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Effect of buffer growth temperature on crystalline quality and optical property of $In_{0.82}Ga_{0.18}As/InP$ grown by LP-MOCVD

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Abstract

$In_{0.82}Ga_{0.18}As$ epilayers were grown by LP-MOCVD on InP (1 0 0) substrates with two-step growth method. It was analyzed that growth temperature of buffer layer exerted an influence on its crystalline quality and optical property, which were characterized by X-ray diffraction, scanning electron microscopy, and photoluminescence. The experiments showed that the crystalline quality and the optical property of the $In_{0.82}Ga_{0.18}As$ epilayers had close relation to the growth temperature of buffer layer and the optimum buffer's growth temperature was about 450 °C.

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Keywords: $In_{0.82}Ga_{0.18}As$; MOCVD; Buffer layer

1. Introduction

$In_xGa_{1-x}As$ materials are very important for light emitters [1], field-effect transistors [2], thermophotovoltaic devices [3], and detectors [4], etc. In recent years, there are great needs for 1–3 μm infrared detectors, and the most important applications are space imaging (including earth observation, remote sensing, environmental monitoring, etc. [5]) and spectroscopy. One of the goals of growing $In_{0.82}Ga_{0.18}As$ materials is the extension of the response wavelength of the InGaAs infrared detector. But the large mismatch between epilayers and substrates results in poor material quality. In order to overcome this limitation, many schemes [6–10] have been developed. The two-step growth method has often been adopted in growing highly mismatched heteroepitaxy layers, in which the low-temperature growth of thin buffer layers is followed by annealing and then growth of thick epilayers at higher temperatures [11]. The low-temperature deposited buffer layer is believed to act as a template for succeeding high-temperature grown epilayers and to accommodate lattice strain caused by both lattice mismatch and thermal one. In two-step growth method, the buffer layer is an important issue and an actively investigated subject. Two-step growth methods of SiGe [12], AlGaN [13], InAs [14], and GaN [15] have been reported. However, $In_{0.82}Ga_{0.18}As$ with this growth method is rarely studied. In this paper, we report LP-MOCVD growth of $In_{0.82}Ga_{0.18}As$ epilayers on InP (1 0 0) substrates with the two-step growth method and the study on the effect of buffer growth temperature on crystalline quality and optical property of $In_{0.82}Ga_{0.18}As$ epilayers. The X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL) are used to evaluate the property of materials.

2. Experimental

All samples were grown on semi-insulating (1 0 0) InP substrates by LP-MOCVD. The growth was performed using trimethylindium (TMIn), trimethylgallium (TMGa), and 10% arsine (AsH_3) in H_2 as precursors. Palladium-diffused hydrogen was used for carrier gas. The substrates on a

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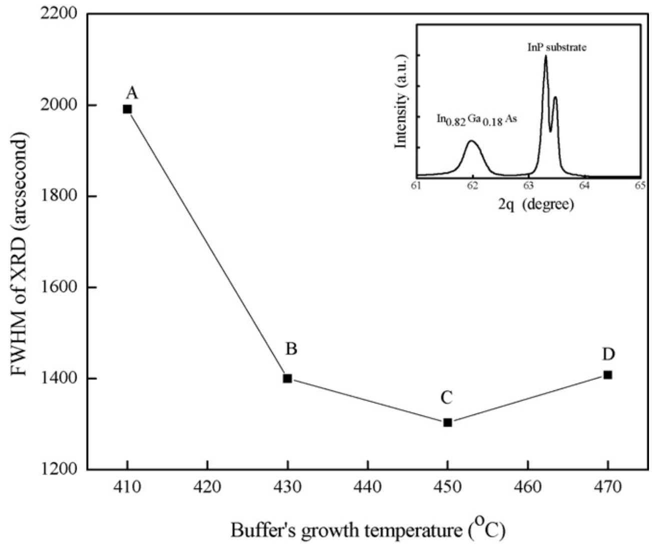

Fig. 1. Dependence of the FWHM of the X-ray diffraction of $In_{0.82}Ga_{0.18}As$ epilayers on buffer's growth temperatures. The inset shows the X-ray diffraction of the sample C.

graphite susceptor were heated by inductively coupling radio frequency power, the temperature was detected by a thermocouple, and the reactor pressure was kept 10,000 Pa, the growth temperature of $In_{0.82}Ga_{0.18}As$ buffer layer of four samples with two-step growth method were selected between 410 and 470 °C, and their thickness was fixed 100 nm. However, $In_{0.82}Ga_{0.18}As$ epilayers was grown at 530 °C and its thickness was fixed 0.8 μm. The crystalline quality of $In_{0.82}Ga_{0.18}As$ epilayers was characterized by XRD and SEM. The optical property of the $In_{0.82}Ga_{0.18}As$ was investigated by PL spectrum.

