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Optical investigation of InAs quantum dashes grown on InP(001) vicinal substrate

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ABSTRACT

We investigate with photoluminescence (PL) measurements the optoelectronic properties of self-organized InAs quantum dots (QDs) grown on nominal InP(001) substrate. InAs/InP(001) QDs are grown by Molecular Beam Epitaxy (MBE) method with optimized conditions in Stranski-Krastanov regime. A lateral coupling behavior was shown by photoluminescence spectroscopy. This phenomena is considered as a degradation source of the optoelectronic properties of InAs/InP(001) QDs used in lasers applications. In order to overcome this disadvantage behavior, we have studied the optical properties of InAs quantum islands (QIs) grown on vicinal InP(001) with 2° off miscut angle toward the [110] direction. From Polarized Photoluminescence (PPL) measurements, we have deduced that InAs quantum nanostructures have quantum dashes (QDas) form elongated in [1–10] direction. From excitation density PL measurements, we have evidenced that the different observed PL peaks are attributed to the emission of InAs QDas of different size. The lateral coupling behavior is completely eliminated in the case of this sample. The temperature-dependent PL measurements show a good thermal stability and an emission wavelength at room temperature around 1.55 μm of the vicinal sample. All these properties prove that this sample possess favorable characteristics for microlasers based devices functioning at room temperature and for optical telecommunication with long range weapon. The broad emission range observed at 300 K of the vicinal sample

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gives the possibility to use it as an active zone in solar cells and in infrared photodectectors of high optical gain and excellent sensitivity on a wide energy range.

1. Introduction

Semiconductor research and device development has seen a progressive reduction in dimensionality, from bulk, through quantum wells (QWs), to quantum dots (QDs). QDs represent the ultimate limit in carrier confinement with discrete atomic-like energy states. The energy state discretization is significantly different from that of higher dimensionality systems, resulting in a wide range of new carrier processes and potential applications in a number of improved and novel electro-optical devices [1]. In the past few years, self-organized InAs/InP QDs grown in Stranski-Krastanov mode, have attracted a great interest from their unique physical properties and applications in various nanoscale devices [2,3]. They are introduced in photodetectors and in ultra-low threshold microlasers, since the recent demonstrations of high temperature stability and high optical gain with a reduction of the threshold current [4,5]. In particular, one of the very important issues and challenge is the tuning of the emission wavelength of InAs/InP QDs to 1.5 μm for the optical devices for telecommunication applications [6]. However, the InAs/InP(001) system is characterized by its low lattice mismatch (~3.2%) and As/P exchange reactions at the surface during the growth [7]. These factors make the self-organization difficult. Consequently, the size distribution of InAs/InP islands will be higher compared with the InAs/GaAs systems with ~7% of lattice mismatch. This is unfavorable for high optical gain and low threshold current operation. In this way, many works have recently been devoted in order to reduce the size dispersion of InAs/InP QIs. Among them, optimizing the epitaxial growth parameters (reducing arsenic pressure and increasing the growth temperature with increasing the deposition thickness) [8] or the growth on misoriented InP substrates [9]. In this paper, we investigate the optical properties of self-organized InAs QDs grown on nominal InP(001) substrate in optimized conditions. These properties have been studied by photoluminescence spectroscopy (PLS) measurements. We further identify the origin of different PL peaks trough the evolution of PL spectra with the excitation density. We continue our study on a second sample of InAs quantum dashes (QDas) grown on vicinal InP(001) substrate. The structure of this sample is verified using Polarized Photoluminescence (PPL) measurements. We check the nature of different PL transitions as a function of the excitation density and the temperature. Furthermore, we study the thermal stability and the spatial confinement of photogenerated carriers created in InAs QDas elaborated on vicinal InP(001) substrate.

2. Experiments

The samples investigated in this study were grown by solid-source Molecular Beam Epitaxy (MBE) in a Riber 2300 reactor. InAs self-assembled quantum islands were grown on semi-insulating InP(001), simultaneously on nominally oriented (n) and vicinal (2 F) substrates. 200 nm-thick InP buffer layer was grown at 480 °C using a phosphorus pressure equals to 1×10^{-5} Torr, then 3 monolayers (ML) of InAs were grown at 520 °C under an arsenic pressure fixed at 2×10^{-6} Torr. The elaborated samples are no-intentional n type doped (about 10^{16} cm^{-3}). In order to characterize the carrier confinement in these quantum islands with PL measurements, the samples were capped with a 300-nm-thick layer of InP. The PL spectra were obtained in the 12–300 K temperature range. The PL was excited using the 514.5 nm line of an Ar–Kr ion laser and was dispersed by a spectrometer and detected by a thermoelectrically cooled InGaAs photodetector using a conventional lock-in technique.