GaSb-Based Mid-Infrared Photonic Devices Monolithically Integrated onto Silicon

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GaSb-based materials can be used to produce high performance photonic devices operating in the technologically important mid-infrared (MIR) spectral range (2 to 5 µm). Direct epitaxial growth of GaSb on silicon (Si) is an attractive method to reduce manufacturing costs and opens the possibility of new applications in lab-on-chip MIR photonic integrated circuits. However, the fundamental material dissimilarities including the large lattice mismatch, the polar-nonpolar character of the III-V/Si interface and differences in thermal expansion coefficient lead to the formation of threading dislocations (TDs) and antiphase domains (APDs) which effect the device performance. This work reports on the molecular beam epitaxial (MBE) growth of high quality GaSb-based materials and devices onto Si. This was achieved using a novel growth procedure consisting of; an efficient AlSb interfacial misfit array, a two-step GaSb growth temperature procedure and dislocation filters, resulting in a low defect density, anti-phase domain free GaSb buffer layer on Si. A nBn barrier photodetector based on a type-II InAs/InAsSb superlattice was grown on top of the buffer layer (Fig 1). The device exhibited an extended 50 % cut-off wavelength at 5.40 µm at 200 K which moved to 5.9 µm at 300 K. A specific detectivity of 1.5 x10^{10} Jones was measured corresponding in an external quantum efficiency of 25.6 % at 200 K [1]. InAsSb p-i-n LEDs were also grown on the GaSb-on-Si buffer layer which showed bright room temperature electroluminescence (EL) peaking around 4.5 µm (Fig 2).

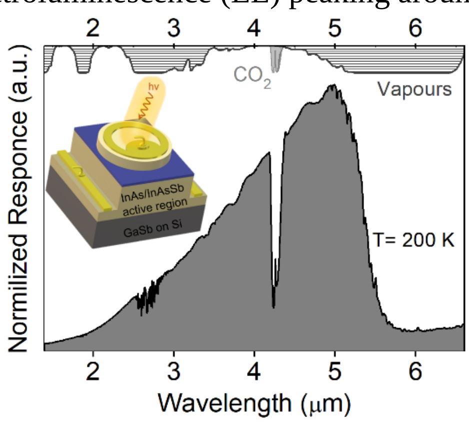

Figure 1 Photoresponse measured from the nBn detector grown on Si at 200 K.

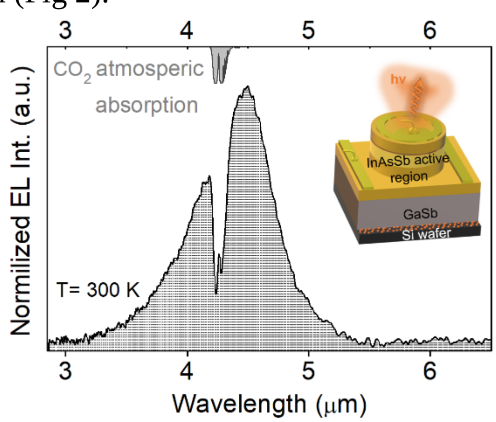

Figure 2 Room Temperature EL measured from the LED peaking at 4.46 µm.

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Supplementary Pages (Optional)

