Chapter 2
Silicon Photonics

Lorenzo Pavesi

Abstract Silicon Photonics is no more an emerging research topic but is an actual technology with commercial products already available on the market. Quantum confinement of carriers or spatial localization of photons allows enhancing dramatically and widening the scope and potential of silicon photonics.

The tremendous evolution of internet has urged the microelectronic and telecommunication industries to look at technologies to face the bandwidth, speed and power consumptions that internet requires. One technology which is emerging as a comprehensive solution to this is integrated photonics where complexity, reconfigurability and intelligence are thrusts. An ideal platform for such integration is to use the same material that has permitted the success of microelectronics in the last century, i.e., silicon. Silicon photonics is a technology where photonics devices are fabricated by using standard silicon technologies [1–4]. In this way it is possible to leverage on the capabilities of the silicon industry to mass manufacture cheap photonics devices. A key ingredient to achieve this goal is to exploit the high level of integration that parallel and planar processing allows. Still, integration in photonics is limited to few hundreds of different components in a single chip due to the complexity of integrated photonic circuits and to the needs of hybrid integration technologies to face all the different functionalities needed. Nowadays, all the different functions have been generated and integrated in silicon photonics by using silicon based materials or, when they are not possible, hybrid integration [4]. An example of this is the signal source which in silicon photonics is provided by a hybrid III–V on silicon laser.

L. Pavesi (✉)
Nanoscience Laboratory, Department of Physics,
University of Trento, Trento, Italy
e-mail: pavesi@science.unitn.it

© Springer India 2015

V. Lakshminarayanan and I. Bhattacharya (eds.), *Advances in Optical Science and Engineering*, Springer Proceedings in Physics 166,
DOI 10.1007/978-81-322-2367-2_2

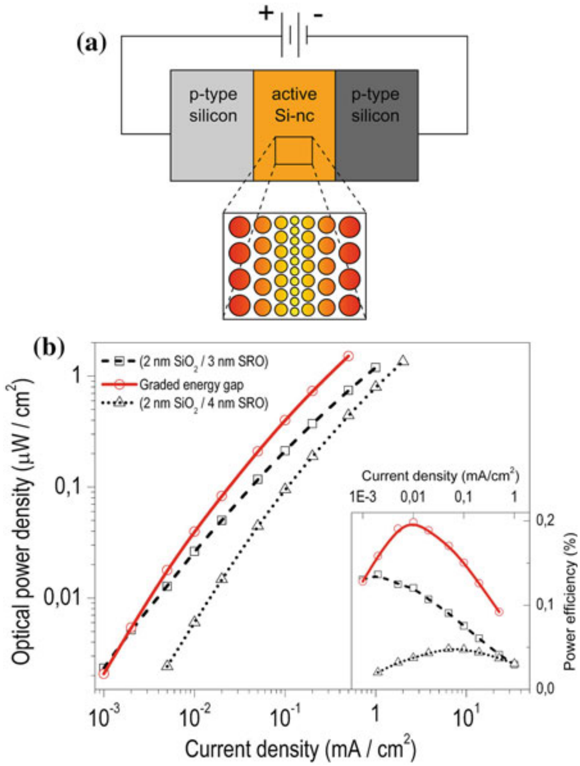

Fig. 2.1 **a** Scheme of graded band-gap LED. **b** Electro-optical characterization of LED with different Si-nc sizes (*black curves*) and multilayer structure (*red curve*). The *inset* shows the power efficiency

Alternatively one can try to change the properties of silicon: the use of nano-silicon is one of such an attempt [5]. The use of nano-Si in silicon photonics (waveguides, modulators, switches, sources and detectors) is reviewed and discussed in [6, 7]. Recent advances of nano-Si devices such as bio-imagers, optical resonators (linear, rings, and disks) are treated in [5, 8]. High efficiency light emitting diodes (Fig. 2.1, [9]) can be used for interchip bidirectional optical transceiver [10]. Silicon nanocrystals improve silicon solar cells [11]. In addition, third order nonlinearities in silicon nanocrystals allow fast all-optical switches (Fig. 2.2, [12]). On the other hand, confinement of photons to small microresonators allows tuning the photon properties [13]. Here also novel effects are found. Ultra high bandwidth robust optical switches for UDWDM [14], active suspended microdisk bistable devices [15], nonlinear optical generations [16] are only few applications where nanophotonics can be appreciated.

