Direct growth of InAs/GaSb type II superlattice photodetector on silicon substrates

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Introduction

- p-i-n InAs/GaSb* type II superlattice (SL) photodiodes were directly grown on Si* substrates.
- SL structures were grown monolithically on miscut Si substrates via a 10nm AlSb* nucleation layer.
- AFM and XRD measurements revealed degraded material quality of type II superlattices grown on Si, compared with the sample grown on GaAs.
- PL characterization indicates comparable optical properties with about 39% deduction of peak intensity.
- Dark current measurements were also used to study the electrical properties of the samples.

Method

- All epi-layers were directly grown on a Si(100) substrate by molecular beam epitaxy (MBE).
- Si substrate was heated in ultra-high vacuum at 900° C for 30 minutes to remove native oxide.
- The substrate was cooled down to 400° C and a 10nm AlSb nucleation layer was deposited.
- The growth temperature was raised to about 500° C and a buffer was grown, which consisted of two superlattices each followed by 500nm GaSb.
- The superlattices, 100nm in thickness, were made from alternating GaSb and AlSb layers. The growth of the superlattices was performed at a lower substrate temperature.
- Each period consisted of 10ML (monolayer) GaSb and 10ML InAs. The lattice constant of InAs is 0.75% smaller than that of GaSb and a thin InSb layer within 1ML was inserted between the InAs and GaSb layers for strain balance[1].
- The T2SL photodiodes had a standard p-i-n structure with 500nm p-region, 2μm intrinsic region, and 500nm n-region.
- Finishing with a heavily doped 50nm GaSb top contact layer. A reference sample with the exact same T2SL photodiode structure was grown on a GaAs(100) substrate with 1μm GaSb deposited on the GaAs surface after 200nm GaAs buffer instead of the AlSb nucleation layer.

** Si (Silicon), In (Indium), As (Arsenic), Ga (Gallium), Sb (Antimony), Al (Aluminum)*

Results and Discussion

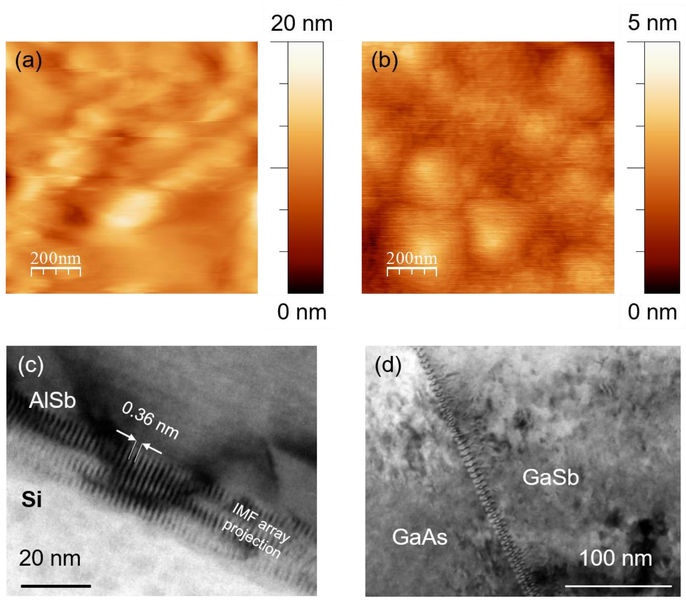

Figure 1: T2SL photodiode in Si (a, c) and GaAs (b, d). AFM images (a, b) and TEM images (c, d).

Figure 1(a) Si has a rough surface with irregular undulation, with root mean square (RMS) roughness of 1.7nm for a 1×1μm2 area and 12.0nm for a 5×5μm2 area.

Figure 1(b) GaAs has a very smooth surface with clear atomic terraces, with RMS roughness of 0.5nm for a 1×1μm2 area and 0.9nm for a 5×5μm2 area.