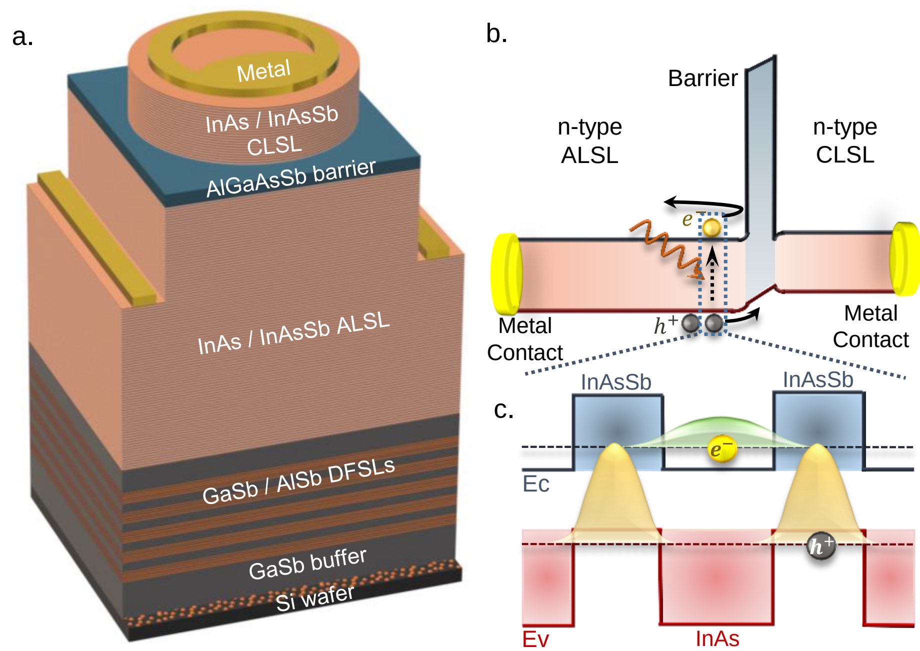

Figure 3: (a) Schematic of the InAs/InAsSb type-II SL nBn structure grown on top of the GaSb/AlSb/Si buffer, using AlSb/GaSb dislocation filters. (b) Diagram of the full device's bandgap structure showing the barrier layer which blocks the flow of electrons. (c) InAs/InAsSb SL bandstructure with first electron and hole energy levels and wavefunctions. The dashed lines represent the minibands formation.

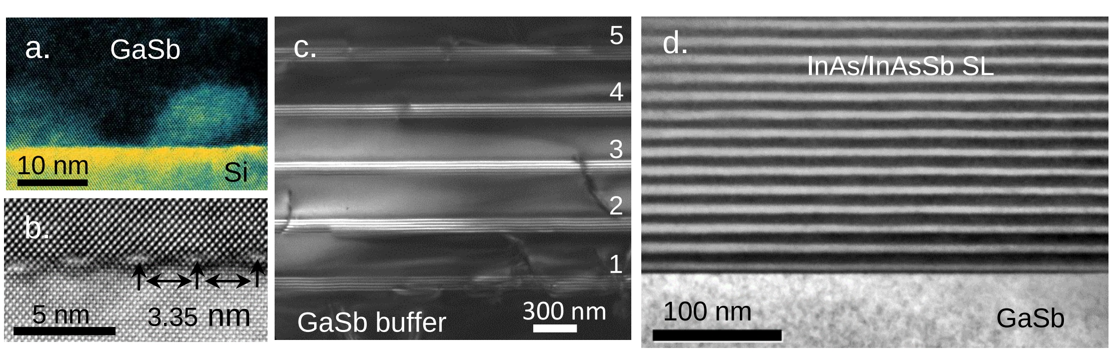

Figure 4: (a) False-colour high resolution TEM image taken along the III-V/Si interface, showing the formation of AlSb islands. (b) High resolution image was taken along the [110] showing the misfit dislocations with spacing of 3.35 nm. (c) Cross-sectional dark field [220] TEM micrograph of the area with the AlSb/GaSb dislocation filter layers. The numbers indicate the five sets of DFSLs. (d) High resolution cross section TEM image of the InAs/InAsSb SL showing well-formed layers with abrupt interfaces.

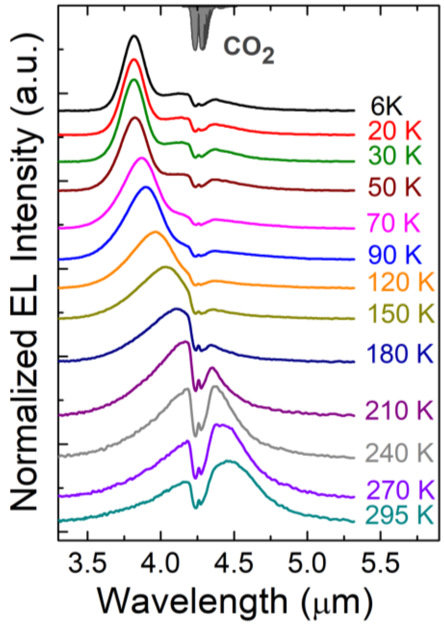

Figure 5: The temperature dependent normalized EL emission spectra obtained from the InAsSb p-i-n LED grown on top of the GaSb/Si buffer layer using 190 mA, 1kHz and 50% duty cycle.