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Effect of Buffer Layer Growth Temperature on Structural and Electrical Properties of $In_{0.82}Ga_{0.18}As$ with Two Step Growth Technique

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Abstract: $In_{0.82}Ga_{0.18}As$ was grown by low-pressure metal organic chemical vapor deposition (LP-MOCVD) on InP substrates with two-step growth technique. Effect of buffer layer growth temperature on structural and electrical properties of $In_{0.82}Ga_{0.18}As$ was analyzed, which was characterized by scanning electron microscopy (SEM), Raman scattering and Hall measurement. The results showed that the properties of epilayers have close relation to the buffer layer growth temperature and the optimum buffer layer growth temperature was about 450 ℃.

Key words: $In_{0.82}Ga_{0.18}As$; MOCVD; buffer; growth temperature
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1 Introduction

In recent years, there have been great needs for 1 ~ 3 μm infrared detectors, and the most important applications are in the fields of space imaging (including earth observation, remote sensing, environmental monitoring, *etc*[1]) and spectroscopy. $In_xGa_{1-x}As$ is very important material for light emitters, field-effect transistors, thermophotovoltaic devices and detectors[2~5], *etc.* One of the goals of growing $In_{0.82}Ga_{0.18}As$ is to extend the response wavelength of the $In_xGa_{1-x}As$ near infrared detector. However, a large lattice mismatch between epilayer and substrate results in poor material quality. In order to overcome this limitation, many schemes[6~8] have been developed. Two-step growth technique has been adopted in growing highly mismatched heteroepitaxy layer. The growth of buffer layer at low-temperature was followed by annealing and then growth of epilayer at higher temperatures[9]. The low-temperature deposited buffer layer is believed to act as a template for succeeding high-temperature grown epilayer and to accommodate lattice strain caused by both lattice mismatch and thermal one. In the two-step growth technique, the buffer layer has become an important issue and an actively investigated subject. SiGe, AlGaN, InAs and GaN[10~13] with the two-step growth technique were reported. We reported the effects of In content of the buffer layer[14] on $In_{0.82}Ga_{0.18}As$ epilayer. In this paper, LP-MOCVD growth of $In_{0.82}Ga_{0.18}As$ epilayer on InP substrate with the two-step growth technique was reported and the effect of buffer layer growth temperature on properties of $In_{0.82}Ga_{0.18}As$ epilayer was studied. The SEM, Raman scattering and Hall measurement were used to evaluate the properties of epilayer.

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2 Experiments

All samples were grown on semi-insulating InP (100) substrate by LP-MOCVD with the two-step growth technique. The growth was performed using trimethylindium (TMI), trimethylgallium (TMG), and 10% arsine (AsH_3) in H_2 as precursors. Palladium-diffused hydrogen was used for carrier gas. The substrate on a graphite susceptor was heated by inductively coupling radio frequency power, the temperature was detected by a thermocouple, and the reactor pressure was kept at 10 000 Pa. The growth temperature of $In_{0.82}Ga_{0.18}As$ buffer layer was selected from 410 ℃ to 470 ℃, and buffer thickness was fixed at 100 nm. However, $In_{0.82}Ga_{0.18}As$ epilayer was grown at 530 ℃, and its thickness was fixed at 800 nm. Surface morpholgy of $In_{0.82}Ga_{0.18}As$ epilayer was studied by scanning electron microscopy. Stress of epilayer was studied by Raman frequency shift ($\Delta\Omega$) of GaAs-like LO-phonon. The Raman measurements were performed at room temperature in backscattering geometry, in which the 514 nm line of an Ar^+ laser was used for the exciting light and incident light on the samples was kept to the same intensity. The electrical properties were measured using Van der Pauw technique at room temperature.

3 Results and Discussion

Fig. 1(a) ~ (d) shows the 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 epilayer is in the growth mode of the two-dimensional (2D) characteristic. However, for sample C, the buffer layer growth temperature is at 450 ℃. It shows that the surface morphology is better than those of sample A, B and D with some pits. The dramatic improvement of the surface morphology indicates that the buffer growth temperature is optimized. It is well known that the surface morphology is influenced by some defects in the epilayer. The surface-diffusion kinetics plays an important role in the transition from 2D to 3D growth[15]. In particular, decreasing the growth temperature reduces the surface diffusion coefficient thus delaying from 2D to 3D growth mode transition[16]. The strain existing at interface between the epilayer and the buffer layer can be released easily by generating dislocations in the buffer layer. Therefore, the misfit dislocations and some defects in epilayer are reduced. When the buffer

