Extended Abstracts of the 1994 International Conference on Solid State Devices and Materials, Yokohama, 1994, pp. 166-168 **PB-1-7**

Compositional Disordering of AlGaAs/GaAs Superlattices by Low Temperature Grown GaAs

J. S. Tsang, C. P. Lee, J. C. Fan, K. L. Tsai, and H. R. Chen

Department of Electronics Engineering and
Institute of Electronics
National Chiao Tung University
Hsinchu, Taiwan 30050, Republic of China

The use of low-temperature (~ 200 °C) grown GaAs by molecular beam epitaxy to induce compositional disordering of AlGaAs/GaAs superlattice has been studied. After furnace annealing between 700 °C and 850 °C for 30 minutes, obvious blue shift in the peak wavelength of the superlattice emission is observed by the 77K photoluminescence (PL), indicating that the emission has been changed from that of the GaAs quantum wells to that of the intermixed AlGaAs. The PL shift and the depth profile of Al concentration measured by secondary ion mass spectrometry indicate that the superlattice is nearly totally disordered after 850 °C annealing.

1. TEXT

Compositional disordering of III-V superlattices has been extensively studied. The disordering techniques reported include impurity induced disordering, diffusion induced disordering, and implantation enhanced intermixing.[1-3] All of these methods need impurities or defects to induce the disordering process under thermal treatment. The GaAs epilayers grown by molecular beam epitaxy (MBE) at low substrate temperatures (~200 °C) have been found to be semi-insulating and can be used for many device applications. This interesting property has stirred a lot of interest among material scientists in finding out the physical properties of this material. Kaminska et al.[4-5] have reported a large amount of defects exist in the low temperature grown GaAs (LT-GaAs) layers. They have found that the arsenic antisite defects (As_{Ga}) and the gallium vacancies (V_{Ga}) are the dominate point defects in LT-GaAs layer. In this study, we have studied and demonstrated the use of LT-GaAs as the defect source to induce the disordering of the AlGaAs/GaAs superlattices. The disordering has been verified by 77K photoluminescence (PL) spectra and secondary ion mass spectrometry (SIMS) measurement.

The structure, shown in Fig.1, used in this study was grown by a Varian GEN II MBE system on semi-insulating GaAs substrates. It consists of a 0.5 μm GaAs buffer layer and a 4.5 pairs of 65 Å $Al_{0.45}Ga_{0.55}As$/40Å GaAs superlattice sandwiched between two GaAs layers. All the layers were grown at 580 °C except the two GaAs confining layers. Two samples with the confining GaAs layers grown at 580 °C and 200 °C were compared. The thicknesses of the bottom and top confining layers were chosen to be 0.5 μm and 0.1 μm, respectively. The V/III beam equivalent pressure ratio was around 15 and the growth rate was 1 μm/h. Growth interruption was used before and after the growth of the AlGaAs/GaAs superlattices for both samples. After growth, the samples were furnace annealed in forming gas between 700 °C and 850 °C for 30 minutes. During annealing, the samples were placed in between two semi-insulating GaAs wafers to avoid arsenic loss. The samples were then characterized by 77K photoluminescence and SIMS. The photoluminescence was excited with the 514.5 nm line of an Ar laser. The power density was about $1W/cm^2$. The depth profile of Al was measured by a Cameca IMS-5F SIMS spectrometer.

