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Investigation of $Al_xGa_{1-x}As/GaAs$ Heterostructure by Annealing at 300~800℃

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Abstract - Photoreflectance (PR) has been measured to investigate the characterization of the $Al_{0.20}Ga_{0.80}As/GaAs$ heterostructures. In the PR spectrum, the "C" peak is confirmed as the carbon defect with residual impurity originating from the growth process. After annealing, binding energy is relatively weak with As evaporation being done to increase Ga. Also obtained is the electric field value according to annealing temperature (300~800℃).

Keywords: PR, AlGaAs, GaAs, Heterostructure

1. Introduction

Photoreflectance (PR) spectroscopy is one of the experimental methods that enables the measurement of built-in electric fields and can provide evidence of the presence of a defect [1-3]. The advantages of this technique are its contactless character and high sensitivity even at room temperature.

As well, AlGaAs/GaAs heterostructures have induced great interest due to their important technological applications[4]. The electrical and optical properties of many novel heterostructure devices depend directly on interface quality. Photoreflectance spectroscopy (PR) has been recognized as the most promising method of investigated GaAs-related semi conducting structures[5]. The PR technique utilizes the modulation of a built-in electric field at the semiconductor surface through photo-injection of electron-hole pairs generated by a modulated incident laser beam[6]. The resulting change in dielectric constant is detected by reflectance. The simplicity and accuracy of PR, which provides sharp structures in the vicinity of charac-teristic energies and requires no specimen preparation, has rendered it particularly useful for epitaxially grown layers [7]. In this work we present a detailed study on the optical properties of AlGaAs/GaAs heterostructures by PR. We found the electric field magnitude was determined by PR. The AlGaAs/GaAs samples were annealed under a con-trolled NH_2 in order to investigate the thermal effect.

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2. Results and discussions

Fig. 1 shows the PR spectrum of our first investigated structure (as-grown) at room temperature. The obtained spectrum may be divided into two main peaks. The first peak is associated with band gap transition in the GaAs (1.42 eV) buffer layer.

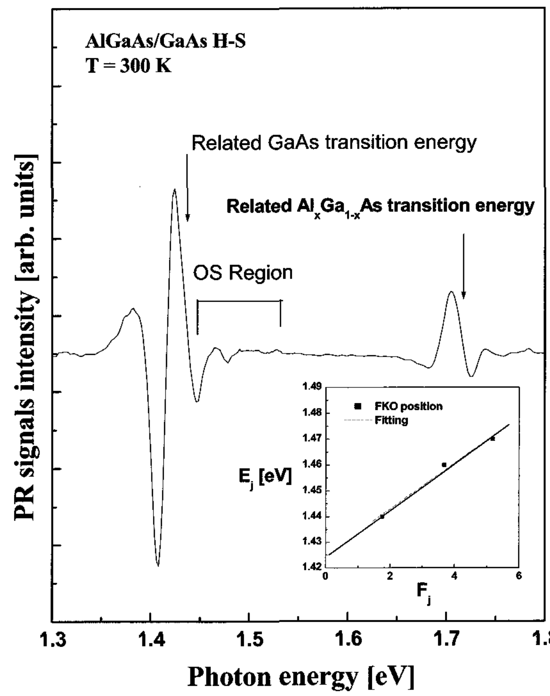

Fig. 1 PR spectrum obtained as-grown structure at room temperature

The peak from GaAs presents strong, and strongly damped Franz-Keldysh oscillations [FKO; OS region]. To analyze those oscillations we can use the fact that the energies of extrema FKO depend linearly on the parameter

F_j, which is the function of number of extremum j, where F_j is

$$F_j = [\frac{3}{2}\pi(j - \frac{1}{2})]^{2/3}$$

The linear dependence has the form

$$E_j = \hbar\Omega \cdot F_j + E_o$$

Where E_j is the energy of FKO extremum, E_o is the energy of critical point and $\hbar\Omega$ is the so-called electro-optical energy. The second peak is the $Al_{0.20}Ga_{0.80}As$ band gap transition around 1.71 eV. The Al composition was determined from the position $E_o(Al_xGa_{1-x}As) = E_o(GaAs) + 1.45x$ for x<0.4 [8]. In this result, the Al composition was 20%. The expressed electric field value from FKO oscillation is expressed in Table 1.

