B−2−6

LPE Growth and Photoluminescence of Visible-Semiconductor-Laser Material $In_{1-x}Ga_xP_{1-y}As_y$ on GaAs

A. Suzuki, H. Kyuragi, S. Matsumura, and H. Matsunami

Department of Electronics, Kyoto University

Kyoto, 606, Japan

INTRODUCTION Development of visible semiconductor lasers is one of the recent topics in the field of optoelectronics. Since lattice-matched $In_{1-x}Ga_xP_{1-y}As_y$ layers on GaAs substrates have wide band gaps of 1.4 ∿ 1.9 eV, they are suitable for red-light-emitting double-heterostructure lasers of 720 ∿ 750 nm wavelengths. However, the $In_{1-x}Ga_xP_{1-y}As_y$ layers on GaAs have not been studied in detail.[1,2] In the present paper, lattice-matched LPE growth and photoluminescence of $In_{1-x}Ga_xP_{1-y}As_y$ layers on GaAs are described.

LPE GROWTH A horizontal graphite slider-boat was used for LPE growth. Substrate crystals were GaAs (100) wafers of 10 mm × 6 mm in size. In order to obtain $In_{1-x}Ga_xP_{1-y}As_y$ layers with a wide band gap, a source melt with a small atomic fraction of As was used.[3] A typical source melt consisted of 1.52 g In, 37.8 mg InP, 13.4 mg GaP, and 0.9 mg InAs. LPE growth was carried out at 785 °C by the supercooling method. Flat and uniform mirror-like layers of 2 to 10 μm in thickness were obtained under the following conditions: initial supercooling, 15 °C; cooling rate, 0.2 °C/min; growth time, 10 to 30 min. A cleaved and etched cross-section of the layer is shown in Fig. 1. The interface between the epitaxial layer and the substrate is fairly flat.

Figure 2 shows lattice mismatch between the epitaxial layer and the substrate determined by X-ray diffraction measurement as a function of x^l_{Ga} (the atomic fraction of Ga in the source melt). Flat and uniform mirror-like layers were obtained within the range of x^l_{Ga} from 0.0091 to 0.0099 (lattice mismatches from +0.25 % to ±0.0 %) in Fig. 2. When the difference in thermal-expansion coefficient between the epitaxial layer and the substrate is taken into consideration, the lattice mismatches of +0.25 ∿ ±0.0 % at room temperature correspond to +0.15 ∿ -0.10 % at the growth temperature of 785 °C. This indicates that good epitaxial layers are obtained under tha lattice-match condition at growth temperature.

Typical compositions x and y determined by EPMA were 0.51 and 0.03, respectively.

Typical values of the carrier concentration and the mobility of undoped n-type layers were

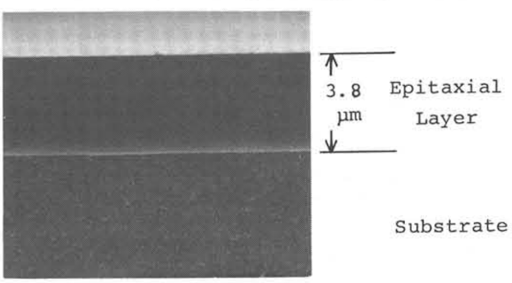

Fig. 1. Cleaved and etched cross-section of an epitaxial layer.

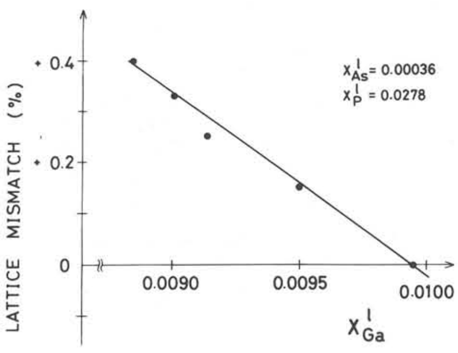

Fig. 2. Lattice mismatches of epitaxial layers as a function of x^l_{Ga}.

3×10^{16} cm^{-3} and 1200 $cm^2/V{\cdot}s$, respectively. By the addition of 2.1×10^{-2} at. % Zn to the source melt, p-type layers of 2×10^{17} cm^{-3} were obtained.

PHOTOLUMINESCENCE Figure 3 shows typical photoluminescence spectra of undoped layers at 77 K and 290 K. The peak photon-energies were 1.986 eV at 77 K and 1.908 eV at 290 K. These peaks are considered to be due to band-edge transitions. The theoretical spectra for direct-gap band-to-band transitions[4)] are also shown with solid lines. The spectral shapes measured at 77 K and 290 K were in considerable agreement with the theoretical ones except at tails of lower photon energies. The measured half width of 12 meV at 77 K agreed completely with the theoretical value. At 290 K, the half width of 36 meV was smaller than 45 meV, the theoretical one, which seems to be due to re-absorption of emitted photons with much higher energies than the band gap. The narrow half widths indicate the good quality and the uniform composition of the epitaxial layer. Band gaps determined from the spectra were 1.983 eV at 77 K and 1.895 eV at 290 K.

Figure 4 shows photoluminescence spectrum of the Zn-doped p-type layer at 77 K. Another broad peak due to Zn acceptors was observed at 1.934 eV, approximately 40 meV lower than the band-edge peak at 1.971 eV. At room temperature, the peak due to Zn acceptors disappeared and only the band-edge peak was observed.

REFERENCES

1) O. N. Ermakov et al.: IEEE Trans. Electron Devices ED-26 (1979) 1190.
2) Zh. I. Alferov et al.: Sov. Tech. Phys. Lett. 1 (1975) 147.
3) T. H. Glisson et al.: J. Electron. Mater. 7 (1978) 1.
4) H. B. Bebb et al.: Semiconductors and Semimetals, Vol. 8, Chap. 4, p.238.

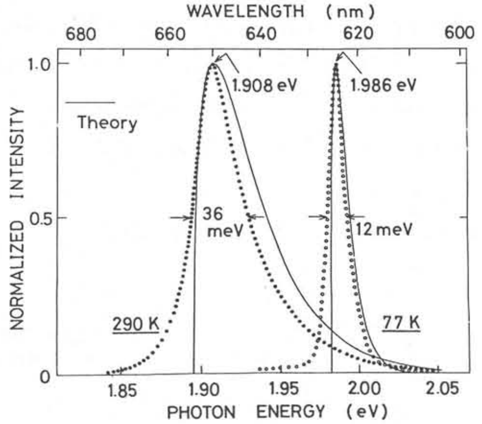

Fig. 3. Photoluminescence spectra of an undoped epitaxial layer at 77 K and 290 K.

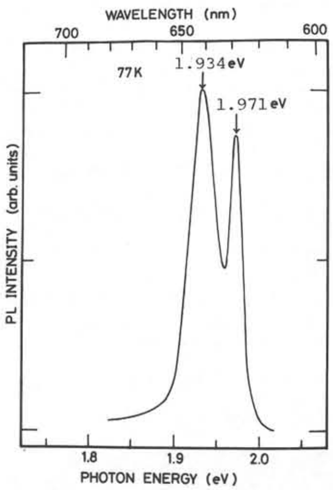

Fig. 4. Photoluminescence spectrum of a Zn-doped p-type epitaxial layer at 77 K.