Fig.2 shows the PL spectra of the samples before and after thermal treatment. Only the emission peaks from the superlattice region are shown in the figure. The PL spectra of the sample with high temperature (580 °C) grown GaAs before and after annealing did not show any obvious difference with annealing temperatures up to 800 °C.(see Fig. 2(a)) A shift in the peak wavelength (from 7429Å to 7312Å) occurs only after the sample was annealed at 850 °C. This is due to the intrinsic self-interdiffusion of the AlGaAs/GaAs superlattice. The PL spectra, shown in Fig. 2(b), of the sample with low temperature grown GaAs, however, are very different before and after annealing. Obvious blue shift in the peak wavelength of the superlattice emission is observed even after 700 °C annealing. This phenomenon indicates that the presence of the low temperature grown GaAs enhances the intermixing of GaAs and AlGaAs. After 850 °C annealing the peak wavelength shifts to 6731Å, which corresponds to the emission peak of bulk $Al_{0.23}Ga_{0.77}As$, indicating that the superlattice is nearly totally disordered (a totally disordered layer should have an Al content of 28% in our structure). The full width at half maximum (FWHM) of the PL spectra for both of the samples before and after annealing is shown in Fig.3. The FWHM of the sample with high temperature grown GaAs did not show any obvious difference with annealing temperature up to 800 °C. The FWHM of the sample with the low temperature grown GaAs obviously increased with the increase of the annealing temperature. After the sample was annealed at 850 °C for 30 minutes, the FWHM of the sample with the LT-GaAs layer increased from 12 meV to 31 meV. The increase in FWHM after thermal treatment indicated the intermixing between GaAs and AlGaAs. The presence of Al in the GaAs region and the gradual change in the Al composition at the superlattice interfaces caused the increase of the PL linewidth. We have noticed that the PL intensity of the sample with LT-GaAs first increased with annealing temperature up to 750 °C then decreased at higher temperatures. The enhancement in PL intensity can be explained by the reduction of light absorption in the LT-GaAs layer due to annealing of the defects in the material after thermal treatment. But at very high temperatures, because of the formation of AlGaAs with high Al content, the PL intensity decreases again.

The disordering of GaAs/AlGaAs because of low temperature grown GaAs has also been verified by SIMS. Fig.4 shows the Al composition profile of the superlattice sandwiched between low temperature grown GaAs layers before and after annealing at 850 °C for 30 minutes. The results clearly shows that the superlattice is disordered after annealing. The disordered layer has a nearly average Al composition of the AlGaAs/GaAs superlattice.

In conclusion, the low temperature MBE grown GaAs used as the defects source to induce compositional disordering of AlGaAs/GaAs superlattices has been studied. After furnace annealing between 700 °C and 850 °C for 30 minutes, obvious blue shift in the peak wavelength of the superlattice emission is observed by the 77K photoluminescence, indicating that the emission has been changed from that of the GaAs quantum wells to that of the intermixed AlGaAs. The presence of the low temperature grown GaAs enhances the intermixing of GaAs and AlGaAs even after 700 °C annealing. For the sample with LT-GaAs layers after 850 °C annealing, the peak wavelength shifts to 6731Å, which corresponds to the emission peak of $Al_{0.23}Ga_{0.77}As$, indicating the superlattice is nearly totally disordered. The Al composition profile measured by SIMS also shows the superlattice disordering taking place and resulting in the formation of a disordered layer with a nearly average Al composition of the superlattice. Because the low temperature grown GaAs can be easily incorporated in various multi-layer heterostructures, the use of such material for superlattice disordering should find applications for many devices.

The authors would like to thank Miss P. F. Chou for the SIMS measurements and for useful discussions. This work was supported by the National Science Council of the Republic of China under Contract No. NSC82-0404-E009-381.

2. FIGURES

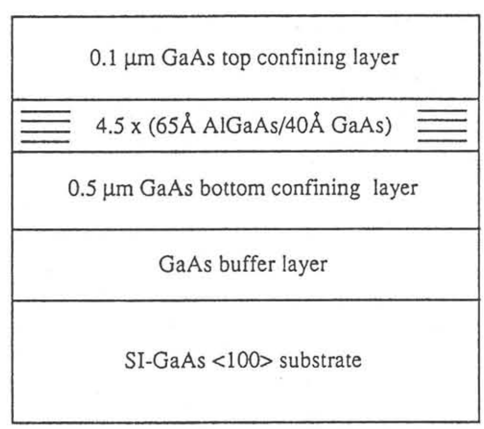

Fig.1 Layer structure used in this study. The top and bottom confining layers are 0.1 µm and 0.5 µm thick respectively.

