

Defect Characteristics of Be-doped GaSb Film Grown on GaAs

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Abstract—The defect characteristics of the Be-doped GaSb and no-doped GaSb film grown on GaAs and GaSb substrate respectively were analysed by the method of molecular beam epitaxy (MBE), positron annihilation Doppler broadening spectroscopy (PADBS), X-ray diffraction spectra (XRD) and atomic force microscopy (AFM). The experimental results show that the defects in Be-doped semiconductor GaSb could be attributed to existence of intrinsic defect, which has no complex defects in it. After doped Be atom, the crystallization of GaSb become worse, and the Be existed mainly in the interstitial atom.

Keywords—GaSb; positron annihilation spectroscopy; XRD; defect

I. INTRODUCTION

Semiconductor GaSb has the unique band-structure alignment, small electron effective mass and high electron mobility [1-3]. Compared to the GaSb, GaAs can form excellent n and p Ohmic contacts, and has semi-insulating and favorable thermal properties. GaSb film based on GaAs usually has been applied to fabricate photoelectrical device [4]. The structure of film has recently attracted significant research interest because of its importance for photoelectrical performance. The p-type Si-doped, p-type Zi-doped, and n-type Te-doped of GaSb film have been published [5-7]. The p-type Be-doped of GaSb film has never been reported.

Many measurement techniques have been used to characterize the structure of the film, such as transmission electron microscopy (TEM), Rutherford backscattering (RBS), elastic recoil detection (ERD) analysis, X-ray diffraction (XRD) and positron annihilation spectroscopy (PAS) and so on [6]. Among them, the positron annihilation spectroscopy being easily susceptible to open-volume defects, it has been usually employed to probe the microscopic information of defects, such as their size, charge states, concentration, and chemical surrounding. The structure characteristics in GaSb films by variable energy positron annihilation spectroscopy (VEPAS) have been first carried out [7].

At present, doped-Be atom GaSb epitaxial layers grown on semi-insulating GaAs (001) substrates, another non-doped GaSb film grown on GaSb substrate with nearly same growth conditions. The atomic force microscope (AFM), XRD and Positron annihilation doppler broadening spectroscopy (PADBS) were used to measurement it.

The full width at half maximum (FWHM) of the X-ray

diffraction patterns of GaSb and Be-doped GaSb epitaxial layers were used to study, and analysis the trends of Doppler broadening S, W parameters of samples as well.

II. EXPERIMENTAL PROCESS

The Be-doped GaSb epitaxial layers grown on the top of GaAs (001) substrate, and the thickness about 580 nm, the concentration of Be atom approximates to 10^{18} ppm [8]. For comparative, choose another sample, which was non-doped GaSb film grown on GaSb substrate with nearly same conditions. The diffractometer of XRD (DX-1000) using Cu K α X-ray source worked in a 2θ mode, scanning from 10° to 80° with a step of 0.06° , and the wavelength λ is 1.5406 \AA , the diffractometer operating voltage is 35 KV, accelerated current is 25 mA. A slow positron beam was employed for positron doppler broadening measurements, which were carried out in a vacuum chamber at about 10^{-6} Pa. The energy of the positron beam varied from 0.1 to 20 keV. The energy of γ photo from the e^+e^- annihilation radiation was recorded by a p-type high-purity germanium detector [9].

III. RESULTS AND DISCUSSION

Figure I (a-b) shows the AFM image of samples measured within the $10 \times 10 \mu\text{m}$. From the AFM image can be seen, the sample A surface is smooth, no obvious spiral structure of dislocations and the island, indicating its has good crystallization. Figure II (a-b) shows the X-ray diffraction pattern of the 200 direction for GaSb and Be-doped GaSb epitaxial layers respectively. Referring to the Table I, another important point in this figure of the crystal in equality is that the FWHM, using the following relation [9]:

$$FWHM = 0.9\lambda / t \cos \theta$$

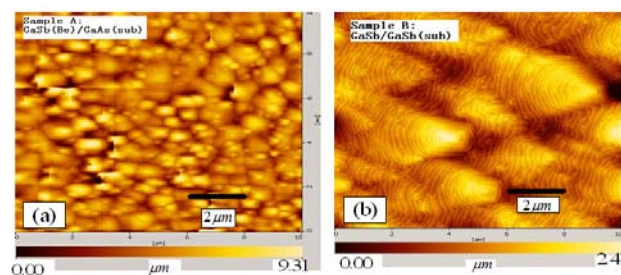


FIGURE I. THE PLAN-VIEW BRIGHT-FIELD AFM IMAGES OF SAMPLE A AND SAMPLE B.

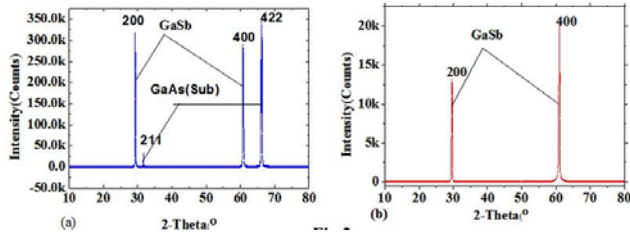


FIGURE II. THE X-RAY DIFFRACTION SPECTRA OF SAMPLE A AND SAMPLE B.

where t is size of crystallites, λ is the wavelength of Cu- $K_{\alpha 1}$ radiation and θ is the Bragg's angle [10-14]. Result indicates that the Be-doped GaSb has better crystalline than the undoped GaSb. Feel free to the GaSb which grown by molecular beam epitaxy (MBE) on GaAs substrates with high quality buffer layer has nearly 7 % lattice mismatch between the GaAs and GaSb [8]. Owing to the high level of Be, the crystallization is slightly well [15]

TABLE I. ANALYSIS RESULT OF X-RAY DIFFRACTION SPECTRA.

