Coherent longitudinal optical phonon and plasmon coupling in the near surface region of InN


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Recent progress in growth techniques has made it possible to grow high crystalline quality wurtzite structure InN epitaxial layers with low carrier concentrations. Their optical characterization reveals the band gap around 0.7-0.9 eV, much narrower than the 1.9 eV measured in earlier studies of InN. The band gap energy of the InGaN ternary alloys can now cover a wide spectral range from the infrared for InN to the near ultraviolet for GaN. This tunability is very promising for developing many optoelectronic devices. Hence it has attracted scientists a lot of attentions to investigate the structure, electronic and optical properties of InN in many aspects, such as XRD, HREELS, optical absorption, photoluminescence, and Raman scattering. However, its transient carrier and phonon properties in the near surface region have not been fully explored yet.

The development of femtosecond laser system has made it possible to generate and detect coherent phonons in semiconductors with time-resolved pump and probe technique. The carrier and phonon dynamics can now be investigated at femtosecond timescale. In this paper, we demonstrate the coherent phonon spectroscopy of a high quality single crystal InN (001) epitaxial layer with time-resolved second-harmonic generation (TRSHG) technique. This technique is capable of exploring the carrier and phonon dynamics in the top tens of nanometer of InN because of its intrinsic surface sensitivity. In the spectrum, only coherent longitudinal optical phonon and plasmon coupling (LOPC) mode at 447 cm⁻¹ (or 13.4 THz), but not A₁(LO) phonon at 589 cm⁻¹ (or 17.6 THz), can be resolved. Its frequency shows no dependence on the photo-injected carrier density in the range of 2.0×10¹⁸ to 1.5×10¹⁹ cm⁻³. Its dephasing time is about 0.6-0.8 ps. The dephasing process is governed by the anharmonic decay of A₁(LO) phonon population. We attribute these phenomena to the hybridization of coherent LO phonon with the intrinsic cold plasma accumulated in the near surface region, where the plasma density is estimated to be in the order of 10²⁰ cm⁻³, much higher than the bulk carrier concentration, 1×10¹⁸ cm⁻³, determined by Hall effect measurement. Meanwhile, spontaneous Raman spectroscopy is also performed for comparison. The discrepancy in the obtained phonon spectra will be discussed in the presentation.