Thermal energy transport in different alloys composition with Raman Scattering

Thee Ei Khaing Shwe[1], Tomoya Nakayama[1], Tastuya Asaji[1], Daisuke Iida[2], Mohammed A. Najmi[2], Ryota Kimura[1], Yuki Kikuchi[1], Kazuhiro Ohkawa[2], and Yoshihiro Ishitani[1]

Chiba Univ. [1], KAUST[2]

E-mail: ishitani@faculty. chiba-u.jp

Enhancement of thermal energy transport from active regions in devices is an important measure to improve device operation characteristics. Observation methods of surface temperature of devices have been developed by thermal reflectance, Raman spectroscopy, and so forth, whereas the analytical method of energy transport and phonon dynamics dominating the thermal conductance is still under developing. We have reported a vehicle to analyze phonon dynamics: a doble laser system enabling the layer-identified temperature variation by photo-generation of thermal energy.[1,2] In this analysis, we came to a question of mode dependent phonon dynamics; LO phonon, which is the most harmful mode for electronic function, is the firstly generated phonon mode by the thermal energy relaxation of photo-excited carriers. Further, InGaN alloys have significant spatial nonuniformity, which increases as the InN mole fraction increases. We have a question for the effect of this nonuniformity on phonon dynamics including spatial transport. In this article, we investigate the difference in the mode-energy variation when heating between the phonon modes of E_2(high) and A_1(LO) in $In_xGa_{1-x}N$/GaN heterostructures by microscopic Raman spectroscopy using the heat generation laser of 325 nm. In this study, heterostructures of $In_xGa_{1-x}N$ (100-110 nm)/GaN(6.5um) grown on sapphire substrates by metal-organic vapor phase epitaxy was investigated. InN mole fraction x was 5% for sample A and 9% for sample B. Sample B is partially lattice-relaxed. Figure 1 shows the correlation of these two mode energies. When considering the thermal strain and mode energy shift of bulk material due to temperature increase[1,2], the shift of the A_1(LO) mode is unexpectedly higher than that of the E_2(high) mode. The decrement for the E_2(high) mode energy shows significant nonuniformity in the observed area, while the shift of the A_1(LO) mode approximately agrees between samples and measurement positions. Generally, A_1(LO) mode energy increases by increasing the carrier density, while E_2(high) mode energy is independent of that. In the present analysis, excitation power is set to be the same for different positions and samples. It is suggested that the Raman signals for these two modes includes different information. It is estimated that the analysis of a few different phonon mode gives us the phonon dynamics in the excited area.

1) S. Okamoto et al. Appl. Phys. Lett. 116, 142107(2020)
2) T. Nakayama et al. Mater. Sci. Semicond. Process. 150, 106905 (2022)

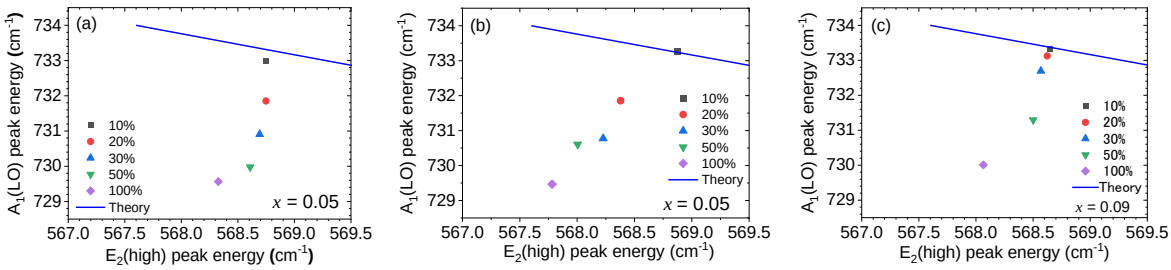

Figure 1 Correlation of E_2(high) and A_1(LO) mode-peak-energies for sample A and sample B. The excitation power is 11 meV for 100 %, and the excitation spot diameter is expected to be 0.42 μm.

© 2023年 応用物理学会