

## Raman scattering of the N-related vibrational modes in high N-content GaPN films grown on GaP (001) substrates by MOVPE

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The N related vibrational modes (N-RVMs) in high quality GaPN films ( $0 < N \leq 5.4$  at%) on GaP (001) substrates grown by metalorganic vapor phase epitaxy (MOVPE) have been investigated. This study used two sets of samples with different growth times of 5 min and 10 min. N contents, which were examined from high resolution X-ray diffraction (HRXRD) measurements, are 1.8 at%, 2.9 at% and 3.6 at% for growth time of 5 min and are 0.8 at%, 1.8 at%, 3.4 at% and 5.4 at% for growth time of 10 min. Mirror like surface and fairly flat interface were observed for all the films. Atomic force microscopy (AFM) images showed smooth surfaces with root mean square (RMS) roughness lower than 0.5 nm. These results suggest that the high quality GaPN films with high N contents were obtained, despite the fact that an incorporation of N is as high as 5.4 at%. Raman spectroscopy studies were performed to examine the effect of N incorporation on the vibrational modes of the GaP lattice. It is clearly observed that Raman spectra between  $440$  and  $520$   $\text{cm}^{-1}$  were significantly influenced by the N incorporation, which is attributed to N-RVMs. Integrated Raman intensity ratio of N-RVMs with respect to GaP-LO phonon (at  $401$   $\text{cm}^{-1}$ ) linearly increased with the N incorporation. Additionally, the N-RVMs, which are attributed to the  $\text{NN}_i$ -pairs, were remarkably appeared at  $465$   $\text{cm}^{-1}$  and  $485$   $\text{cm}^{-1}$  for the films with N contents higher than 1.8 at%. While, local vibrational mode (LVM) of the isolated N-atoms on P sites was clearly observed near  $500$   $\text{cm}^{-1}$ .

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