Gas source MBE growth of TlInGaAs layers on GaAs substrates

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GaInNAs/AlGaAs heterostructures are widely studied to fabricate the temperature-stable threshold current laser diodes (LDs) in the wavelength range of 1 μm because of their large conduction band discontinuity [1]. However, there exists a long wavelength limit of 1.3 μm in this material system. To overcome this problem, we propose here new alloy semicondctors; TlGaNAs or TlGaInNAs. These new semiconductors are alloys of semiconductor, GaNAs or GaInNAs, and semimetal, TlAs. Bandgap energy versus lattice constant relationship is shown in Fig.1. As clearly seen in this figure, much lower bandgap energy, therefore longer wavelength, can be easily obtained for these new semiconductors compared with GaInNAs. TlGaNAs/AlGaAs and TlGaInNAs/AlGaAs heterostructures have also large conduction band discontinuity similar to GaInNAs/AlGaAs ones. Furthermore, TlGaNAs and TlGaInNAs are expected to show temperature-stable bandgap energy because of the alloy of semiconductor and semimetal, as already proposed and confirmed in TlInGaAs and TlInGaP [2-4].

TlInGaAs/GaAs DH and MQW structures were grown on (001) GaAs substrates at 450 ℃ by gas source MBE. Elemental Tl, In and Ga and thermally cracked AsH_3 and PH_3 were used as group III and group V sources. Their optical properties were studied by photoluminescence (PL) measurement. For comparison, InGaAs/GaAs DHs and MQWs were also grown under the same growth conditions. Growth rates of TlInGaAs and InGaAs were measured with reflection high-energy electron diffraction (RHEED) intensity oscillations (Fig.2), where they were grown with the same In and Ga fluxes. From the oscillation periods in Fig.2, Tl composition was calculated to be 9%. In the 77K PL spectra, the lower energy shift of the PL peak energy was observed (Fig.3), which agrees well with the incorporation of Tl as expected. For the TlInGaAs/GaAs MQWs, sharper PL spectrum was observed, indicating improved optical properties (Fig.4). At present, it is still not enough to emit PL at room temperature, although the PL intensity for the MQWs was increased by several factor from that of DHs. Further optimization of the growth condition is needed.

In summary, we have proposed new semiconductors TlGaNAs and TlGaInAs for the fabrication of temperature-stable threshold current and wavelength LDs and succeeded in the growth of TlInGaAs on GaAs substrate by gas source MBE and observed PL emission at 77K.

Reference

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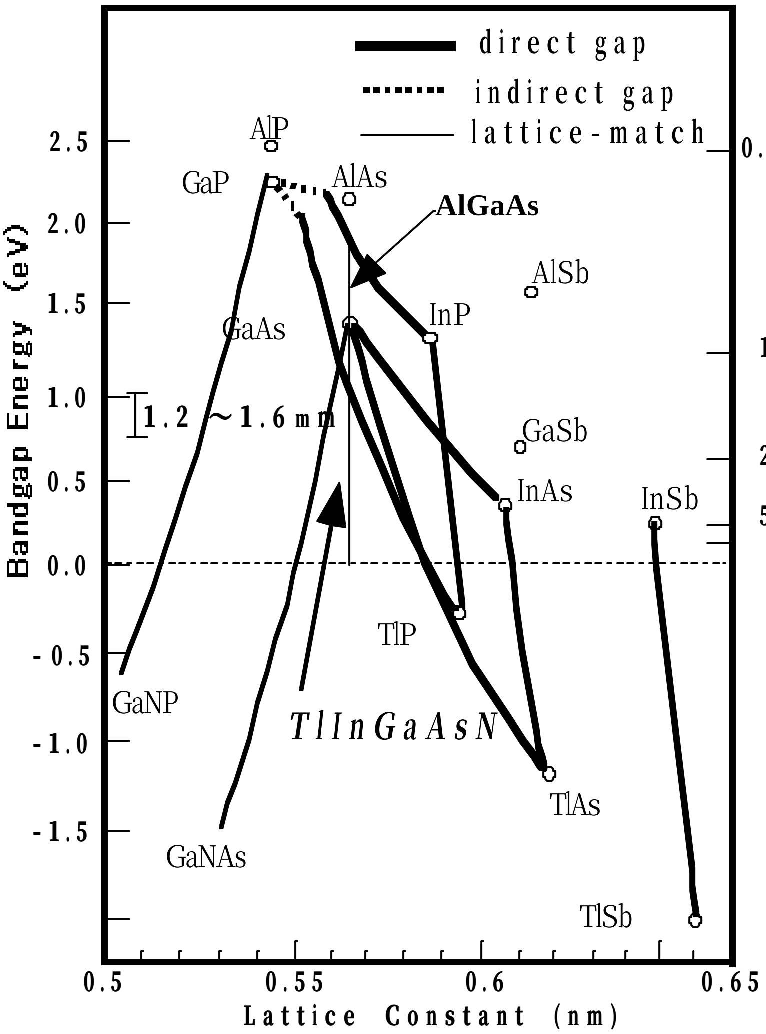

