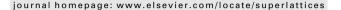


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Optical properties study of In_xGa_{1-x}As/GaAs structures using spectral reflectance, photoreflectance and near-infrared photoluminescence



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ABSTRACT

Optical properties of $In_xGa_{1-x}As$ films grown on GaAs substrates by metalorganic vapor phase epitaxy were investigated. Spectral reflectance (SR) and photoreflectance (PR) at room temperature and near-infrared photoluminescence (PL) at 10 K were performed. SR signals in the range of 200-1700 nm provided the x-dependence of the critical point energies E_1 , $E_1+\Delta_1$ and E_2 . Furthermore, bandgap and spin-orbit splitting energies, as well as their broadening parameters were determined from PR spectra and studied as function of In composition ranging from 0 to 0.37. On the other hand, the origins of luminescence bands observed in PL spectra were revealed. A redshift of 16 meV/%In in the band-to-band transition was obtained. All results issued from different characterizations tools are correlated and compared to the literature.

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1. Introduction

 $In_xGa_{1-x}As/GaAs$ structures present a practical use in the active zone of microelectronics and optoelectronics devices notably in the areas of infrared emitters or detectors [1–3]. These structures are of specific interest in the study of low-dimensional systems such as quantum wells and quantum

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dots [4,5] and also allow the understanding of InGaAsX (X = N, Bi, etc.) quaternary alloys behavior [6,7]. The growth optimization of $In_xGa_{1-x}As$ thin films is a determinist step to improve the performance of these materials. Thus, many researchers have successfully quantified the evolution of indium composition in $In_xGa_{1-x}As$ layers as function of growth parameters by metalorganic vapor phase epitaxy (MOVPE) [8,9]. In situ monitoring of InGaAs layers epitaxy can be performed using laser reflectometry (LR) [8,10]. In addition, LR was used to determine indium composition dependence of refractive indices n and extinction coefficients k of InGaAs alloys [10]. Results showed a quadratic variation of n and k with x ranging from 0% to 50%.

In a previous work [11], spectral reflectance (SR), photoreflectance (PR) and near-infrared photoluminescence (PL) measurements were carried out to investigate optical properties of $In_xGa_{1-x}As/GaAs$ structure with a low indium composition of 8%. We have determined the critical points (CPs), bandgap (E_0) and spin-orbit splitting (Δ_0) energies at 300 K for both GaAs and $In_{.08}Ga_{.92}As$ materials. Moreover, the origins of PL peaks were also revealed. However, optical properties knowledge of InGaAs structures over a wide spectral range is crucial. As continuity to our previous work, in this paper we extend the investigations of $In_xGa_{1-x}As/GaAs$ structures to a large indium composition range $0 \le x \le 0.37$ using optical techniques (SR, PR and PL). CPs E_0 and Δ_0 variations, as well as PL bands luminescence are analyzed as function of indium composition. Besides, the behavior of broadening parameters Γ_0 and Γ_0 related to E_0 and $E_0 + \Delta_0$ respectively was compared to the full width at half maximum (FWHM) of layer peaks obtained by high-resolution X-ray diffraction (HRXRD) measurements in rocking curve mode. All data were discussed and compared to previous works reported in the literature.

2. Experimental procedure

Series of $\ln_x Ga_{1-x} As/GaAs$ samples, denoted S_1 (for x=0), S_2 (for x=0.02), etc., and S_8 (for x=0.37) were grown on (001) GaAs substrate by MOVPE in horizontal-type atmospheric pressure reactor. In order to cover the solid indium composition range of 0–0.37, the vapor indium composition x^v was varied from 0 to 0.16 and the growth temperature T_g was changed from 450 to 605 °C as reported in Table 1. Indium compositions were determined by HRXRD. Trimethylgallium (TMGa), trimethylindium (TMIn) and arsine (AsH₃) were used as precursors. Bubblers were kept in thermal baths at 5 and 20 °C for TMGa and TMIn respectively. The carrier gas was Pd-diffused hydrogen (H₂). V/III ratio was

Table 1 Summary of $\ln_x Ga_{1-x}As$ parameters $(0 < x \le 0.37)$ derived from MOVPE, HRXRD, SR, PR and PL measurements.

Samples		S_1	S_2	S_3	S_4	S_5	S_6	S ₇	S ₈
MOVPE									
X		0	0.02	0.08	0.13	0.16	0.20	0.23	0.37
T_g (°C)		605	605	520	605	605	450	450	450
HRXRD @ 300 K FWHM (deg)		0.009	0.056	0.090	0.256	0.197	0.265	0.217	0.601
SR @ 300 K									
C ₁₂₀₀ (a.u.)		0	1.9	4.4	8.5	13.0	14.0	12.9	18.7
$P_{1200} (nm)$		-	170	150	164	137	293	227	285
$\langle d \rangle$ (μ m)		1.20	1.08	1.60	1.18	1.21	0.56	0.63	0.63
PR @ 300 K									
Γ_0 (meV)		5	13	10	51	23	36	73	60
Γ'_0 (meV)		9	14	25	32	49	58	72	75
F(kV/cm)		-	-	17.2	-	-	-	145.1	-
$\hbar\Omega$ (meV)		_	-	10	-	-	-	41	-
PL @ 10 K									
FWHM (meV)	Peak1	12	25	15	31	_	_	_	81
	Peak2	15	35	29	24	-	-	-	21
	Peak3	39	100	23	-	26	-	-	117

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