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Cation Source Dependence of $Ga_{0.5}In_{0.5}P$ Growth Rate by Low-Pressure Metalorganic Chemical Vapor Deposition

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The $Ga_{0.5}In_{0.5}P$ epilayer was grown by low-pressure metalorganic chemical vapor deposition. Trimethylgallium and triethylgallium were used as the gallium sources, while trimethylindium and ethyldimethylindium were used as the indium sources. The use of triethylgallium incorporated with trimethylindium enhanced the growth rate of $Ga_{0.5}In_{0.5}P$ as compared to incorporation with ethyldimethylindium. While the use of trimethylgallium incorporated with ethyldimethylindium enhanced the growth rate of $Ga_{0.5}In_{0.5}P$ significantly, as compared to incorporation with trimethylindium.

KEYWORDS: GaInP, low-pressure MOCVD, TMGa, TEGa, TMIn, EDMIn

1. Introduction

The ternary compound GaInP has high potential for applications in electronic and optoelectronic devices. $Ga_{0.5}In_{0.5}P$ can be grown lattice-matched to GaAs, and has a band gap of 1.9 eV. The GaAs/GaInP heterojunction has a larger valence band discontinuity,[1,2] and lower interface recombination velocity[3,4] than the GaAs/AlGaAs heterojunction. Moreover, aluminum-free GaInP can replace AlGaAs and eliminate DX-center (deep-level state) problems. Furthermore, wet chemical etchants with excellent selectivity between GaInP and GaAs are readily available, which simplifies and improves process yield. All of these features make $Ga_{0.5}In_{0.5}P$ an important alternative to AlGaAs for optoelectronic device applications.

Considerable efforts have been devoted to the epitaxial growth of $Ga_{0.5}In_{0.5}P$ in the past few years, and include liquid phase epitaxy (LPE),[5] molecular beam epitaxy (MBE),[6] chemical beam epitaxy (CBE),[7] gas source MBE (GSMBE)[8,9] and metalorganic chemical vapor deposition (MOCVD).[10,11]

In this paper, a $Ga_{0.5}In_{0.5}P$ grown on (100)-oriented gallium arsenide substrates by low-pressure MOCVD is reported. The cation source materials such as trimethylgallium (TMG) and triethylgallium (TEG) are widely used in the MOCVD system. However, less carbon contamination could be achieved by using TEG rather than TMG.[12] Ethyldimethylindium (EDMIn) is a room-temperature liquid that apparently behaves much like triethylindium (TMIn). Early experiments indicated the EDMIn was not as pure as the best TMIn, but recently it has become available in a high-purity form,[13] which makes it an attractive indium source. All the above sources are used in our low-pressure MOCVD system to grow GaAs and GaInP epilayers and compare their growth efficiencies.

2. Experimental

All the samples were grown by low pressure MOCVD with a home-built horizontal reactor. Pure arsine (AsH_3) and phosphine (PH_3) gases were used as group V sources. For the group III sources, TMG, TEG, TMIn and EDMIn were used as precursors. All the GaInP epilayers were grown on (100)-oriented GaAs wafers. The growth was performed at a reactor pressure of 40 Torr and a temperature of 650°C. The total gas flow through the reactor was kept at 9 standard liters per minute (SLM), and the V/III ratio was kept at 60 and 150 for the growth of GaAs and GaInP, respectively. A GaAs buffer layer was grown prior to the growth of the GaInP layer. In order to achieve an abrupt As/P interface, the reactor was purged with hydrogen for two seconds between the growth of GaAs and GaInP epilayers. Then, the precursors (gallium source, indium source and phosphine) were switched simultaneously into the reactor to grow the GaInP layer. The composition of the grown GaInP epilayers was investigated by double-crystal X-ray diffraction, and was controlled by adjusting the feed rate of the indium source with respect to that of the gallium source.