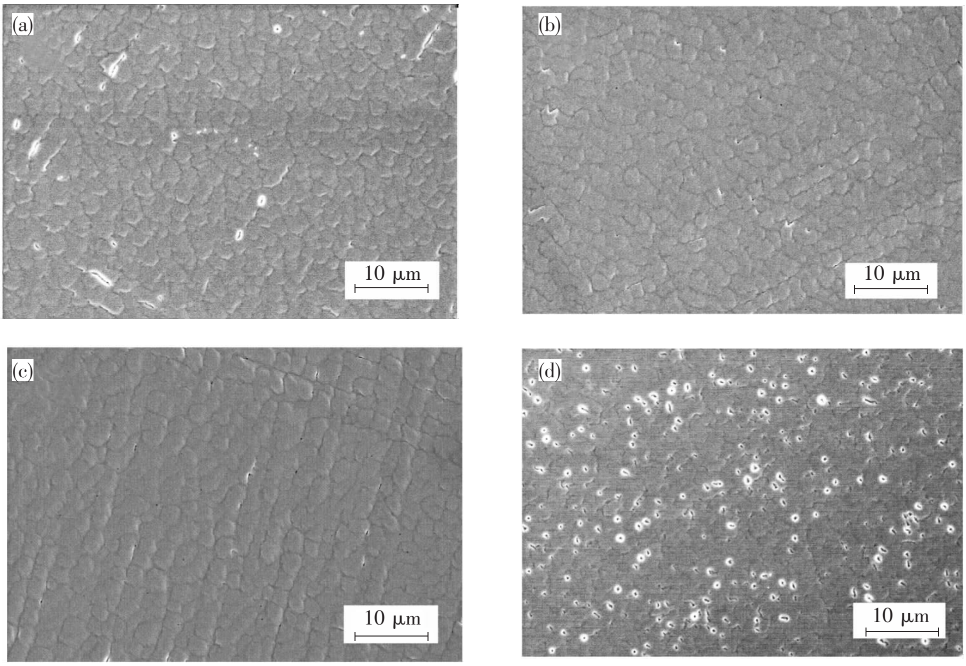

Fig. 1 Surface morphology SEM images of $In_{0.82}Ga_{0.18}As$ epilayer on InP with different buffer layer growth temperature at (a) 410 ℃, (b) 430 ℃, (c) 450 ℃, and (d) 470 ℃, respectively.

temperature is lower than a certain temperature range, for example ~410 ℃, surface atoms do not gain energy enough to migrate and diffuse into the neighboring area. A large density cross-hatched patterns are generated in buffer layer, which is greatly disadvantageous to reduce the defects in epilayer. However, the 3D growth mode of the buffer layer is enhanced when the temperature is higher than a certain temperature range, for example ~ 470 ℃, which will greatly degenerate the properties of the epilayer. It indicates that growing of $In_{0.82}Ga_{0.18}As$ with two-step growth technique at an appropriate buffer layer growth temperature is essential to improve the surface morphology of the epilayer.

The Raman spectra for the four samples are plotted in Fig. 2. There are two Raman peaks in each spectrum, which are around 234 and 252 cm^{-1}, corresponding to the LO-phonon modes of InAs and GaAs, respectively. For $In_{0.82}Ga_{0.18}As$, the GaAs-like LO-phonon modes still dominates the spectra[17]. The inset of Fig. 2 shows the dependence of the $\Delta\Omega_{LO}$ of GaAs-like on the buffer layer growth temperature. It shows that Raman frequency shift ($\Delta\Omega$) of GaAs-like LO-phonon of samples is decreased from 1.30 cm^{-1} to 1.08 cm^{-1} with increasing buffer layer growth temperature from 410 ℃ to 450 ℃ and then is increased from 1.08 cm^{-1} to 1.32 cm^{-1} with increasing buffer layer growth temperature from 450 ℃ to 470 ℃. The stress in $In_{0.82}Ga_{0.18}As$ epilayer can be calculated from a frequency shift of the GaAs-like LO-phonon. Following the formulas and definition in [18] and using the measured results of $\Delta\Omega_{LO}$, stress of $In_{0.82}Ga_{0.18}As$ epilayer could be obtained. For sample C, the $\Delta\Omega_{LO}$ reaches to a minimum, the stress in $In_{0.82}Ga_{0.18}As$ epilayer is also a minimum value.

