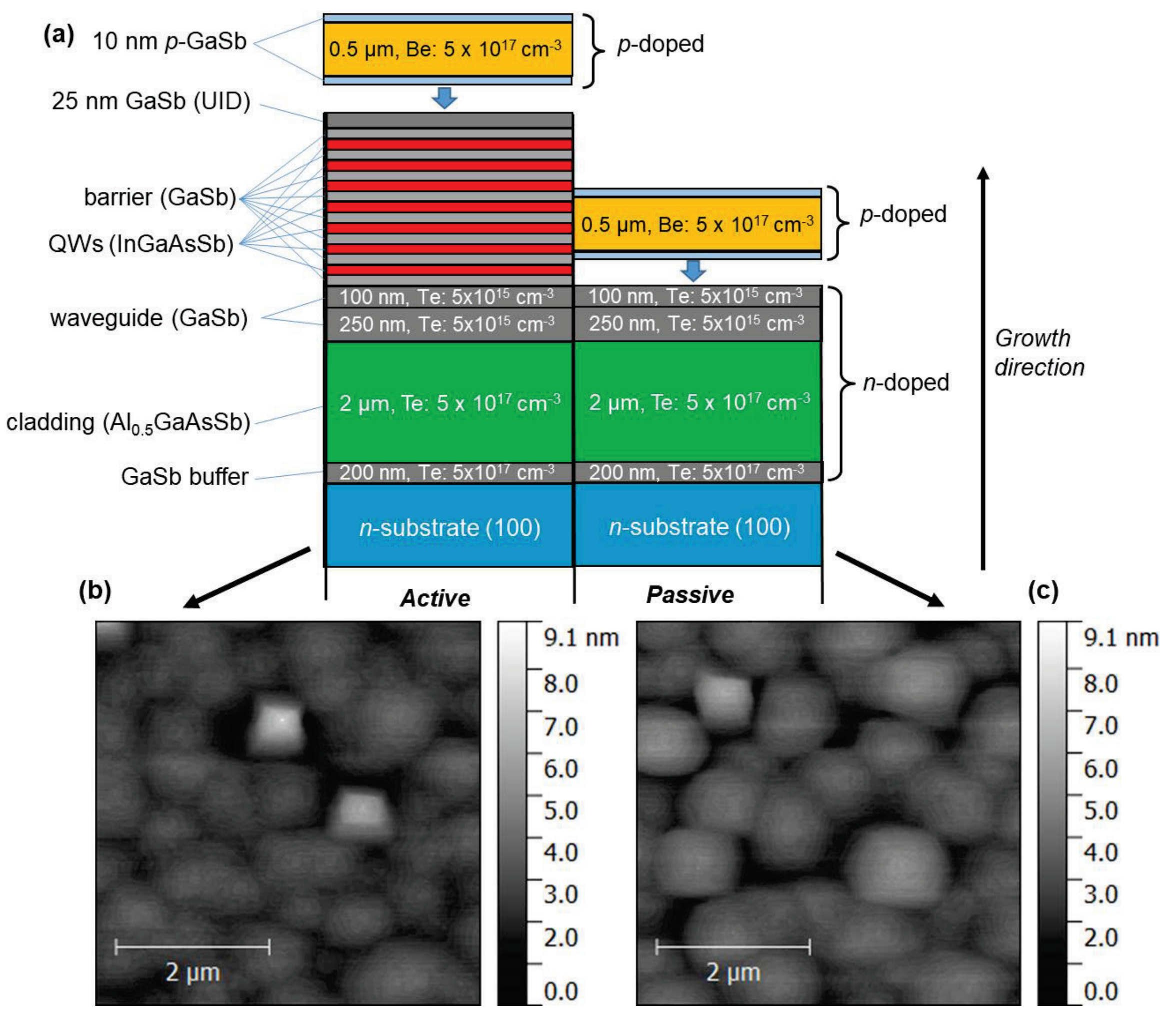

Figure 2: (a) Schematic cross-sectional view of offset quantum-well epitaxial structure – active (left), passive (right) regions with the regrown epilayers on top. 5 µm × 5 µm AFM images of the (b) active (with MQWs) and (c) passive areas (etched MQWs) after MBE regrowth.