3. Result and discussion

The results of XRD measurements are shown in Fig. 1. For the sample A, in which the buffer's growth temperature is at 410 °C, it can be found that the full width at half maximum (FWHM) of the XRD is 1991 s, and it is the widest among the four samples. It shows the sample A is the poorest crystalline quality. The FWHM is 1400 s when the buffer's growth temperature is at 430 °C. It indicates the crystalline quality of the sample B is improved. When the buffer growth temperature is at 450 °C, the FWHM reaches a minimum of 1303 s. It shows the crystalline quality of the sample C is optimum. However, for the buffer's growth temperature of 470 °C, the FWHM is 1408 s. This value is wider than that of the sample C, it means that the crystalline quality of sample D is degraded. In our experiments, the growth conditions, such as thickness, V/III ratio, and pressure are fixed, but only the growth temperature of buffer layer is varied. It indicates that the changes of the FWHM of the XRD of $In_{0.82}Ga_{0.18}As$ epilayers are related to the growth temperature of buffer layer. The selection of growth temperature of buffer layer can improve the crystalline quality of $In_{0.82}Ga_{0.18}As$ epilayers.

Fig. 2(A)–(D) shows that surface morphology of sample A, B, C and D. It is evident that the surfaces of the four samples do not appear three-dimensional (3D) islands, indicating that the epilayers are in the growth mode of the two-dimensional (2D) characteristic. However, the sample C, that the growth temperature of buffer layer is at 450 °C, shows that its surface morphology is better than that of sample A, B, and D with some pits. The dramatic improvement of its surface morphology indicates that the growth temperature of buffer layer is optimized. It is well known that the surface morphology is influenced by some defects in the epilayers. The surface-diffusion kinetics plays an important role in the transition from 2D to 3D growth [16]. In particular, decreasing the growth temperature reduces the surface diffusion coefficient thus delaying the 2D–3D growth mode transition [17]. Since the buffer layer was grown at relatively low temperature, the surface atom migration was significantly restricted during the growth. Therefore, the strain existing at interface between the epilayer and buffer layer

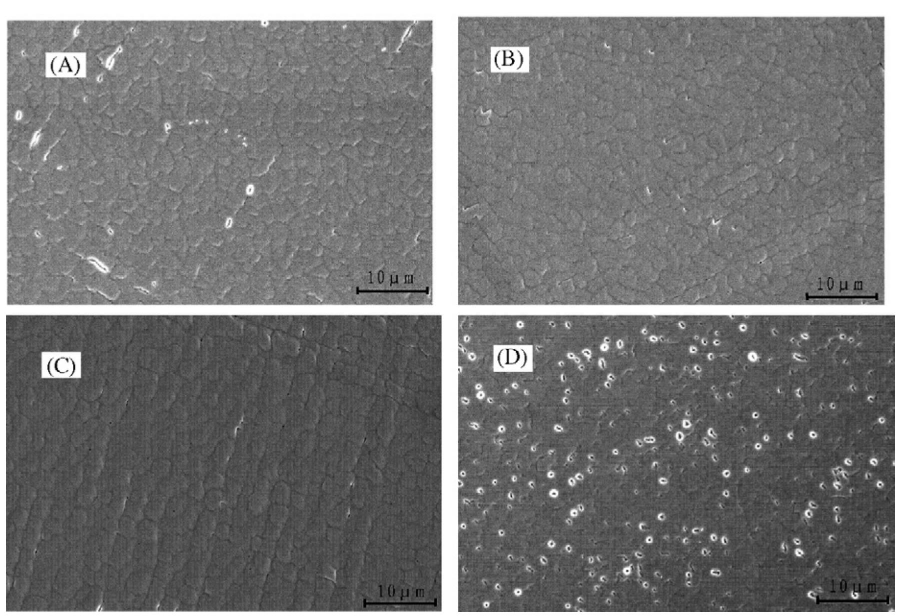

Fig. 2. SEM images of $In_{0.82}Ga_{0.18}As$ on InP with different buffer's growth temperatures at (A) 410 °C, (B) 430 °C, (C) 450 °C, and (D) 470 °C, respectively.

