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GaInAs/InP Superlattice DBR for Long-Wavelength VCSELs

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We propose and demonstrate a novel GaInAsP-based DBR on an InP substrate using GaInAs/InP superlattice (SL) structure. The proposed SL DBR structure is expected to have various advantages in growth, thermal and optical properties. The MOCVD grown GaInAs/InP SL DBR showed a designed PL peak wavelength and SL satellite peaks in X-ray diffraction. The reflectivity of 15pair DBR was about 92%. The SL DBR is exchangeable for the conventional GaInAsP DBR.

Long-wavelength vertical-cavity surface-emitting lasers (VCSELs) are attractive for use in optical fiber communication systems because of their advantages of low power consumption, efficient coupling to optical fibers, dense array integration, and its potential low production cost and so on. However, because of low refractive index difference of InP based materials (GaInAsP, InP etc), a high reflective DBR needs over 50 pairs of material pairs. The difficulty of growing GaInAsP-based DBR is to keep the composition of each layer. For example, the growth temperature variation causes lattice mismatch and refractive index change due to high sensitivity of the As/P composition ratio.

In this study, we propose and demonstrate a novel DBR structure using a GaInAs/InP superlattice for 1.55μm VCSELs by MOCVD. The GaInAsP layer is divided to superlattice layers composed by InP and GaInAs. This structure is stable for the growth temperature change because the As/P composition change is suppressed. In addition, the superlattice structure is expected to have other advantages such as increase of refractive index difference [1] and less thermal resistance than arroy [2] which are not investigated in this study yet.

Figure 1 illustrates a proposed DBR structure in comparison with a conventional GaInAsP/InP DBR. The superlattice structure was formed by the $Ga_{0.468}In_{0.532}As$ and InP for lattice matching to the InP substrate. The SL structure is designed to have a shorter bandgap wavelength than the target lasing one λ(=1.55μm). The number of SL stacking is controlled to have $\lambda/4$ of the optical thickness. The SL/InP DBR structure was grown using TMIn, TEGa, TBA, and TBP and the growth temperature was 640°C. The optimized growth interruption was inserted for each interface.

Figure 2 shows a room-temperature PL spectrum from a 16 period SL structure on a InP substrate. The SL thicknesses are 9ML and 3ML for the GaInAs and InP, respectively. The PL peak wavelength of 1.43μm was good agreed with the calculated bandgap wavelength. A 15 pair of DBR was grown using this SL structure. Figure 3 shows X-ray diffraction patterns from the 15 pair SL DBR and that from 7 pair DBR by etching away the top 8pair. This result indicates that 12ML(=9ML+3ML) SL period and lattice-matching condition was kept without arroying of the SL structure.

Figure 4 shows a reflectivity spectrum of the SL DBR and GaInAsP/InP conventional DBR. The maximum reflectivity was 92% at 1.55μm. The reflectivity and the spectrum are comparable to the conventional GaInAsP DBR. By increasing the pair number, the proposed SL DBR structure is available for 1.55μm VCSELs.

In conclusion, we demonstrated a new GaInAsP/InP DBR using superlattice structure and show the availability of the superlattice DBR as a 1.55μm mirror. We are measuring the thermal resistance and refractive index of the SL.

Reference

[1] R. Tsu, A. Koma, and L. Esaki: J. Appl. Phys. 46, 2, 1975.

[2] T. Yao: Appl. Phys. Lett. 51 (22) 30, 1987.

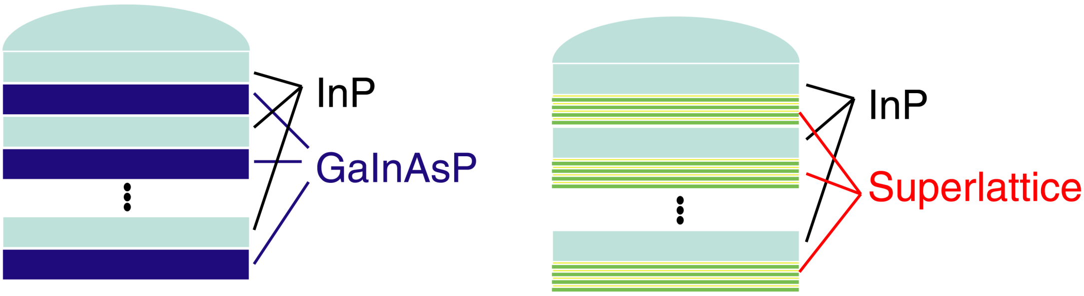

Fig. 1 GaInAsP/InP conventional DBR (left) and superlattice DBR proposed in this study (right).

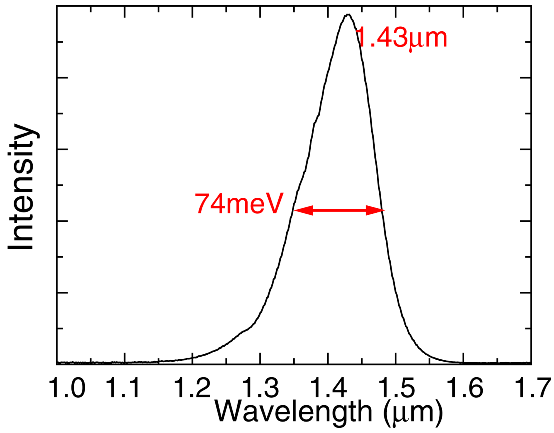

Fig. 2 Photoluminescence spectrum of GaInAs/InP superlattice structure.

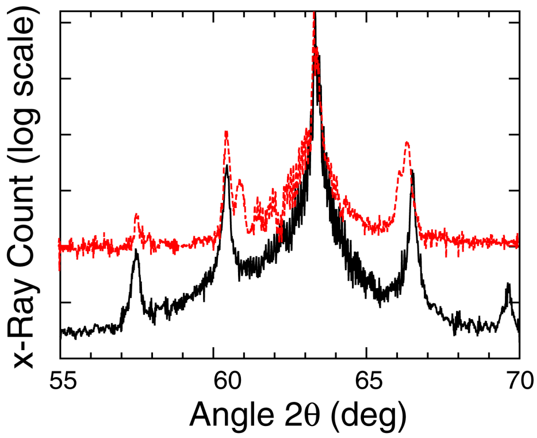

Fig. 3 X-ray diffraction pattern of GaInAs/InP superlattice DBR for 15pair structure (lower) and 8pair etched structure (7 pair) (upper).

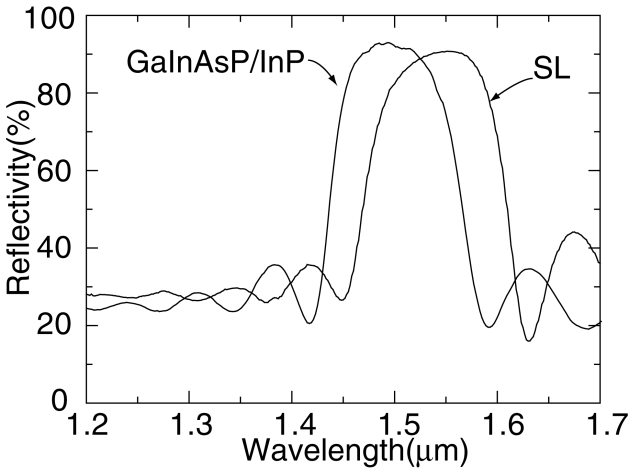

Fig. 4 Reflectivity spectrum of 15pair GaInAs/InP superlattice DBR and GaInAsP(λg=1.43µm)/InP conventional DBR.