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Mid-infrared integrated photonics with Ge-rich SiGe waveguides

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1. Motivation

The recent interest towards applications of spectroscopy for chemical and biological sensing in the mid-infrared (mid-IR) has prompted the need for a new class of photonic integrated circuits operating in this important spectral region. In this context, germanium is considered a key material thanks to its transparency in the 2-15 µm range [1] and its compatibility with standard silicon foundry processes. Ge-rich SiGe layers on top of graded buffers were already successfully employed as waveguides at telecom wavelengths [2] and they were recently proposed as promising platform to develop optical components operating in the mid-IR, offering high versatility and broadband transparency by choosing a suitable Ge content in the alloy and by tailoring the vertical graded refractive index profile to optimize mode confinement. In this work we present our recent results on the realization and characterization of low-loss waveguides and ultra-wideband Mach-Zehnder modulator operating in the mid-infrared. The perspectives about the realization of non-linear devices based on this material platform will also be discussed.

2. Methods

The samples used for this work were grown by Low-Energy Plasma-Enhanced Chemical Vapour Deposition (LEPECVD). The optical devices have been processed by electron-beam lithography and dry etching. The characterization has been performed by using a quantum cascade laser operating in the $\lambda = 5.5$ -8.5 µm spectral range.

3. Results

The sample used for this work consists in an $Si_{1-y}Ge_y$ graded buffer, where the Ge content was linearly increased between 0% and 79%, followed by the deposition of a 2 µm thick, fully relaxed $Si_{0.2}Ge_{0.8}$ layer. The rib waveguides processed out of the epitaxial material have been characterized by the cut-back method. Propagation losses of about 1.5 dB/cm and 2 dB/cm at a wavelength of 4.6 µm were deduced for TE and TM polarization respectively. The propagation losses are similar for all the considered waveguide widths. On the contrary, coupling losses increase for smaller waveguide widths. The fairly good confinement of light at 4.6 μm is illustrated by the optical mode simulation of the

quasi-TE polarization for two waveguides widths (3.5 and 8.5 μ m) (Fig. 1) [3]. The same sample has been used to process and characterize a Mach-Zehnder modulator which fully covers the spectral range comprised between 5.5 μ m and 8.5 μ m [4]. The waveguide design was also theoretically investigated to obtain a tight mode confinement and a flat anomalous dispersion in the 3 μ m – 8 μ m spectral range. The calculated effective non-linear parameter suggests promising performances for supercontinuum generation [5].



Figure 1: Optical mode simulations of the quasi-TE polarization using a finite difference method (FDM) solver at a wavelength of $4.6 \mu m$ for $3.5 \mu m$ and $8.5 \mu m$ wide rib waveguides.

4. Conclusions

Ge-rich SiGe passive optical devices on graded SiGe buffer layer are under investigation as a fundamental building block for mid-IR photonic integrated circuits. Low-loss waveguides and and broadband operation of a Mach-Zehnder modulator have been demonstrated. The simulations show that, by properly engineering the waveguide geometry, this material platform can be used to exploit interesting non-linear phenomena.

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References

- [1] R. Soref, Nat. Photonics, 4, 495 (2010).
- [2] P. Chaisakul et al, Nature Photonics 8, 482(2014)
- [3] J-M. Ramirez et al, Opt. Lett. 42, 105 (2017)

[4] V. Vakarin et al. Opt. Lett. in press (2017)[5] J-M. Ramirez et al, Opt. Expr. 25, 6561 (2017)