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AlGaAsSb/GaSb Distributed Bragg Reflectors Grown by Organometallic Vapor Phase Epitaxy

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NOTICE

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1. Summary

The first AlGaAsSb/GaSb quarter-wave distributed Bragg reflectors grown by organometallic vapor phase epitaxy are reported. The peak reflectance is 96% for a 10-period structure.

1.1 AlGaAsSb/GaSb Distributed Bragg Reflectors Grown by Organometallic Vapor Phase Epitaxy

High reflectivity mirrors have been shown to improve the performance of optoelectronic devices such as vertical cavity surface emitting lasers, resonant cavity photodetectors, and photovoltaics. Al(Ga)As/GaAs quarter-wave distributed Bragg reflectors (DBR's) have been extensively used in GaAs-based devices [1], while AlGaAsSb/(Al)Ga(As)Sb DBR's have been incorporated in both InP- and GaSb-based devices [2,3]. The AlSb-based materials for InP-based devices are attractive because these alloys have a larger index contrast than InP-based materials ($\Delta n \sim 0.6$ compared to 0.4), and consequently fewer periods are required for the same reflectivity. In addition, these alloys can be lattice matched to the InP substrate. However, the growth of AlSb-containing materials by organometallic vapor phase epitaxy (OMVPE) is fundamentally more difficult [4,5], and only molecular beam epitaxy has been used to grow these AlGaAsSb/(Al)Ga(As)Sb DBR's. Since OMVPE technology is a leading technology for epitaxial growth of optoelectronic devices, it is important to develop OMVPE growth of AlGaAsSb/(Al)Ga(As)Sb DBR's. In this report, high-reflectivity AlGaAsSb/GaSb DBR's grown by OMVPE are reported for the first time.

GaSb and $\text{Al}_{0.81}\text{Ga}_{0.19}\text{As}_{0.06}\text{Sb}_{0.94}$ epitaxial layers were grown by OMVPE with all organometallic sources including tri-*n*-butylaluminum, triethylgallium, tertiarybutylarsine, and trimethylantimony as described previously [4]. All layers were grown nominally lattice matched to vicinal (001) Te-doped GaSb substrates miscut $6^\circ \rightarrow (1-11)\text{B}$. The growth temperature was 550 °C. Accurate and reproducible layer thickness and composition must be accurately controlled for high-reflectivity DBR structures, and therefore, in-situ reflectance monitoring was used to calibrate growth rates and alloy composition [6].

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AlGaAsSb/GaSb DBR structures were grown with 10 periods. The layer thickness was adjusted to vary the reflectance stop band from 1.6 to 2.4 μm . High-resolution x-ray diffraction was used to evaluate the structural quality and the reflectance was measured with a Cary 5E spectrophotometer.

Figure 1 shows the in-situ spectral reflectance for growth of a typical AlGaAsSb/GaSb DBR structure at a monitoring wavelength of 633 nm. The intended layer thickness for this sample, which was designed to have a peak reflectivity at 2.2 μm , was 164.4 nm and 141 nm for AlGaAsSb and GaSb, respectively. The reflectance spectrum for growth of AlGaAsSb and GaSb layers is repeatable from one period to the next, which indicates that the growth is highly reproducible from layer to layer. Figure 2 shows the measured (upper) and simulated (lower) x-ray diffraction curves for the DBR structure. The simulation suggested layer thickness of 163.6 and 143.1 nm for AlGaAsSb and GaSb, respectively, and is in very good agreement with the intended layer structure. The high-order satellite peaks are indicative of excellent periodicity.

The spectral reflectance measurement (solid line) and theoretical calculation (dashed line) are shown in Figure 3, and the agreement between the peak reflectance, width of the stop band, and side bands is excellent. A peak reflectance of 95.2% at 2.17 μm was measured. Optical constant data for AlGaAsSb used in the calculation were estimated by linear interpolation of the constituent binaries GaSb, AlSb, and AlAs [7].

Figure 4 summarizes the reflectance for four DBR structures, for which the reflectance stop band was adjusted by varying the thickness of AlGaAsSb and GaSb layers. The center of the stop band ranges from 1.59 μm to 2.47 μm , while the peak reflectance ranges from 93 to 96% for DBR's centered at 2.0 to 2.47 μm , and is 87.4% for the DBR centered at 1.59 μm . This lower value is due to absorption in the GaSb layer of the DBR. A low value of Al in this larger index layer would increase the energy gap of that layer and thus decrease absorption, which will lead to increased reflectance.

In summary, AlGaAsSb/GaSb DBR structures have successfully been grown by OMVPE. Reflectance as high as 96% for a structure with only 10 periods was achieved. These results indicate that OMVPE growth of AlSb-based materials for DBR structures is extremely promising. Although this demonstration was for alloys lattice matched to GaSb substrates, it is expected that alloys lattice matched to InP can also be grown with success.

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References

1. K. Iga, F. Koyama, S. Kinoshita, J. Vac. Sci. Technol. A 7 (1989) 842.
2. G. Almuneau, E. Hall, S. Nakagawa, J.K. Kim, D. Lofgreen, O. Sjolund, C. Luo, D.R. Clarke, J.H. English, L.A. Coldren, J. Vac. Sci. Technol. B 18 (2000) 1601.
3. A.N. Baranov, Y. Rouillard, G. Boissier, P. Grech, S. Gaillard, C. Alibert, Electron. Lett. 34 (1998) 281.
4. C.A. Wang, J. Cryst. Growth 170 (1997) 725.
5. R.M. Biefeld, A.A. Allerman, S.R. Kurtz, J. Cryst. Growth 174 (1997) 593.
6. C.J. Vincis, C.A. Wang, K.F. Jensen, W.G. Breiland, J. Cryst. Growth 195 (1998) 181.
7. C.J. Vincis, Ph.D. thesis, Department of Materials Science and Engineering, Massachusetts Institute of Technology, 2001.

Figure Captions

Figure 1. In-situ reflectance monitoring spectrum during growth of AlGaAsSb/GaSb DBR structure.

Figure 2. Measured (upper) and simulated (lower) high resolution x-ray diffraction curves of 10-period AlGaAsSb/GaSb DBR structure.

Figure 3. Measured (solid line) and calculated (dashed line) reflectivity spectra of 10-period AlGaAsSb/GaSb DBR structure.

Figure 4. Spectral reflectivity of 10-period AlGaAsSb/GaSb DBR structures designed for various stop bands.

Figure 1

Figure 2

Figure 3

Figure 4