Thermal Annealing Induced Optical Quality Enhancement in GaSb-Based Dilute-Nitrides

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Mid-infrared (IR) (3-5 μm) semiconductor lasers are attractive light sources for a variety of applications including directional infrared countermeasures, gas sensing and free space optical communications. GaSb-based type-I quantum well (QW) diode lasers are attractive sources due to their relatively simpler fabrication when compared to quantum cascade lasers and type-II interband cascade lasers. Excellent GaSb-based type-I QW diode lasers based on InGaAsSb QWs and lattice-matched AlGaAsSb barriers have been demonstrated below ~3 μm with high output powers and wall-plug efficiencies. Recently, the emission wavelength of these lasers has been extended to 3.6 μm[1] using AlInGaAsSb quinary barriers; however the performance of these lasers degrades at longer wavelengths due to hole leakage and Auger recombination. This is likely due to the increase in arsenic mole fraction in the QWs necessary for extending the emission wavelength. Therefore, GaSb-based dilute-nitrides offer an alternate path for extending the emission wavelength of type-I QW diode lasers as the emission wavelength can be extended without increasing the QW arsenic content, mitigating Auger recombination and hole leakage issues. In dilute-nitrides, the bandgap reduction is due to band-anticrossing between the host conduction band and the localized level introduced by the nitrogen atom. The bandgap reduction is almost entirely due to a lowering of the conduction band, leaving the valence band essentially unperturbed which is advantageous for hole confinement. While dilute-nitrides are a potentially elegant solution for extending the operating wavelength of GaSb based type-I QW diode lasers, the material quality has been relatively poor due to a significant fraction of nitrogen atoms being incorporated in the form of Sb-N and N-N split-interstitials. Through careful optimization of the molecular beam epitaxy (MBE) growth conditions, we were able to minimize the incorporation of non-substitutional nitrogen species and thus attain material with sufficient optical quality to observe the first room temperature photoluminescence spectra[2]. Post-growth thermal annealing of the samples in the MBE growth chamber under an antimony overpressure resulted in a further improvement in optical quality (Fig. 1). We believe that this improvement is due to the annihilation of remaining non-substitutional nitrogen species. Nuclear reaction analysis (NRA) studies are underway to confirm this hypothesis. The sample structure (Fig. 2) consists of an InGaSb(N) QW with AlSb top and bottom carrier blocking layers to prevent photogenerated carriers from recombining at the surface and in the substrate respectively. The origin of the blueshift in peak emission wavelength is still under investigation, but we believe this is likely due to a combination of nitrogen out-diffusion from the QW and a change in local bonding configuration of the nitrogen atoms. We believe that with further material quality optimization, GaSb-based dilute nitrides hold great promise for extending the emission wavelength of type-I QW diode lasers further into the mid-IR wavelength regime.

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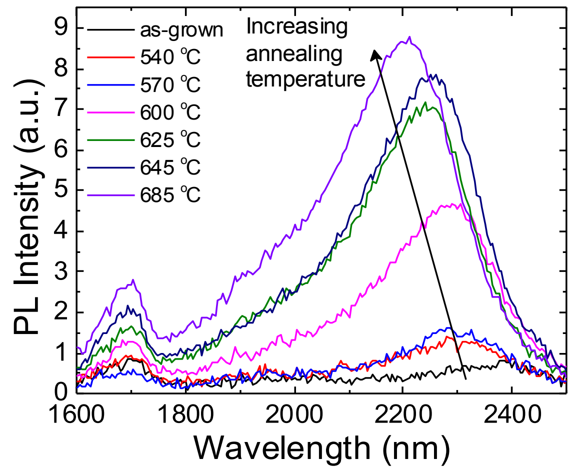

Fig. 1: PL spectra from samples that were annealed post-growth indicating the improvement in optical quality and peak blueshift.

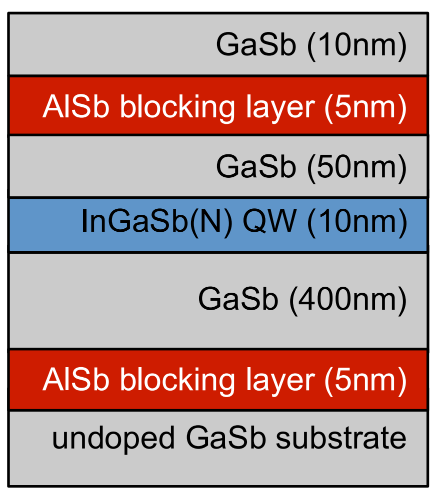

Fig. 2: Sample structure used for photoluminescence study. The AlSb carrier blocking layer prevents recombination of photogenerated carriers at the surface and in the GaSb substrate

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