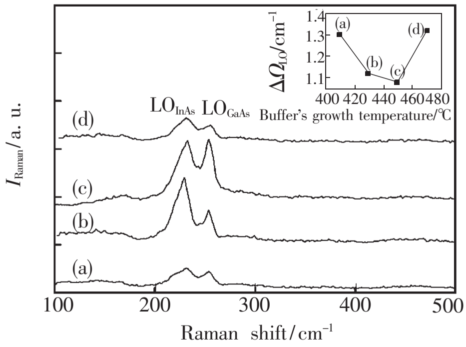

Fig. 2　Raman spectra of samples with the buffer growth temperature at (a) 410 ℃, (b) 430 ℃, (c) 450 ℃, and (d) 470 ℃. The inset shows the dependence of the $\Delta\Omega_{LO}$ of GaAs-like on the buffer growth temperature.

The Hall measurement is performed to determine the electrical properties of the epilayer. The results are shown in Fig. 3. On the one hand, the carrier concentration changes with increasing buffer layer growth temperature from 410 ℃ to 470 ℃, and it reaches the lowest value at 450 ℃. On the other hand, the mobility increases from 2 433 to 3 228 $cm^2/(V\cdot s)$ with the buffer layer growth temperature increasing from 410 ℃ to 450 ℃, and it decreases from 3 228 to 2 449 $cm^2/(V\cdot s)$ with the buffer growth temperature increasing from 450 ℃ to 470 ℃. It is obvious that the changes of carrier concentration and mobility relate to the buffer layer growth temperature. Defects of the $In_{0.82}Ga_{0.18}As$ epilayer are decreased because of using optimum buffer layer growth temperature. The defects caused by the lattice mismatch between the epilayer and the substrate will serve as scatting centers for electrons and influence on the mobility. The carrier concentration is decreased with the improvement of the quality of epilayer.

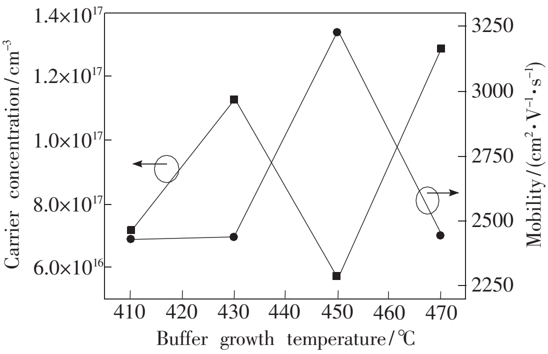

Fig. 3　The dependences of carrier concentration and mobility of the $In_{0.82}Ga_{0.18}As$ epilayer on the buffer layer growth temperature

4　Conclusion

We employed the two-step growth method to grow the $In_{0.82}Ga_{0.18}As$ on InP substrates by LP-MOCVD. The effect of buffer layer growth temperature on structural and electrical properties of the $In_{0.82}Ga_{0.18}As$ epilayer was carefully studied. The

SEM, Raman scattering and Hall measurement were used to characterize the properties of $In_{0.82}Ga_{0.18}As$. With $In_{0.82}Ga_{0.18}As$ grew at 450 ℃ as a buffer layer, the structural and electrical properties of $In_{0.82}Ga_{0.18}As$ epilayer are optimum, that is, the optimum buffer layer growth temperature is around 450 ℃.

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缓冲层生长温度对 $In_{0.82}Ga_{0.18}As$ 薄膜结构及电学性能的影响

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摘要: 采用低压金属有机化学气相沉积(LP-MOCVD)技术,两步生长法在InP衬底上制备 $In_{0.82}Ga_{0.18}As$ 材料。研究缓冲层的生长温度对 $In_{0.82}Ga_{0.18}As$ 薄膜的结构及电学性能的影响。固定外延薄膜的生长条件,仅改变缓冲层生长温度(分别为410,430,450,470 ℃),且维持缓冲层其他生长条件不变。用拉曼散射研究样品的结构性能,测量四个样品的拉曼散射光谱,得到样品的GaAs的纵向光学(LO)声子散射峰的非对称比分别为1.53,1.52,1.39和1.76。测量样品的霍耳效应表明,载流子浓度随缓冲层生长温度变化而改变,同时迁移率也随缓冲层生长温度变化而改变。通过实验得出:缓冲层的生长温度能够影响 $In_{0.82}Ga_{0.18}As$ 薄膜的结构及电学性能。最佳的缓冲层生长温度为450 ℃。

关 键 词: 铟镓砷; 金属有机化学气相沉积; 缓冲层; 生长温度
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