(AlGa)As Grown by Low Pressure Metalorganic Vapor Phase Epitaxy Using a N₂ Carrier

M. HOLLFELDER, HILDE HARDTDEGEN, R. MEYER, R. CARIUS, and H. LUTH
Institut für Schicht- und Ionentechnik (ISI), Forschungszentrum Jülich, Postfach 1913, 52425 Jülich, Germany

We have studied the growth of AlₓGa₁₋ₓAs (0.24 < x < 0.34) using a N₂ carrier in low pressure metalorganic vapor phase epitaxy. Growth temperature, gas velocity, and V/III ratio were varied to achieve optimum growth conditions. Layers with excellent morphology and electrical and optical properties comparable to samples grown using standard conditions (with a H₂ carrier) can be deposited in a nitrogen ambient. Al₀.₉₂Ga₀.₇₈As bulk material grown on an AlAs buffer layer with a background doping of 1.3 × 10¹⁶ cm⁻³ showed Hall mobilities of 4500 and 2300 cm²/Vs at 77 and 300K. Photoluminescence studies at 2K revealed strong bound exciton transitions with a full width at half maximum of 5.2 meV for Al₀.₂₉Ga₀.₇₁As.

Key words: (AlGa)As, low pressure metalorganic vapor phase epitaxy (LP-MOVPE), nitrogen carrier gas

INTRODUCTION
Epitaxially grown GaAs/AlₓGa₁₋ₓAs heterostructures have found wide application in optoelectronic and microwave devices. A well-established process for the deposition of this material system is low pressure metalorganic vapor phase epitaxy (LP-MOVPE) using hydrogen as the carrier gas in the process. The safety of the process would be improved if hydrogen were replaced by an inert carrier gas. A possible candidate is N₂ which has a lower thermal conductivity and a higher molar weight in comparison to H₂. The employment of nitrogen/hydrogen carrier mixtures for the successful growth of InP was first reported by Razeghi et al.¹ and Mircea et al.² The intention was to reduce the parasetic reactions in the vapor phase. Recently, we investigated the growth chemistry of GaAs using a N₂ ambient and showed that it can be employed successfully for normal and selective planar growth.³ This is to our knowledge the first report on the employment of nitrogen in metalorganic vapor phase epitaxy (MOVPE) growth of GaAs based materials. The suitability of N₂ as carrier gas in MOVPE is put to an even harder test when compounds containing Al are grown because of their sensitivity to oxygen.⁴

In this paper, we report on the employment of a nitrogen carrier in the LP-MOVPE growth of AlₓGa₁₋ₓAs. Growth temperature, V/III-ratio, and gas velocity were varied to develop an optimum set of growth parameters, judged by the optical and electrical characteristics of the layers. The effect of AsH₃ and N₂ purification on AlₓGa₁₋ₓAs growth was a further point of investigation. We will emphasize that layers with excellent morphology as well as good optical and good electrical properties can be grown at the same low pressure (20 hPa) as employed for excellent quality GaAs using a N₂ carrier.

GROWTH AND CHARACTERIZATION OF AlₓGa₁₋ₓAs

The epitaxial growth was carried out in a gas-cooled horizontal low pressure reactor with an internal cross section of 7 × 3 cm², equipped with a vent run switching manifold. We employed trimethyl gallium (TMG), trimethyl aluminium (TMA), and AsH₃ as precursors for the growth of AlₓGa₁₋ₓAs. The process gases AsH₃, H₂, and N₂ were purified in a Waferpure™ gas purifica-
Hollfelder, Hardtdegen, Meyer, Carius, and Lüth

Temperature dependence of the growth rate of GaAs and AlAs using a N₂ carrier at a reactor pressure of 20 hPa.

**Fig. 1.** Temperature dependence of the growth rate of GaAs and AlAs using a N₂ carrier at a reactor pressure of 20 hPa.

---

RESULTS AND DISCUSSION

Variation of Growth Temperature

The growth rates of GaAs and AlAs were determined over a range of temperatures. The curves of GaAs and AlAs in Fig. 1 exhibit a diffusion controlled growth regime in the higher temperature region, in which mass transport is the rate-limiting step, i.e., the growth rate is temperature independent. In the lower temperature region, the curves exhibit kinetically controlled growth, in which reaction kinetics are the rate-limiting step. The different slopes of the curves for AlAs and GaAs in the kinetic range are due to different surface reactions of the precursors involved.

In consideration of possible lateral temperature gradients over a whole wafer, excellent layer homogeneity is only obtained in the diffusion controlled region. Therefore, we deduced a temperature range from both curves where diffusion controlled growth of AlₓGa_{1-x}As is to be expected. A nearly constant growth rate of Al₀.29Ga₀.7₁As was determined in the selected temperature range from 873 to 1023K. The Al₀.29Ga₀.7₁As samples were grown using the following parameters: reactor pressure \( P_{\text{tot}} = 20 \text{ hPa} \), gas velocity \( v_{\text{gas}} = 0.9 \text{ m/s} \), partial pressure of TMG \( p_{\text{TMG}} = 0.71 \text{ Pa} \), partial pressure of TMA \( p_{\text{TMA}} = 0.14 \text{ Pa} \), and \( \text{V/III} = 160 \).

Photoluminescence spectroscopy of these Al₀.29Ga₀.7₁As layers at 2K was used to determine the optimum growth temperature of our N₂ process. The PL spectra exhibit donor acceptor (DA) recombination involving carbon acceptors and a bound exciton (BE) recombination (i.e., excitons bound to donors and acceptors). A merit factor for the optical quality of the samples is the (BE)/(DA) intensity ratio and the full widths of the bound exciton recombination line at half maximum (FWHM), as long as the (DA) recombination mechanism is not saturated by a high laser excitation power. The broadening of the recombination lines is caused mainly by the random occupation

\[
E_{\text{ex}}(x) = 1.5152 + 1.36x + 0.22x^2 \text{ eV}
\]  

In addition, the composition and crystalline quality were also determined by a horizontal high resolution five crystal x-ray diffractometer (XRD) from Phillips. Electrical characterization was performed by van der Pauw-Hall measurements at 77 and 300K.