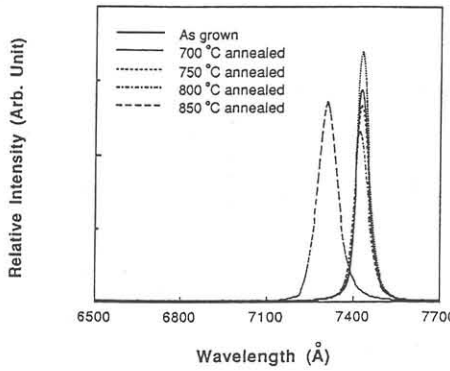

Fig.2(a) The 77K PL spectra of the sample with 580 °C grown GaAs confining layers before and after furnace annealing. The annealing temperatures were 700 °C, 750 °C, 800 °C. and 850 °C and the annealing time was 30 minutes.

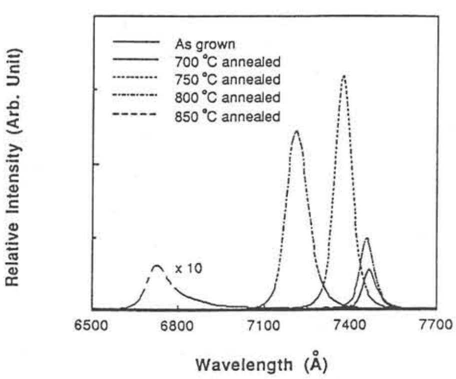

Fig.2(b) The 77K PL spectra of the sample with LT-GaAs confining layers before and after furnace annealing. The annealing temperatures were 700 °C, 750 °C, 800 °C. and 850 °C and the annealing time was 30 minutes.

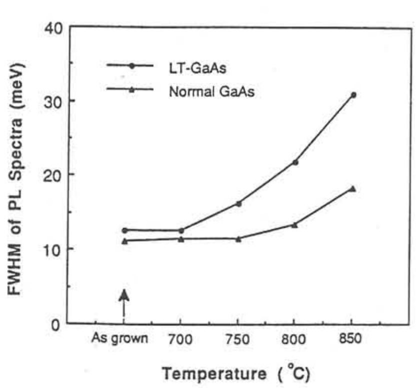

Fig.3 The FWHM of the PL spectra for samples before and annealing at various temperatures.

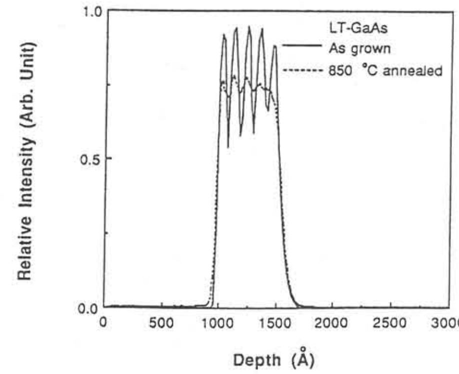

Fig.4 The Al compositional profile of the sample with LT-GaAs layers before and after annealing. The intermixing of GaAs and AlGaAs is clearly observed.

3. REFERENCES

1) P. Mei, H. W. Yoon, T. Venkatesan, S. A. Schwarz, and J. P. Harbison, Appl. Phys. Lett. 50(1987) 1823.

2) N. Holonyak, Jr., W. D. Laidig, M. D. Camras, J. J. Coleman, and P. D. Dapkus, Appl. Phys. Lett. 39(1981) 102.

3) J. Cibert, P. M. Petroff, D. J. Werder, S. J. Pearton, A. C. Gossard, and J. H. English, Appl. Phys. Lett. 49(1986), 223.

4) M. Kaminska, Z. Liliental-Weber, E. R. Weber, T. George, J. B. Kortright, F. W. Smith,, B. Y. Tsaur, and A. R. Calawa, Appl. Phys. Lett. 54(1989) 1881.

5) M. Kaminska, E. R. Weber, Z. Liliental-Weber, and R. Leon, and Z. U. Rek, J. Vac. Sci. Technol. Vol. B7,(1989) 710.