Photoreflectance study of stress in GaAs/Si structure

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Abstract - Photoreflectance (PR) measurement have been employed to study the uniformity of GaAs/Si 3" wafer. The PR shows the energy of light and heavy hole even at room temperature. From the observed energy of LH and HH, it can be seen that the center of the wafer is more stressed than the edge. On the basis of biaxial tensile stress the higher and lower transitions are attributed to heavy and light hole respectively.

1. Introduction

Recently, heteroepitaxial growth of Gallium Arsenide epilayer on Silicon substrate attracts much attentions for several reasons. Silicon substrate has superior thermal conductivity and mechanical strength to GaAs substrate.

However, residual strain is introduced in GaAs films as a result of the lattice constant mismatch (4.1%) and thermal expansion coefficient mismatch (60%) of the constituent materials [1]. This strain changes band gap energy and lifts valance band degeneracy.

This residual stress and strain can be easily measured by Photoreflectance (PR). A modulation spectroscopy, PR is a reflectance modulation produced by a laser beam, which is a contactless form of electroreflectance (ER). It is possible to easily determine the band edge energy even at room temperature.

In this paper, the uniformity of GaAs film grown on a Si substrate and temperature dependence of bandedge energy in this heterostructure system have been studied by PR spectroscopy.

2. Experimental

The modulation in the reflectivity is produced by mechanically chopping the laser beam used to create the electron-hole pairs. A 5-mW He-Ne laser chopped at 80HZ was used for this purpose. The probe light from a tungsten lamp passed through the monochromator was irradiated on the surface of GaAs film. The reflected light signal was detected with Si photodiode using lock-in amplifier. The GaAs layer grown on Si substrate used. The carrier concentration of GaAs layer is p = 1.9×10^{13} /cm^3.

3. Results and Discussions

In the low-field regime, the derivatives line shape of $\Delta R/R$ spectra can be fitted with this function

$$\Delta R/R = Re[\sum_{j=1}^{3} C_j e^{i\theta_i}(E - E_{g,j} + i\Gamma_j)^{-m_j}]$$

where p is the number of interband transitions included, and C_j, θ_j, $E_{g,j}$, Γ_j, and m_j are amplitude, phase factor, energy, broadening parameter, and a parameter that depends on critical point type and order of derivative of the jth feature, respectively.

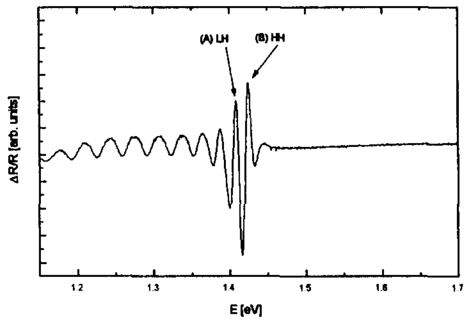
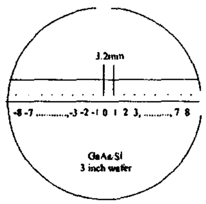


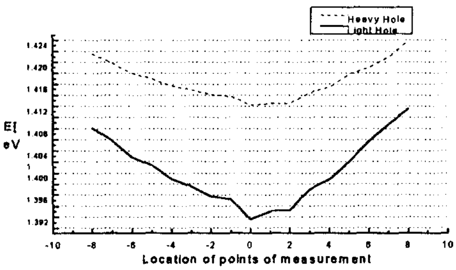
Fig. 1. PR spectrum of GaAs/Si at 300K using the He-Ne laser as the pump source.

Fig. 1. shows the PR spectra measured at room temperature. The obtained PR spectra shows oscillation behavior due to interference below near the bandgap energy. Although we expected the peak-to-peak intensity of heavy hole(B) is much higher than that of light hole as like Dimoulas et al. [2] proposing the light and heavy holes should have relative intensities of 1:3 respectively by calculating the optical matrix, the PR spectra shows discrepancy due to signal distortion by the

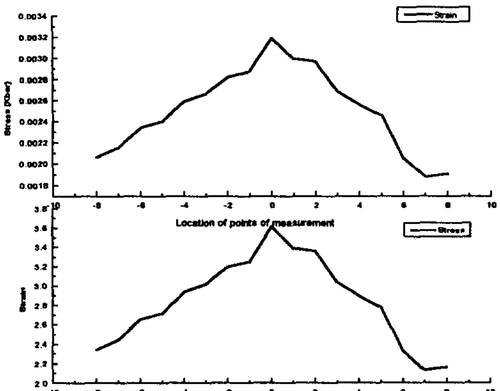
interference fringe. Therefore, we could't identify the heavy hole and light hole. But we assumed feature with lower energy was light hole, which is consistent with many preceding report [2] and the widely used assumption of biaxial tensile stress in GaAs/Si.



(a)



(b)



(c)

Fig. 2. (a) Measurement points along the diameter of a GaAs/Si wafer. (b) The graph of extracted energy parameter & sampling point location. (c) stress and strain distribution of the sample

For the observation of uniformity in 3 inch GaAs/Si wafer, we chose 17 points along the diameter of a wafer as shown in Fig. 2a and obtained the energy of heavy hole and light hole about each point by fitting the PR spectra using above equation including $m_j = 2$. The graph of extracted energy parameter versus sampling point location was plotted in Fig. 2b, which is in good agreement with Koshi et al. [4] who used only cleaved sample. Fig. 2c shows stress and strain distribution of the sample. The result clearly indicate that the center of the wafer is under larger stress than the edge of the wafer. This distribution profile of stress/strain is similar to the previous investigation on much smaller sample [3].

In Fig. 3., the temperature dependence of bandedge energy is plotted. We also observed the bandedge energy shifts to higher energy as decreasing temperature.

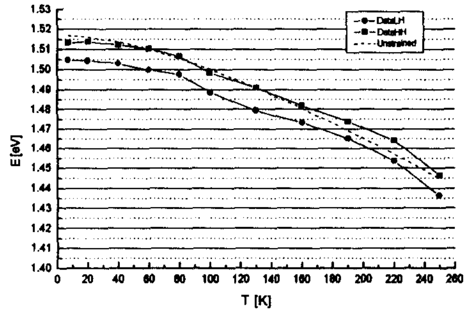


Fig. 3. Temperature dependence of HH and LH energy of GaAs/Si.

4. Conclusions

Uniformity and temperature dependence residual strain studies of GaAs/Si wafer were carried out using photoreflectance (PR) spectroscopy. Fitting the third derivatives line shape of $\Delta R/R$ spectra, the energy of LH and HH was obtained. From this result we found the center of the wafer is more stressed than the edge. We also observed the bandedge energy shifts to higher energy as decreasing temperature.

References

[1] S. F. Fang et al., J. Appl. Phys. 68, (7), R31 (1990)

[2] A. Dimoulas et al., J. Appl. Phys. 67 (9), (1990)

[3] Koshi Ando et al., Japanese J. of Appl. Phys. 28 (11), (1989)