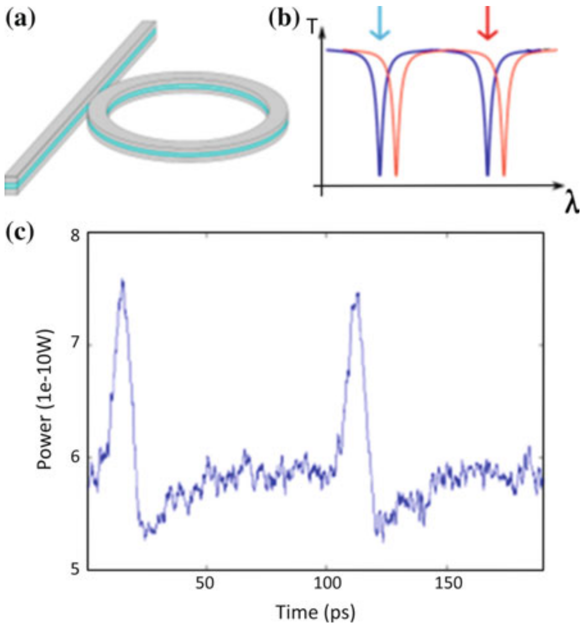

Fig. 2.2 **a** Scheme of the waveguide and the microring. The cyan layer indicates the nanosilicon layer. **b** Switching mechanism: *red arrow* indicates the pump beam, *cyan arrow* the CW signal beam. In the unperturbed state (*blue line*) the transmission of the probe is low, due to the intrinsic ring losses. While pumping (*red line*), a red shift is achieved and the probe beam is temporarily out of resonance and completely transmitted along the WG. **c** Experimental data of the optical switching achieved. FWHM of the pulses is about 20 ps

Acknowledgments This work was supported by ITPAR and the Italian Foreign Ministry.

References

1. Pavesi L, Lockwood D (eds) (2004) Silicon photonics. Topics in applied physics, vol 94. Springer, Berlin
2. Pavesi L, Guillot G (eds) (2006) Optical interconnects: the silicon approach. Springer series in optical sciences, vol 119. Springer, Berlin
3. Lockwood DJ, Pavesi L (eds) (2011) Silicon photonics II: components and integration series: topics in applied physics. vol 119, 1st edn. Springer, Berlin
4. Vivien L, Pavesi L (eds) (2013) Handbook of silicon photonics. CRC Press, Taylor and Francis Group, Florida, 849 pp. ISBN: 978-1-4398-3610-1
5. Pavesi L, Turan R (eds) (2010) Silicon nanocrystals; fundamentals, synthesis and applications. Wiley-VCH Verlag GmbH, Berlin. ISBN: 978-3-527-32160-5 (hardcover 688 pages Mar 2010)
6. Stefano O, Lorenzo P (2003) Priolo Francesco light emitting silicon for microphotonics. Springer Tracts Mod Phys 194:206

7. Gaburro Z, Bettotti P, Daldosso N, Ghulinyan M, Navarro-Urrios D, Melchiorri M, Riboli F, Saiani M, Sbrana F, Pavesi L (2006) Nanostructured silicon for photonics—from materials to devices, volumes 27–28 of materials science foundations. Trans Tech Publications Ltd., Zuerich
8. Daldosso N, Pavesi L (2009) NanoSilicon photonics. Laser Photonics Rev 3:508–534
9. Marconi A, Anopchenko A, Wang M, Pucker G, Bellutti P, Pavesi L (2009) High power efficiency in Si-nc/SiO2 multilayer light emitting devices by bipolar direct tunneling. Appl Phys Lett 94:221110
10. Marconi A, Anopchenko A, Pucker G, Pavesi L (2011) Silicon nanocrystal light emitting device as a bidirectional optical transceiver. Semicond Sci Technol 26:095019
11. Sgrignuoli F, Ingenhoven P, Pucker G, Mihailetchi VD, Froner E, Jestin Y, Moser E, Sánchez G, Pavesi L (2015) Purcell effect and luminescent downshifting in silicon nanocrystals coated back-contact solar Cells. Sol Energy Mater Sol Cells 132:267–274
12. Martínez A, Blasco J, Sanchis P, Galán JV, García J, Martínez JM, Jordana E, Gau-tier P, Lebour Y, Guider R, Pellegrino P, Hernández S, Daldosso N, Garrido B, Fedeli JM, Pavesi L, Martí J (2010) Ultrafast all-optical switching in a silicon-nanocrystal based silicon slot waveguide at telecom wavelengths. Nano Lett 10:1506–1511
13. Pitanti A, Ghulinyan M, Navarro-Urrios D, Pucker G, Pavesi L (2010) Probing the spontaneous emission probability in Si-nc based micro disk resonators. Phys Rev Lett 104:103901
14. Mancinelli M, Guider R, Bettotti P, Masi M, Vanacharla R, Pavesi L (2011) Coupled-resonator-induced transparency concept for wavelength routing applications. Opt Express 19:12227–12240
15. Ramiro-Manzano F, Prtljaga N, Pavesi L, Pucker G, Ghulinyan M (2013) Optical bistability with Si nanocrystals in a whispering gallery mode resonator. Opt Lett 38:3562
16. Cazzanelli M, Bianco F, Borga E, Pucker G, Ghulinyan M, Degoli E, Luppi E, Véniard V, Ossicini S, Modotto D, Wabnitz S, Pierobon R, Pavesi L (2012) Second harmonic generation in silicon waveguides strained by silicon nitride. Nat Mater 11:148–154

Springer

http://www.springer.com/978-81-322-2366-5

Advances in Optical Science and Engineering
Proceedings of the First International Conference, IEM OPTRONIX 2014
Lakshminarayanan, V.; Bhattacharya, I. (Eds.)
2015, XXXIX, 644 p. 399 illus., Hardcover
ISBN: 978-81-322-2366-5