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Photoreflectance Measurement in $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ Heterostructure

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Abstract-Photoreflectance (PR) has been measured to investigate the characterization of the $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ and $Al_{0.21}Ga_{0.79}As/GaAs$ heterostructures. In the PR spectrum, the caplayer thickness was 170 nm and Si_3N_4 was utilized as the capping material. The "C" peak is confirmed as the carbon defect with residual impurity originating from the growth process. After annealing, in the presence of the Si_3N_4 cap layer, band gap energy was low shifted. This result indicates that the Si_3N_4 cap layer controlled evaporation of the As atom.

Keywords:

1. Introduction

The thin films of amorphous and crystalline silicon nitride exhibit a variety of attractive properties, like significant degree of hardness, chemical stability, high dissociation temperature, considerable thermal shock resistance and a wide band gap. These properties suggest mechanical, optical and electronic application in various branches of technology [1, 2]. As well, AlGaAs/GaAs heterostructures have induced great interest due to their important technological applications [3,4,5]. 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 [6]. 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 [7]. The resulting change in dielectric constant is detected by reflectance. The simplicity and accuracy of PR, which provides sharp structures in the vicinity of characteristic energies and requires no specimen preparation, has rendered it particularly useful for epitaxially grown layers [8]. In this work we present a detailed study on the optical properties of $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ and $Al_{0.21}Ga_{0.79}As/GaAs$ heterostructures by PR. We found the electric field magnitude was determined by PR. The samples ($Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ and $Al_{0.21}Ga_{0.79}As/GaAs$) were annealed under a controlled NH_2 in order to investigate the thermal effect of the Si_3N_4 cap layers.

2. Result and discussions

Fig. 1 presents the PR spectra from sample S1 to S6 with various Si_3N_4 cap layers. In these spectra we can clearly observe two regions: the GaAs band edge at approximately 1.42 eV and the $Al_{0.21}Ga_{0.79}As$ band gap transition around 1.72 eV. At Si_3N_4 cap layer thickness of 170 nm, broader PR signals between 1.52 and 1.68 eV (denoted by EH) were observed. The origin of the EH signals could be attributed to interference effects from the $Si_3N_4/Al_{0.21}Ga_{0.79}$

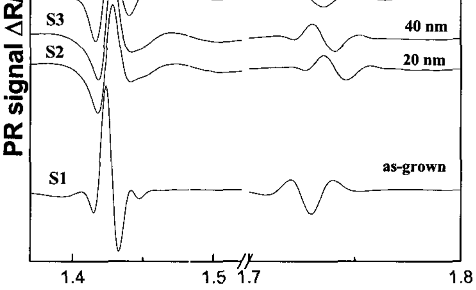

Fig. 1 The PR spectra from sample S1to S6 with Various Si_3N_4 cap layers.

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As/GaAs multilayered structure. A clear signature of the existence of intense internal electric fields in the presence of damped oscillations at energies above the band gap in the PR spectra are identified as Franz-Keldysh oscillation (FKO). The expressed electric field value from FKO oscillation is expressed in Fig. 2.

The C signal observed in the sample was not observed in the as-grown sample. However, the cap layer of 170 nm is observed and is clearly evident by high electric field effect, which appears by a signal that is formed by carbon impurities and remnants when grown by MBE method to demonstrate $Al_{0.21}Ga_{0.79}As$ epi layer's signal and about 28 mV variances [9]. As seen in Fig. 3, to clear this is a sample in which cap layer thickness is 170 nm with pump beam intensity in the range of 2 ~ 15 mW to decide and measure PR. As shown 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.

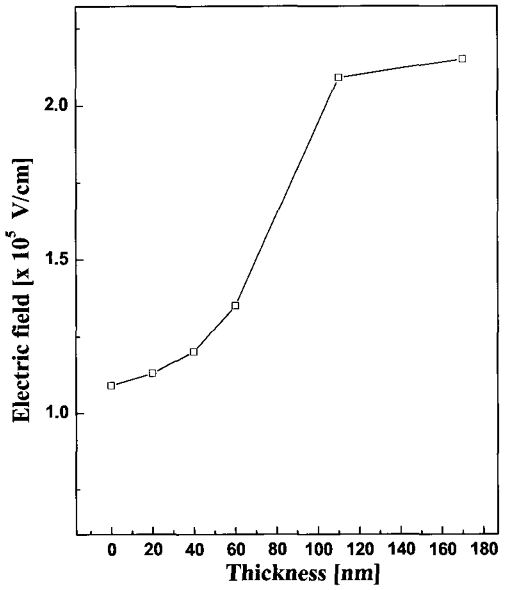

Fig. 2 The graph of electric field value obtained according to cap layer thickness.