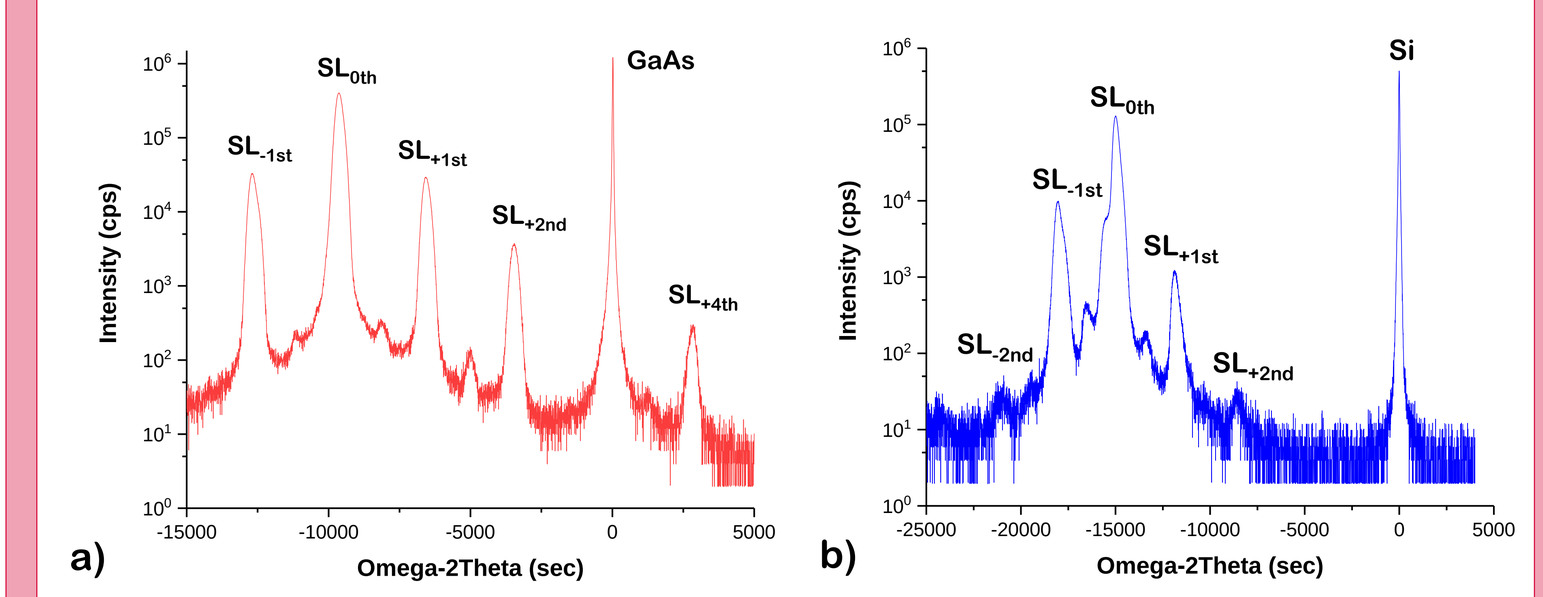

Figure 2: High resolution omega-2theta scans of the T2SLs grown on (a) GaAs and (b) Si substrate.

The full width at half maximum (FWHM) of the zeroth peak is: on GaAs 300.2 arcsec and on Si 331.9 arcsec

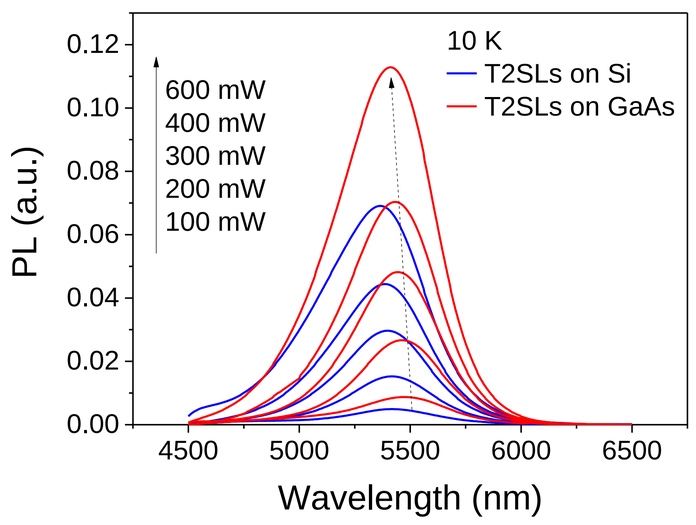

Figure 3: Power dependent PL spectra collected at 10K. The PL intensity on Si is 44% less than GaAs within the entire power range.

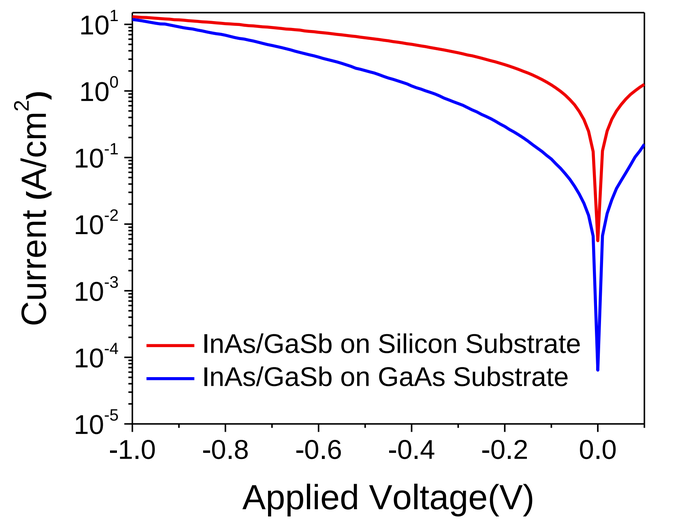

Figure 4: Current density voltage characteristics at 10K. The higher quality of the GaAs gives a lower dark current density, both devices showed comparable levels within one order of difference in magnitude and significant leakage currents.

References

[1] J. Chen et al, *"Growth and fabrication of InAs/GaSb type II superlattice mid-wavelength infrared photodetectors*," Nanoscale Research Letters, vol. 6, (1), pp. 635, 2011.

Conclusion

- Direct growth of InAs/GaSb T2SL photodiodes have been carried out on Si substrate for the first time by MBE.
- Compared with the reference sample on GaAs, similar structural and optical properties have been achieved for the T2SL photodiode on Si by AlSb/GaSb buffer layers.
- The measured XRD FWHM is only slightly reduced indicating similar dislocation density.
- PL studies also show the optical emission of the T2SL on Si is only reduced less than half.
- A large leakage current has been measured for both samples.
- The growth and fabrication of T2SL may require further optimization, like decrease threading dislocations by using threading dislocation filter layers.

Business Card

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