SIGE: A MATERIAL PLATFORM FOR NEAR AND MID-INFRARED PHOTONICS

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1. Introduction

The recent push towards chemical and biological sensing in the mid-infrared (MIR) has fostered the need of high performance photonic integrated circuits operating in this spectral region.
In this framework germanium and SiGe heterostructures might enable the development of a photonic platform for mid- and near-IR applications.
At variance with Si and SiO_2, Ge exhibits a large transparency window in the 2 to 14 μm region [1], making it a suitable material for the fabrication of MIR waveguides also thanks to the high refractive index contrast between Ge and Si ($\Delta n = 0.7$).
The key elements of our approach are $Si_{1-x}Ge_x$ graded buffers epitaxially grown on Si. The linear grading of the Ge concentration from Si to $Si_{1-x}Ge_x$ with a properly designed grading rate, allows a unique flexibility to engineer the refractive index profile of the structure, ensuring a strong confinement of the optical mode far from the lossy Si substrate.
In this work, we present our recent results on the broadband operation of low loss waveguides and Mach-Zehnder (MZ) interferometers operating in the MIR.

2. SiGe linearly graded buffers for mid-IR photonics

Linearly graded buffers (GBs) have been known for quite some time [2] as a means to obtain fully relaxed pseudo substrates with a relatively low threading dislocation density. The composition grading results also in the increase of the refractive index which can be exploited to confine the optical mode in the top part of the GB (see Figure 1).
The samples have been grown by low energy plasma enhanced chemical vapor deposition (LEPECVD) on Si (100) substrates. The waveguides have been processed by optical lithography and ICP etching, followed by a wet etching in H_2O_2 to smoothen the sidewalls of the waveguides. The MZ interferometers have been patterned by e-beam lithography and ICP etching.
The fine tuning of the refractive index profile offers an additional degree of freedom in WG design and allows for single mode operation over a large wavelength range (λ=5 - 11.5 μm) with losses typically below 2 dB/cm [3].
The processed MZ interferometers can operate with an extinction ratio higher than 10 dB in the 5.5 – 5.8 μm range for TE and TM polarization. The coupling losses have been estimated to be ≈ 4dB/facet and the propagation losses are lower than 5 dB/cm for both polarizations in the spectral range investigated [4,5].

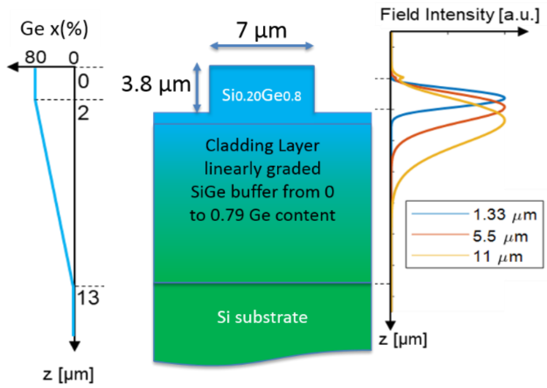

Fig. 1 Refractive index profile of a waveguide based on $Si_{1-x}Ge_x$ GBs and mode confinement at different wavelengths.

3. Conclusions

In summary, low-loss wide-band Ge-rich SiGe waveguides and MZ interferometers operating in the MIR have been demonstrated. The remarkable optical properties of these devices rely on the smooth increase of the refractive index obtainable with the $Si_{1-x}Ge_x$ graded buffers. These results pave the way for the future development of a SiGe based integrated photonic platform operating in the MIR

References

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