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Room-temperature 1.3μm and 1.5μm Electroluminescence from Si/$Si_{1-x}Ge_x$ Quantum Wells

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Strained SiGe alloys are promising candidates for optical devices. The strained SiGe has a bandgap which spans the low loss optical windows of 1.3μm and 1.5μm used in fiber optics communication and it is compatible with Si VLSI processing technology. Light emission from exciton recombination in electrically pumped strained $Si_{0.85}Ge_{0.15}$ quantum wells, with peak emission at 1.2 μm at 77 K was reported recently, but it diminished rapidly above 77 K.[1] In this paper, we report the first room-temperature electroluminescence (EL) from Si/SiGe quantum well structures with peak emissions at 1.3μm and 1.5μm. The peak intensities are relatively insensitive to temperature from 77 K to 300 K.

The LED has a p-i-n structure with an active intrinsic-region which consists of ten 60Å $Si_{0.65}Ge_{0.35}$ quantum wells for the 1.3μm device and a single 13Å Ge layer for the 1.5μm device. The $Si_{1-x}Ge_x$/Si structures were grown by Rapid Thermal Chemical Vapor Deposition on n-type (100)Si. All devices were mesa-isolated, and light was observed through the partially-metal-covered top surface.

Well-resolved low temperature (4 K) photoluminescence (PL) shows that the 1.3μm luminescence is from the no-phonon band-edge exciton recombination in the $Si_{0.65}Ge_{0.35}$ quantum wells. The emitted photon energy closely agrees with that expected for the strained bandgap after correcting for quantum confinement effects. We conclude that the same physical mechanism is responsible for room-temperature 1.3μm luminescence from the observation that the PL and EL spectra at 77 K and room temperature are similar. The 1.5μm PL is not well-resolved at low temperature, and the emission mechanism has not yet been identified as being band-edge or defect related.

The internal quantum efficiency of the 1.3μm LED diode is estimated to have a lower limit of 2×10^{-4}. The 1.5μm EL and PL are substantially weaker for the LED sample, but for other samples with similar structures, the PL efficiency is about equal to that of the 1.3μm samples at 77K and 300K. In both devices the peak emission decays by less than a factor of 3 from 77 K to room temperature (CW). The dependence of the EL intensity on drive current in both samples at room temperature is linear above a certain threshold, which can be as low as 30A/cm^2. The output of the devices has been successfully coupled into optical fibers for data transmission.

In conclusion, we have observed the first room-temperature 1.3μm and 1.5μm EL from strained $Si_{1-x}Ge_x$ quantum wells with a minimum internal efficiency of 2×10^{-4}. The support of the ONR and NSF (Princeton) and NSERC (Simon Fraser) is acknowledged.

1. D. J. Robbins, P. Calcott, and W. Y. Leong, *Appl. Phys. Lett.* 59, 1350(1991).

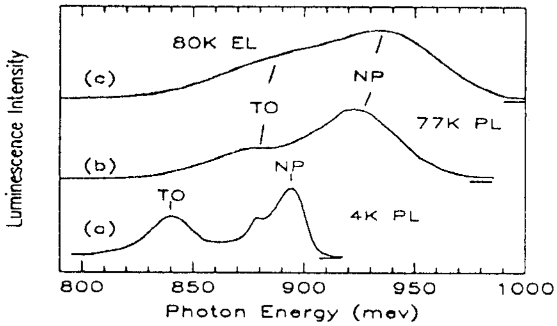

Figure 1. $1.3\mu m$ device's photoluminescence spectra at (a) 4.2K and (b) 77 K and (c) CW electroluminescence spectrum with 10 mA drive current and heat sink temperature at 80 K. Note the no-phonon signal (NP) and phonon replica (TO).

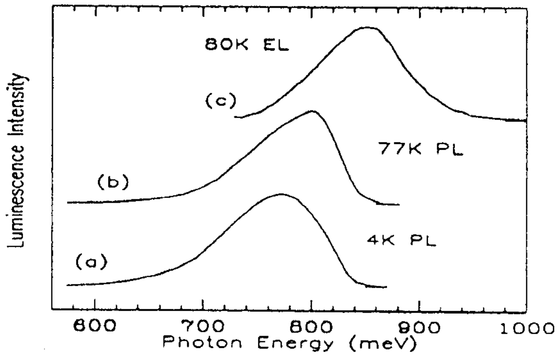

Figure 2. $1.5\mu m$ device's CW EL spectra with 90 mA drive current and heat sink temperature at 80 K. PL spectrum of similar structure sample at (a) 4.2 K and (b) 77 K.