Fig. 1 Band-gap vs lattice constant of TlInGaAsN

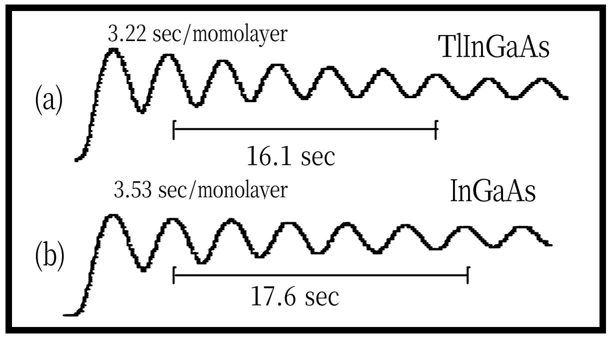

Fig. 2 RHEED oscillations for the gorwth of (a) TlInGaAs and (b) InGaAs

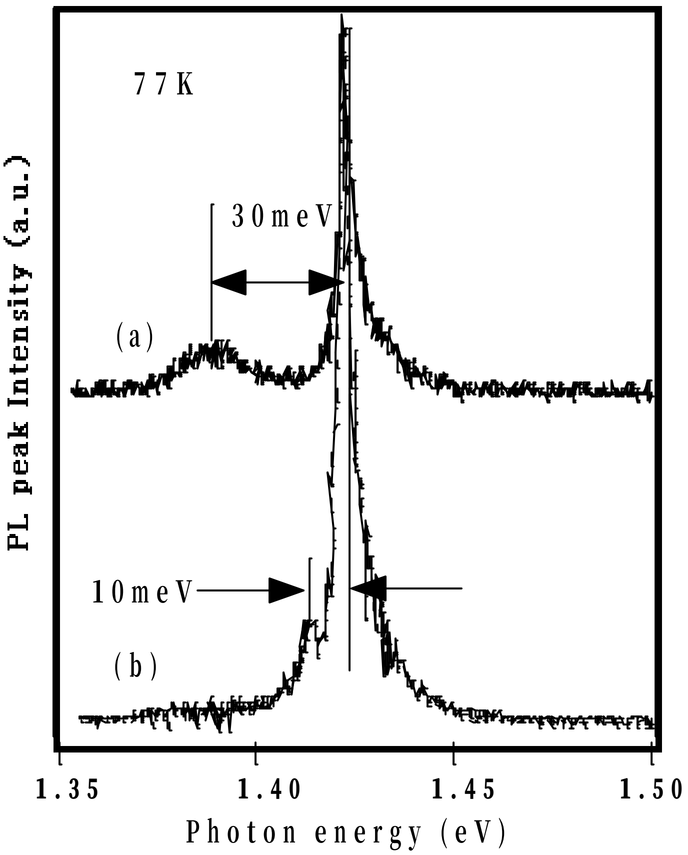

Fig. 3 77K PL spectra for (a) TlInGaAs/GaAs and (b) InGaAs/GaAs DH samples

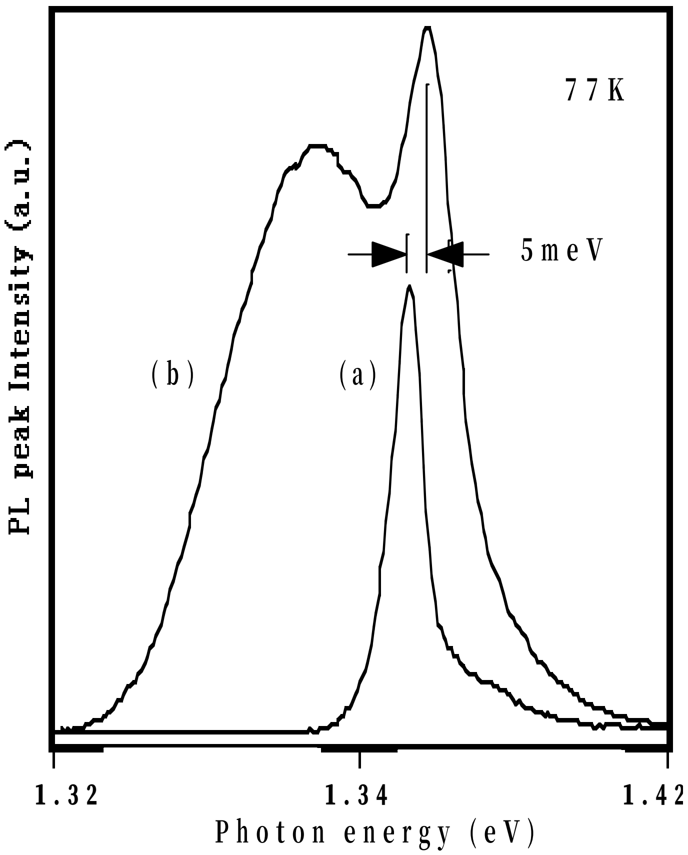

Fig. 4 77K PL spectra for (a) TlInGaAs/GaAs and (b) InGaAs/GaAs MQW samples