MAR16-2015-000831

Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

Ga-free InAs/InAsSb type-II superlattice and its applications to IR lasers and photodetectors

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This talk will review the research on Ga-free InAs/InAsSb type-II superlattices (T2SL), especially their growth, structural and electronic properties, and applications to IR lasers and photodetectors with the following highlights: 1) Review of the previous study of InAs/InAsSb T2SL and its application to IR lasers and photodetectors in the 90's. 2) Long minority carrier lifetime up to 12.8 μs in mid-wavelength infrared (MWIR) InAs/InAsSb T2SL was observed at 15 K, and 412 ns for long-wavelength infrared (LWIR) InAs/InAsSb T2SL were measured using time-resolved photoluminescence. The record long carrier lifetime in the MWIR range is due to carrier localization, which is confirmed by a 3 meV blue shift of the photoluminescence peak energy with increasing temperature from 15 K to 50 K, along with a photoluminescence linewidth broadening up to 40 K. In contrast, no carrier localization is observed in the LWIR T2SL. Modeling results show that carrier localization is stronger in shorter period (9.9 nm) MWIR T2SL as compared to longer period (24.2 nm) LWIR T2SL, indicating that the carrier localization originates mainly from InAs/InAsSb interface disorder. Although carrier localization enhances carrier lifetimes, it also adversely affects carrier transport. 3) Pressure-dependent photoluminescence (PL) experiments under hydrostatic pressures up to 2.16 GPa were conducted on a MWIR InAs/InAsSb T2SL structure at different pump laser excitation powers and sample temperatures. The results show a pressure coefficient of the T2SL transition was found to be 93 2 meV•GPa^{-1}; a clear change in the dominant photo-generated carrier recombination mechanism from radiative to defect related, providing evidence for a defect level situated at 0.18 0.01 eV above the conduction band edge of InAs at ambient pressure. 4) LWIR InAs/InAsSb T2SL nBn photodetectors on GaSb substrates were demonstrated. The typical device consisted of a 2.2 micron thick absorber layer and has a 50% cutoff wavelength of 13.2 μm, a measured dark current density of 5e-4 A/cm^2 at 77 K under a bias of -0.3 V, a peak responsivity of 0.24 A/W at 12 μm and a maximum RA product of 300 ohm-cm^2 at 77 K. The calculated generation-recombination noise limited specific detectivity (D*) and experimentally measured D* at 12 μm and 77 K are 1e10 (cm-Hz$^{1/2}$)/W and 1e8 (cm-Hz$^{1/2}$)/W, respectively.