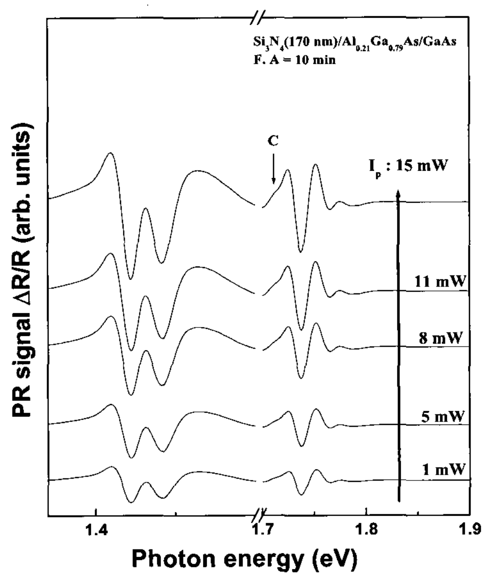

Fig. 3 The PR spectra according to modulation beam intensity of the Si_3N_4(170 nm)/$Al_{0.21}Ga_{0.79}As$/GaAs heterostructure.

Expressed signal amplitude related with GaAs, signal amplitude related with $Al_{0.21}Ga_{0.79}As$, and amplitude of C signal with relation to pump beam intensity are all shown in Fig. 4. According to the amplification of the pump beam shown in the picture, related signal amplitude to GaAs and related signal amplitude to $Al_{0.21}Ga_{0.79}As$ indicates that C signal has become saturated in the neighborhood of about 8 mWs while increasing linearly. ΔR/R that trails the pump beam intensity (ρ: mW/mm^2) of this is provided by equation (1) .

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

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

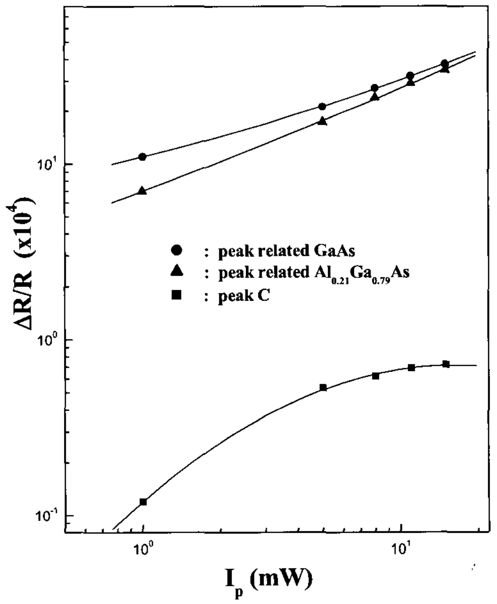

Fig. 4 The graph of the PR signal amplitude according to modulation beam intensity in the Si_3N_4(170 nm)/$Al_{0.21}Ga_{0.79}As$/GaAs heterostructure.

If signal century increases linearly, it is result by transition related with band gap, and it is when is related to impurities in case is gotten saturated while increase linearly [9,10,11]. Fig. 5 shows PR spectra that follow $Al_{0.21}Ga_{0.79}As$/GaAs heterostructure sample in annealing temperature. GaAs signal did not appear and observed $Al_{0.21}Ga_{0.79}As$ signal in heat treatment temperature 800℃.

After annealing, binding energy relatively weak As evaporation being done Ga increase. Therefore, GaAs signal does not appear and is observed weakly $Al_{0.21}Ga_{0.79}As$ signal in PR spectra. Fig. 6 is spectrums that are grown Si_3N_4 cap layer 170 nm to $Al_{0.21}Ga_{0.79}As/GaAs$ heterostructure, and measures by PR method after do annealing. When did not annealing, GaAs signal's intensity appeared predominating but observed by 1:1 ratio almost after do annealing by 800℃.

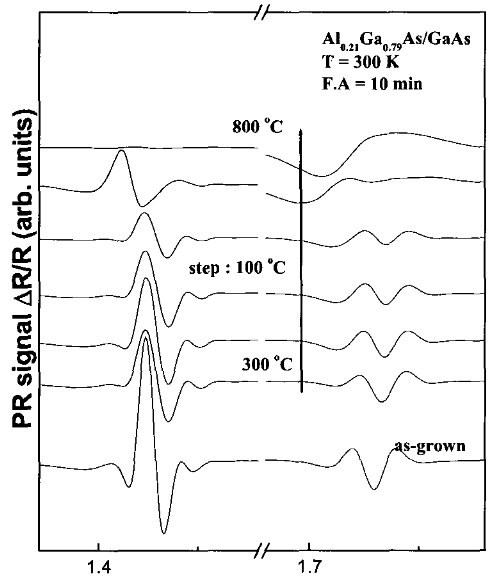

Fig. 5 The PR spectra that follow $Al_{0.21}Ga_{0.79}As/GaAs$ heterostructure in annealing temperature.

