Electrically Pumped GeSn/SiGeSn Multiple Quantum Well Laser Operating in Continuous Wave Mode at Low Temperatures

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Si-based photonic integrated circuits (PICs) in which optically active components are monolithically integrated on chip are transforming the next generation of information and communication technology infrastrucutre[1]. In the quest for a fundamental direct bandgap, group-IV semiconductor alloys have been intensely investigated to obtain an electrically pumped, continuous-wave Si-based laser. Along this path, it has been demonstrated that the electronic band structure of the newly developed GeSn/SiGeSn heterostructures can be tuned, via stoichiometry and strain engineering, into a direct bandgap quantum structure providing optical gain for lasing[2]. In this paper, we present a versatile electrically-pumped laser emitting at a near infrared wavelength of 2.35 µm with a low threshold current of 4 mA (5 kA/cm^2) at low temperatures. It is based on a 6 periods SiGeSn/GeSn multiple quantum-well structure deposited on a Si substrate with a relaxed Ge buffer layer. The small footprint micro-disk cavity laser are fabricated by defining a circular Mesa structure etched through the layer stack down till the Si substrate. Subsequently the rim of the disc was underetched by 900 nm by removing the Ge buffer in this area. The remaining Ge pedestal is used as p-contact area as well as heat sink for the laser (Fig 1 a,b). In this simple construction the actual lattice temperature in the active region is about 60K higher than that of the thermal bath T_b, due to the poor heat conductivity of SiGeSn. However, the laser operates in continuous-wave (CW) regime up to T_b=40K, but can also efficiently work in a direct modulation regime down to ns pulses at T_b=77K.

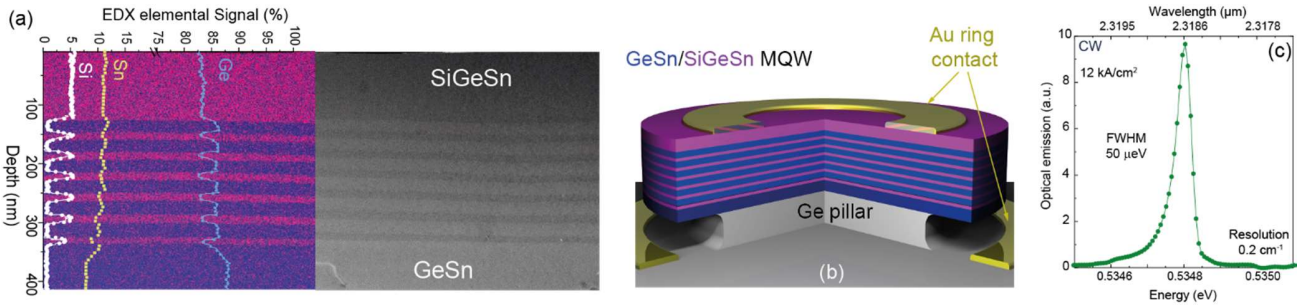

Fig. 1 a) Elemental map of the SiGeSn/GeSn multiple quantum well structure and associated TEM cross section. b) Schematic view of the fabricated device c) High resolution spectrum showing FWHM of 60 µeV, spectrometer bandwidth 25µeV

At higher T_b as well as higher injection currents (>32 kA/cm^2) the laser emission collapses and spontaneous emission is observed. A typical high resolution lasing spectrum with a FWHM of 50µeV is shown in Fig. 1c at T_b=5K and a pump power of 12 kA/cm^2. The demonstration of a CW, electrically pumped, all-group-IV laser is a major breakthrough towards achieving a complete truly-silicon photonics technology platform. It opens up applications ranging from quantum to neuromorphic cryogenic computing, and to the rapidly developing mid-infra-red imaging and sensing.

References

[1] J. Yang, M. Tang, S. Chen and H.Liu, Light Sci. Appl. 12, 12 (2023)
[2] S. Wirths et.al. Nature Photonics 9, 88 (2015).