3. Results and Discussion

Figure 1 shows double-crystal X-ray diffraction splitting between the substrate and the GaInP epilayer. As is shown, the composition of the grown GaInP epilayer is very uniform. Double-crystal X-ray diffraction splitting between the substrate and epilayer signal peaks is about 466 s. The deviation of peak splitting is below 5%, except that at the wafer edge. The epilayer thick-

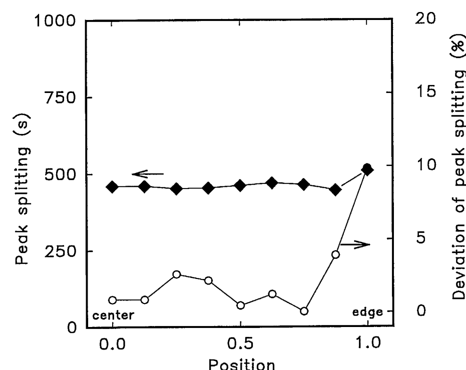

Fig. 1. The position dependence of double-crystal X-ray diffraction peak splitting.

ness was measured using a field emission scanning electron microscope (FESEM). Metalorganic chemical vapor deposition is an irreversible process. The growth mechanism could be mainly attributed to the gas phase diffusion limited at high temperatures[14] under sufficient phosphine supplement. However, some other factors could be taken into account. One is the parasitic depletion of source materials on the ceiling and the side wall. The second is adduct formation between group III sources and phosphine. The third is the exchange reaction of alkyl ligands of the indium source with those in the gallium source. As depicted in Fig. 2, the growth rate of GaInP by using TMGa and EDMIn is higher than that using TMGa and TMln. The pyrolysis of TMGa could be enhanced due to the existence of EDMIn. In the case of TMGa, a few ethyl radicals could increase the growth rate of GaInP. The growth

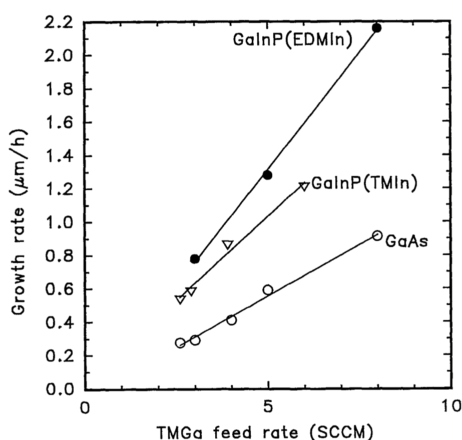

Fig. 2. The growth rate of GaAs and GaInP using TMIn and EDMln as indium source, and TMGa as gallium source.

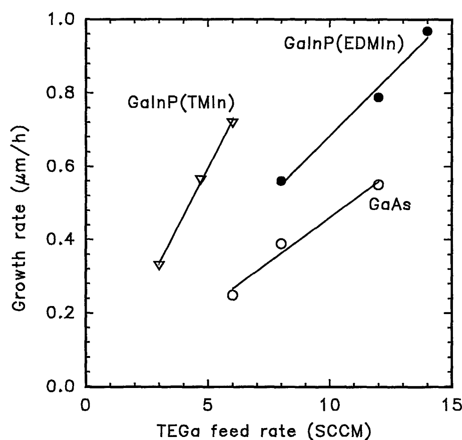

Fig. 3. The growth rate of GaAs and GaInP using TMIn and EDMIn as indium source, and TEGa as gallium source.

rate of GaInP using EDMIn is about three times larger than that of GaAs. On the other hand, the growth rate of GaInP using TEGa and TMIn is higher than that using TEGa and EDMIn, which is illustrated in Fig. 3. Thus, the pyrolysis of TEGa is enhanced by the existence of methyl radicals. For the same flow rate of TEGa, the growth rate of GaInP using EDMIn is suppressed and is no more than two times larger than that of GaAs. In summary, the growth rate of GaInP cannot be directly described by two independent factors (r_{Ga} and r_{In}), where r_{Ga} is growth rate of GaP and is r_{In} the growth rate of InP.

4. Conclusions

The GaInP epilayer is grown using TMGa incorporated with EDMIn (TMGa+EDMIn), and the growth rate is increased as compared to using TMIn, while TEGa+TMIn can enhance the growth rate significantly, as compared to EDMIn. Considering the growth efficiency (the growth rate per mole fraction of TMGa or TEGa), TMGa+EDMIn is the same as TEGa+TMIn. However, the efficiency of GaInP growth using TEGa+EDMIn is the lowest.

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