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Optical properties study of $In_{.08}Ga_{.92}As/GaAs$ using spectral reflectance, photoreflectance and near-infrared Photoluminescence

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ABSTRACT

Optical properties of $In_{.08}Ga_{.92}As/GaAs$ structure grown by metal-organic vapor phase epitaxy have been investigated. Spectral reflectance (SR) and photoreflectance (PR) as well as near-infrared Photoluminescence (PL) were performed in this study. In fact, SR signals in the range 200–1700 nm provided specific parameters of materials such as optical constant spectra, sensitivity to wavelength and critical point energies. In addition, band gap energy was determined by both PR and optical absorption measurements at room temperature. Spin-orbit splitting, internal electric field and electro-optical energy were also calculated. Results provided by previous techniques present a good correlation and complementarities and agree well with the literature. On the other hand, the origins of 12 K PL peaks at 1.42, 1.38 and 1.29 eV, have been identified by performing excitation power (P_{ex}) study. Finally, the peak at 1.38 eV has two regimes of variation with P_{ex} separated by a critical power around 50 mW.

1. Introduction

III–V semiconductor compounds and their alloys have been studied to determine various band parameters like band gap energy and spin-orbit splitting [1] and to investigate optical properties such as optical dispersion relations and critical point energies [2,3]. Particularly, thanks to their specific properties, InGaAs alloys are very useful for microelectronic and optoelectronic applications [4,5]. These ternary have been grown on InP or GaAs substrates by molecular beam epitaxy or metalorganic

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vapor phase epitaxy (MOVPE) [6,7]. $In_{.53}Ga_{.47}As$ layers lattice matched to InP substrate form good systems for previous applications [8]. However, advanced properties of strained layers have been proven and have changed the direction of applied researches for other indium compositions [9]. Ng et al. [10] have studied the influence of strain on velocity and mobility of carriers in strained $In_{.65}Ga_{.35}As/In_{.52}$-$Al0_{.48}As$ HEMT's. Moreover, despite the problems related to strain, $In_xGa_{1-x}As/GaAs$ ($0 < x < 1$) lattice mismatched heterostructures are of an important technological interest including infrared photoemission in the 1.05–1.55 μm wavelength range [11]. Relaxation of strain can be overcome if the InGaAs epilayer thickness exceeds the critical thickness expected by the models of Matthews and Blakeslee [12] and the People and Bean one [13]. Previous works have required growth optimization based on perfect control of growth parameters such as V/III ratio, growth temperature and growth rate [14]. Moreover, layer thicknesses and indium compositions are decisive parameters to achieve advanced structural and optical properties of InGaAs layers. In order to improve crystal quality and to contribute to the understanding of the growth kinetic, Habchi et al. [15] have studied structural and optical properties of InGaAs layers grown on (001) GaAs substrate by atmospheric pressure MOVPE with different indium solid compositions (x). They have found that x increases by decreasing growth temperature below 520 °C but it remains constant above, whereas the growth rate was stabilized for temperature above 500 °C. The obtained results were correlated to high resolution X-ray diffraction measurements. Besides, laser reflectance (LR) signal was theoretically adjusted to determine optical constants and growth rate of layers [16]. The complex refractive index of InGaAs alloys was quantified as a function of temperature and indium composition. In a previous work [17], we have studied the temperature effect on morphological and structural properties and growth process of $In_{.08}Ga_{.92}As/GaAs$ structures. The samples differ only by growth temperature varying from 520 to 680 °C. We have shown that the temperature of 520 °C corresponds to the best crystal quality basing on dislocations and islands densities and alloy disorders in the crystalline structure. Note that the thickness of $In_{.08}Ga_{.92}As$ active layer was superior to the critical one. So, our sample was expected to be fully relaxed. In this work, to further explore the optical properties of $In_{.08}Ga_{.92}As/GaAs$ structure, we have performed spectral reflectance (SR) in the range 200–1700 nm in order to determine optical dispersion relations, critical point energies and the sensitivity to the excitation wavelength. Photoreflectance (PR) and optical absorption (OA) spectra at room temperature have revealed some parameters like band gap energy, spin-orbit splitting and electro-optical energy. We have finalized InGaAs/GaAs optical study with infrared Photoluminescence (PL) behavior analysis.

2. Experiment

InGaAs layers were grown on semi-insulating (SI) GaAs (001) substrates by MOVPE. Growth was carried out at atmospheric pressure in horizontal reactor. Substrate surface was cleaned by thermal desorption at 650 °C. Then, growth temperature T_g was set at 520 °C. Vapor indium composition x^v was fixed at 0.09 leading to a solid indium composition x of 0.08. V/III ratio was equal to 36. Trimethylgallium (TMGa) and arsine (AsH_3) were used as precursors. Hydrogen (H_2) purified through a palladium cell, was the carrier gas. LR at $\lambda = 632.8$ nm was used to *in situ* monitor the epitaxy. In order to carry out SR experiment at room temperature in the whole spectral range 200–1700 nm (0.73–6.20 eV), two setups were used: the first includes a deuterium–halogen lamp as excitation source emitting in the wavelength domain extended from 200 to 2400 nm. The reflected light was detected by the coupled charge device, denoted CCD1, operating in the wavelength range of 200–1000 nm (1.24–6.20 eV). The second setup contains a halogen lamp with spectral emission from 400 to 2400 nm. A second coupled charge device, denoted CCD2, operates in the wavelength range of 1000–1700 nm (0.73–1.24 eV) and collects the reflected wave. We note that SR signal was measured under normal incidence. Reflected beams detected by CCD1 and CCD2 were transmitted to a personal computer PC via USB port. Setups were equipped by optical fiber systems. PR measurements were carried out at room temperature employing a standard setup with the 514.5 nm line of an argon laser as the pump light. The probe light was obtained from a tungsten–halogen lamp analyzed with a 500 mm focal length monochromator. The reflected light was collected by Si photodiode detector. Output of the latter was connected to lock-in amplifier. Data were supplied to a PC via an IEEE 488