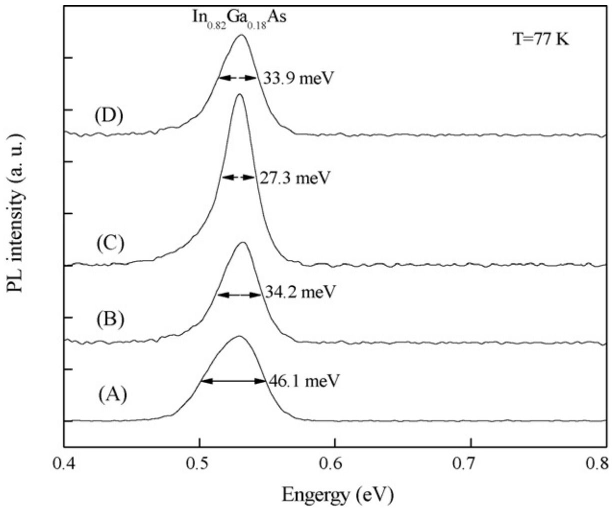

Fig. 3. PL spectra of $In_{0.82}Ga_{0.18}As$ on InP with different buffer's growth temperatures at (A) 410 °C, (B) 430 °C, (C) 450 °C, and (D) 470 °C measured at 77 K.

could be released easily by generating dislocations in the buffer layer. The misfit dislocations and some defects in epilayers are reduced. It indicates that the growing of $In_{0.82}Ga_{0.18}As$ with two-step growth method at an appropriate buffer growth temperature is essential in improving the surface morphology of its epilayers.

The optical property of the samples is investigated by PL. Fig. 3 shows the PL spectra of the four samples at 77 K. As seen from this figure, the spectra show a strong band edge emission at 0.529 eV (2.34 μm). The FWHM of PL is 46.1, 34.2, 27.3, and 33.9 meV, corresponding to the sample A, B, C, and D, respectively. In general, luminescent efficiency increases with increasing purity of the crystal for the band edge emission [18]. Misfit dislocations and some defects are known to quench luminescence due to nonradiative recombination as well as to broaden photoluminescence linewidths. So the change of the FWHM of PL is related to the growth temperature of buffer layer.

In order to achieve the optimum property of materials, a 100 nm thick $In_{0.82}Ga_{0.18}As$ buffer layer is deposited on InP substrate at low-temperature. When the temperature of buffer layer is lower than a certain temperature range, a dense cross-hatched pattern appears in the buffer layer, which is greatly disadvantageous to reduce the defects in $In_{0.82}Ga_{0.18}As$ epilayers. However, the 3D growth mode of buffer layer is enhanced when the temperature is higher than a certain temperature range, which will degenerate the properties of $In_{0.82}Ga_{0.18}As$ epilayers. From the results of XRD, SEM, and PL, there exists an optimum growth temperature of buffer layer for the growth of $In_{0.82}Ga_{0.18}As$ epilayers.

4. Conclusions

We employed the two-step growth method to grow the $In_{0.82}Ga_{0.18}As$ on InP substrates. The effect of buffer's growth temperature on the crystalline quality and optical property of epilayers was investigated carefully. We utilized XRD to characterize the crystalline quality of $In_{0.82}Ga_{0.18}As$ epilayers, used SEM to observe its surface morphology, and employed PL to evaluate its optical property. When we grew a 100 nm $In_{0.82}Ga_{0.18}As$ at 450 °C as a buffer layer, its FWHM of XRD was 1303 s, its crystalline quality of $In_{0.82}Ga_{0.18}As$ epilayers was optimum, and its surface morphology was the best. At the optimum growth temperature of buffer layer, the sample had good luminescent property and its FWHM of PL was 27.3 meV. It indicates that a suitable buffer's growth temperature was efficient to improve the property of $In_{0.82}Ga_{0.18}As$ epilayers.

Acknowledgements

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