Peaks of XRD	GaSb 200	GaAs 211	GaSb 400	GaAs 422
FWHM of sample A	0.141°	0.126°	0.156°	0.191°
FWHM of sample B	0.265°		0.325°	

The cure of trends of the positron annihilation Doppler broadening S-parameters and W-parameters are shown in Figure III (a-b). From above curve, the S-parameter and W-parameters as a function of different energies has a significant variation with depth of near the epitaxial layers and the substrate. The mean implantation depth of the positron is calculated using following equation [17]:

$$H = 40E^{1.6} / \rho^{40}$$

Where Z is expressed in units of nanometers, ρ is the density in units of g/cm^3 , and E is the incident energy in kiloelectronvolts.

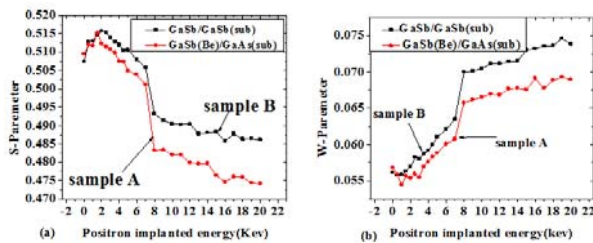


FIGURE III. THE TREND OF DOPPLER BROADENING S-PAREMETERS(A) AND W-PAREMETERS(B).

In Figure III (a), at 8 KeV the slop of curve fast increasing means that energy which below near 8 KeV injected to epitaxial layers and above near 8 KeV injected to the substrate [18-21]. Calculated the S-parameters of sample A were smaller than sample B, this result indicated that quality of sample A is better than sample B, in other words, the crystallization doped Be is better than non-doped in epitaxial layers and in substrate, and this was good agreement with the result of measurement of

XRD and AFM.

However, compared to the S-parameters of sample A and sample B in epitaxial layers and in substrate respectively, as we can see, the gap of S-parameters is even smaller in epitaxial layers than that in substrate. It is possible that the number and size of new micro-defects increase after doped Be, and the crystallization slightly becomes worse than non-doped. After doped the high level of Be, it seems that the inclusion of substitutional Be led to the crystallization slightly becomes worse.

The value of W-parameters indicated that there were more annihilating positron electrons with high momentum. The electron momentum information at different depth was represented by the values of W-parameters as well. The cure of trends of the positron annihilation Doppler broadening W-parameters are shown in Figure III (b). The W-parameters of sample A was less than sample B by calculated. This result indicated that the crystallization doped Be slightly become worse than non-doped, and this was good agreement with the result of the S-parameters.

Analysis the S-W parameter, we can observe the positron interface states owing to the positron annihilation in the interface has the unique information. From the Figure IV. curve, shows the variation of Doppler broadening S-W parameters within from 1 KeV to 8 KeV. Having no large mutations in the curve of sample, and almost located in the same straight line, it seems to be there were no complex defects in it [22].

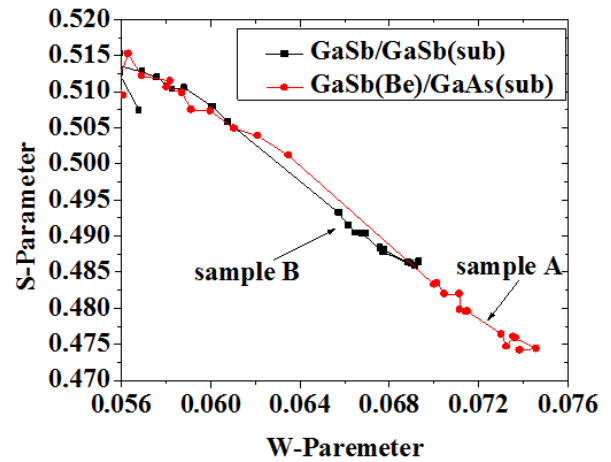


FIGURE IV. THE TREND OF DOPPLER BROADENING S-W PARAMETERS.

IV. CONCLUSIONS

In conclusion, the crystallization of Be-doped GaSb film slightly became worse than that of non-doped sample. In GaSb, V_{sb}^0 occurs at doping levels near the top of the valence band with formation energy of 2.73 eV, and V_{Ga}^0 has formation energy of 1.79 eV as well, V_{Ga}^p accordingly dominate and are likely to have much higher concentrations than V_{sb}^p [23]. The PADBS demonstrated that the crystallization of Be-doped sample become worse than that of non-doped sample. The high concentration of Be atom formed the inclusion of substitution,

accordingly, some vacancies of Sb decrease as well, and Be doped in GaSb became p-type semiconductor [14], and the type of defects in the Be-doped p-type semiconductor GaSb could be attributed to the existence of interstitial atom.

ACKNOWLEDGEMENTS

This work was financially supported by the National Natural Science Foundations of Mianyang Teachers' College (Nos MYSY2017JC10).

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