Table 1 Electric field value obtained according to annealing temperature

Annealing temperature (℃)	The interface electric field (10^5 V/cm)
as-grown	1.68
300	1.77
400	1.92
500	2.01
600	2.23
700	1.85
800	1.59

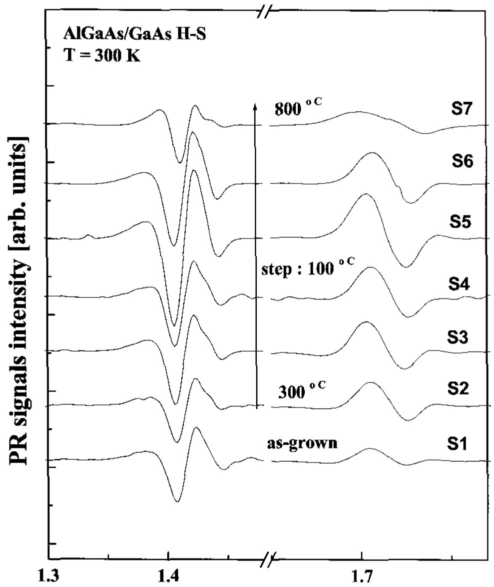

Fig. 2 PR spectra from sample S1 to S7 with various annealing temperatures

Fig. 2 presents the PR spectra from sample S1 to S7 with various annealing temperatures. GaAs peak appears strong and observed $Al_{0.20}Ga_{0.80}As$ peak appears weak in the heat treatment temperature of 800℃. After annealing, binding energy is relatively weak with As evaporation being done to increase Ga. As seen in Fig. 3, to clear this is a sample in as-grown with pump beam intensity in the range of 1 ~ 15 mW to decide and measure PR. As revealed in the picture, while a form of the PR signal shows no change according to the increased intensity of the pump beam, the signal displayed an increase in intensity. Expressed signal amplitude related with GaAs, signal amplitude related with $Al_{0.20}Ga_{0.80}As$, and amplitude of C peak with relation to pump beam intensity are all presented in Fig. 3.

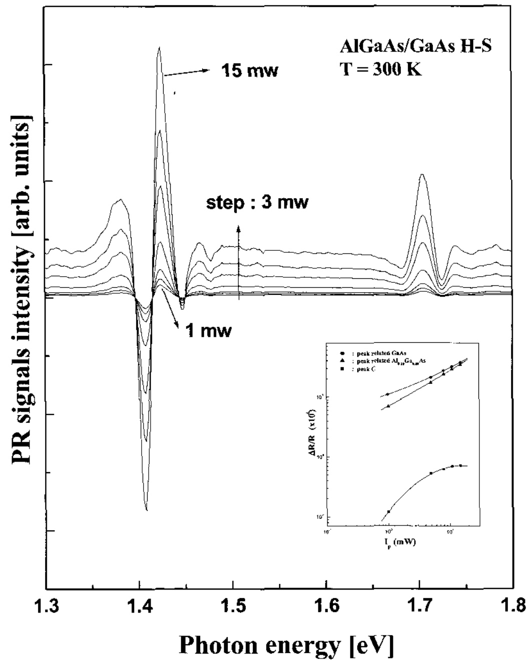

Fig. 3 The PR spectra in as-grown with pump beam intensity in the range of 1 ~ 15mW

The activation energy of C peak was 32 meV (related carbon). According to the amplification of the pump beam shown in the picture, related signal amplitude to GaAs and related signal amplitude to $Al_{0.20}Ga_{0.80}As$ indicates that C signal has become saturated in the neighborhood of about 8 mWs while increasing linearly. ΔR/R, which trails the pump beam intensity (ρ: mW/mm^2) is provided by equation

$$\Delta R/R \propto \rho^{1/n}$$

which indicates that a plot of in (ΔR/R) vs. in (ρ) should yield a straight line of slope 1/n.

If signal century increases linearly, it is the result of transition related with band gap, and occurs in relation to the saturation of impurities during linear increase.

3. Conclusions

GaAs peak appeared strong and was observed when $Al_{0.20}Ga_{0.80}As$ peak was weak during heat treatment at the temperature of 800℃. After annealing, binding energy was relatively weak with As evaporation being done to increase Ga. Also, the electric field value was obtained according to annealing temperature (300~800℃) and the "C" peak was confirmed as the carbon defect with residual impurity originating from the growth process.

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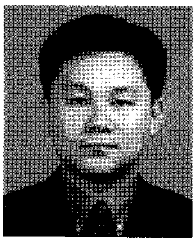

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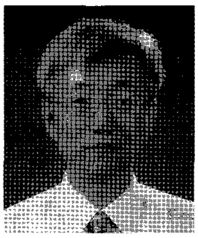

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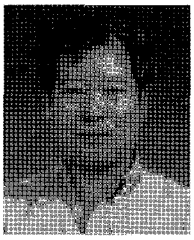

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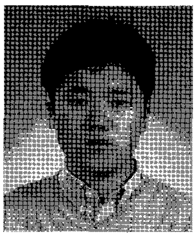

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