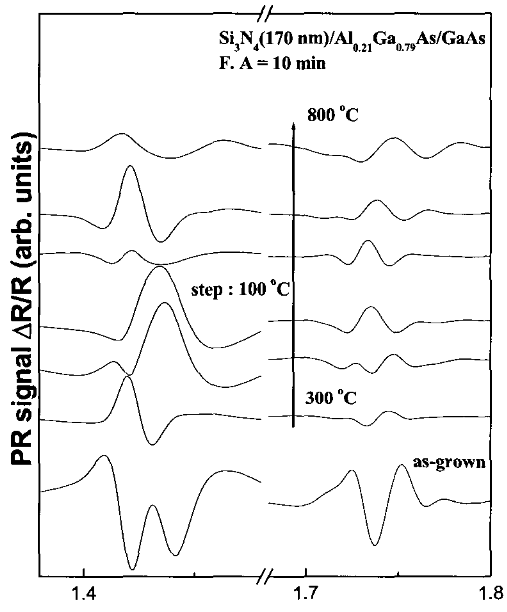

Fig. 6 The PR spectra that follow in Si_3N_4(170 nm)/$Al_{0.21}Ga_{0.79}As/GaAs$ heterostructure in annealing temperature.

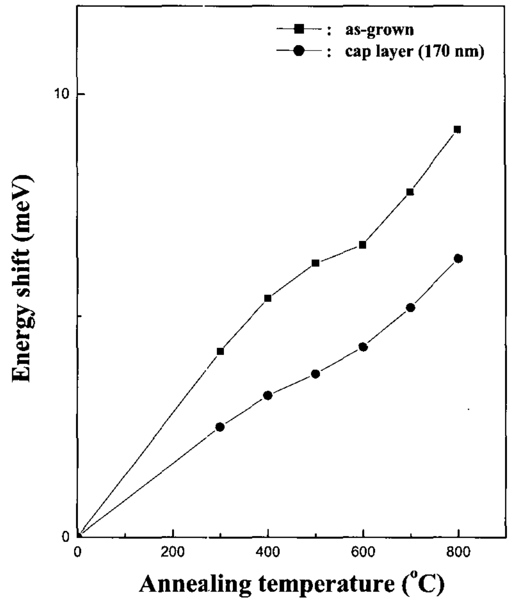

Fig. 7 Graph showing the shift of $Al_{0.21}Ga_{0.79}As/GaAs$ and $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ heterostructures to higher-energy.

But, when annealing temperature is 800℃, it appeared clearly when it compared cap layer with sample's PR spectrum when did not growing. This result can do that cap layer acts role that control As atom evaporation.

Fig. 7. indicates a graph that shows $Al_{0.21}Ga_{0.79}As/GaAs$ and displays a shift from $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ heterostructures to higher-energy after annealing. If annealing is performed first in the as-grown state, as the As atom escapes, a high electric field is formed and $E_g(Al_{0.21}Ga_{0.79}As)$ is shifted to high energy. Whereas, if there is a cap layer in existence, the As atom acts to control escaping

Because of these reasons, the degree to which the electric field is weakened and shifted by high energy is small [12-14].

3. Conclusion

1. When Si_3N_4 thickness cap layer is 110 nm, FKO signal by occurrence of electric field that is higher than the electric field occurring on supplementary sample's interface, is clearly observed.
2. When cap layer thickness is 170 nm, EH and C signals are observed between GaAs and $Al_{0.21}Ga_{0.79}As$ interface. EH signals could be attributed to interference effects from the $Si_3N_4/Al_{0.21}Ga_{0.79}As/GaAs$ multilayered structure. C signal is formed by carbon.
3. After annealing, when there is a cap layer present, the degree that is moved by high energy decreased. This is because As acts as a control in the presence of a cap layer.

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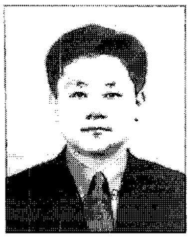

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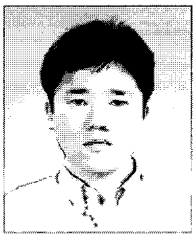

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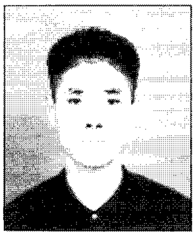

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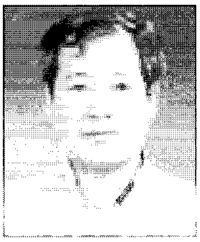

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