Advanced CSiGeSn heterostructures for photonic applications

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Group IV materials provide a foundational platform for advancing silicon-based photonics applications. Especially, GeSn-based Group-IV alloys have demonstrated a direct band gap with higher electron mobility, which is beneficial for photonic integrated chips (PIC) and spintronic fields with complementary metal-oxide semiconductor (CMOS) compatibility.[1] A recent breakthrough in the Si photonics field was the demonstration of continuous-wave, electrically pumped lasing based on advanced SiGeSn/GeSn multi-quantum well structures (MQWs).[2] In addition, theoretical calculations predict that C substitution into the Ge and GeSn lattice further improves the fundamental bandgap directness, enhancing laser performance.[3] Moreover, incorporating C as well as Si and Sn into Ge allowed a large tunability of the light emission in the Mid-infrared range of 2-5 µm. However, the low solid solubility and large lattice mismatch mostly limit the substitutional incorporation of C into the Ge diamond lattice.

a) b)

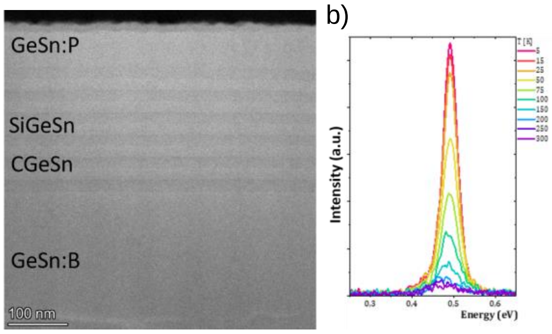

Fig.1 a) Cross-sectional transmission electron microscope (TEM) image of CGeSn/SiGeSn MQWs. b) Temperature dependence EL spectra of the corresponding MQWs for micro-disk LEDs.

We show that the growth of epitaxial C(Si)GeSn alloys on relaxed-GeSn buffer layer instead of on Ge is possible using industrial reduced-pressure chemical vapour deposition (RP-CVD) reactors. Moreover, by controlling the growth conditions, complex CGeSn/SiGeSn heterostructures are feasible without disrupting the diamond cubic lattice, as shown in Fig. 1(a).[4] For photonics applications, MQW heterostructures like 5x {15 nm CGeSn well/ 20 nm (Si)GeSn barrier} have been tested. Electroluminescent (EL) measurements on fabricated vertical microdisk LEDs show light emission at a wavelength of 2.48 µm up to 250K at a current density of 0.7 kA/cm^2, as shown in Fig. 1(b). However, at higher C concentration (>0.2 at.%) crystalline defects are formed, which leads to increased non-radiative Shockley-Read-Hall recombination, degrading the diode performance. Hence, further studies are essential to study the related C and Sn compositions depended emission properties.

References

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