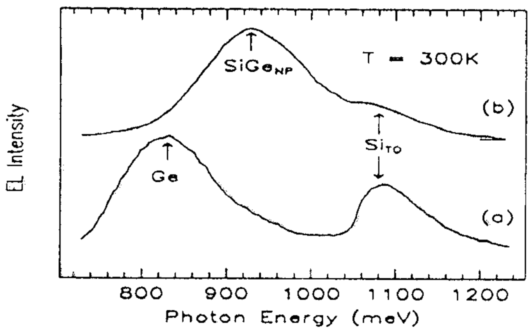

Figure 3. CW electroluminescence spectra with room-temperature heat sink and 15 mA driving current for $1.3\mu m$ device and 90 mA driving current for $1.5\mu m$ device.

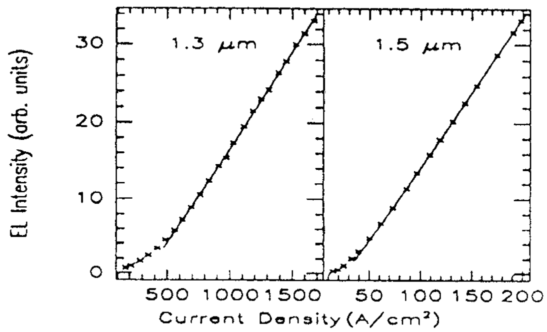

Figure 4. Peak intensity of $1.3\mu m$ and $1.5\mu m$ emission with room-temperature heat sink vs. driving current density.

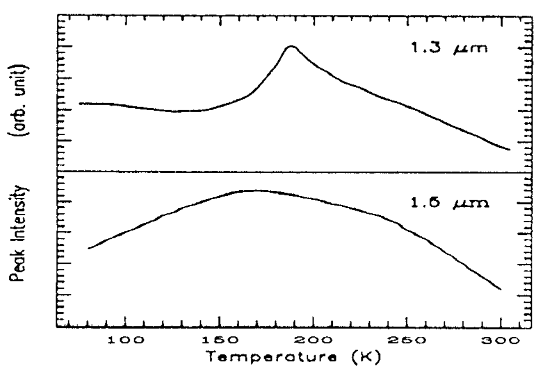

Figure 5. Luminescence peak intensity vs. Temperature. Vertical scale is linear.

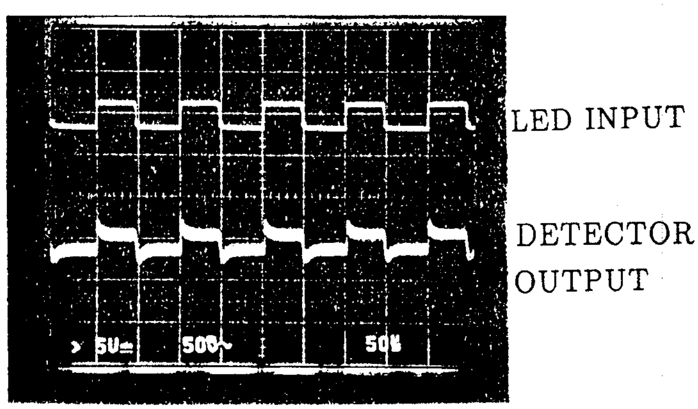

Figure 6. Modulation characteristics of the $1.3\mu m$ LED at 10K Hz. The top and bottom traces are the waveforms of the bias voltage on the LED and light output, respectively.

[2] S. Chandrasekhar, M. K. Hoppe, A. G. Dentai, C. H. Joyner, and G. J. Qua, *IEEE Electron Device Lett.*, vol. 12, p. 550, 1991.

VIB-7 Room-Temperature 1.3-and 1.5-μm Electroluminescence from $Si/Si_{1-x}Ge_x$ Quantum Wells—Q. Mi, X. Xiao and J. C. Sturm, Department of Electrical Engineering, Princeton University, Princeton, NJ 08544; L. C. Lenchyshyn and M. L. W. Thewalt, Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

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