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THE EFFECT OF THICKNESS ON THE OPTICAL PROPERTIES OF INP QUANTUM DOTS GROWN ON GAAS SURFACES

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Abstract
This work studies the influence of thickness on the optical properties of InP quantum dots. The spectral position of the maximum corresponding to the InP quantum dot is determined. With an increase in the thickness of the pseudomorphic InAs layer from 1.8 MS to 3 MS, along with a long-wave shift of the quantum dot FL band, its broadening occurred, which indicates the enlargement of quantum dots with simultaneous disorder in their size and shape.

Keywords: Quantum dot, energy shift, FL intensity, deformation.

Introduction

Interest in reduced-dimensional semiconductor structures is largely driven by the need for efficient solid-state emitters in modern optoelectronics. The possibility of technologically targeted adjustment of the emission spectrum of heteroepitaxial nanostructures is most pronounced for self-organized arrays of quantum dots (QDs). The effects of self-organization in molecular beam epitaxy and its variants in A_3B_5 semiconductor systems have been experimentally confirmed in recent years [1]. The influence of lateral dimensions, surface density, and degree of spatial order of QDs on photoluminescence (PL) spectra has been established. In turn, most of these factors are regulated by technological

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conditions and growth kinetics. Thus, the use of submonolayer migration-stimulated epitaxy (SMCE) and vicinal GaAs substrates allows obtaining InP CT arrays with the closest lateral dimensions, which manifests itself in the narrowing of the FL band [2]. Under certain conditions, a more complex structure of the CT FL spectrum is observed: the main band, interpreted as the exciton recombination of an electron and a heavy hole in the ground state of the CT, turns out to be heterogeneously broadened, and in some cases, additional emission maxima appear. The origin of these maxima is currently the subject of intense debate. This work investigates the nature of various components of the FL spectrum of two-dimensional arrays of InP CTs on vicinal GaAs substrates.

Experimental results

It has been shown that the structure of the FL spectrum is formed by groups of CTs belonging to terraces with discrete widths due to the effect of stacking of monoatomic layer steps (SS) at the edges of the terraces. In this case, the spectral position of the maximum of this band characterizes the average size of the CT, and its half-width characterizes the dispersion of the CT sizes (Fig. 1). In an effort to make maximum use of the hardware factor, we conducted preliminary studies aimed at obtaining CT arrays with the narrowest possible band of radiative recombination.

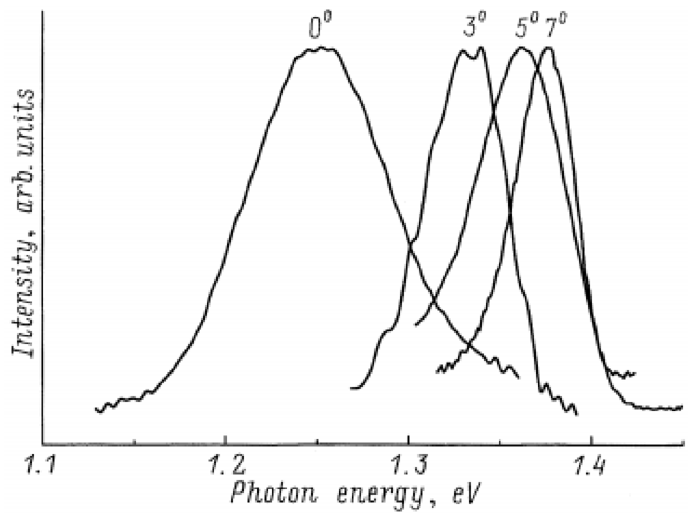

Fig. 1 FL CT spectra of InP grown on vicinal GaP(100) substrates with different misorientation angles relative to the [011] direction. T=5K

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The methods and conditions that allow this to be achieved include SMCE [3], vicinal substrates, the initial stages of CT self-organization, and high-temperature annealing. It is known that the process of CT formation on singular and vicinal surfaces during molecular beam epitaxy in the InP/GaAs system consists of two stages. In the first stage, a pseudomorphic strained InP layer grows.

Our combined use of the SMCE mode and vicinal substrates with a misorientation angle of 5° led to the formation of a CT array starting from an InAs layer with a thickness of 1.8 MS. For a layer of this thickness, clear DBEO reflections and a formed CT FL spectrum in the 1.1–1.45 eV range were always observed, whereas for smaller InAs thicknesses, only the FL signal of the strained GaAs barrier layer near 1.5 eV (radiation of excitons and impurity carbon). Increasing the thickness of the pseudomorphic InAs layer from 1.8 MS to 3 MS, along with a long-wave shift of the FL CT band, led to its broadening, which indicates the enlargement of CTs with simultaneous disorder in their size and shape.

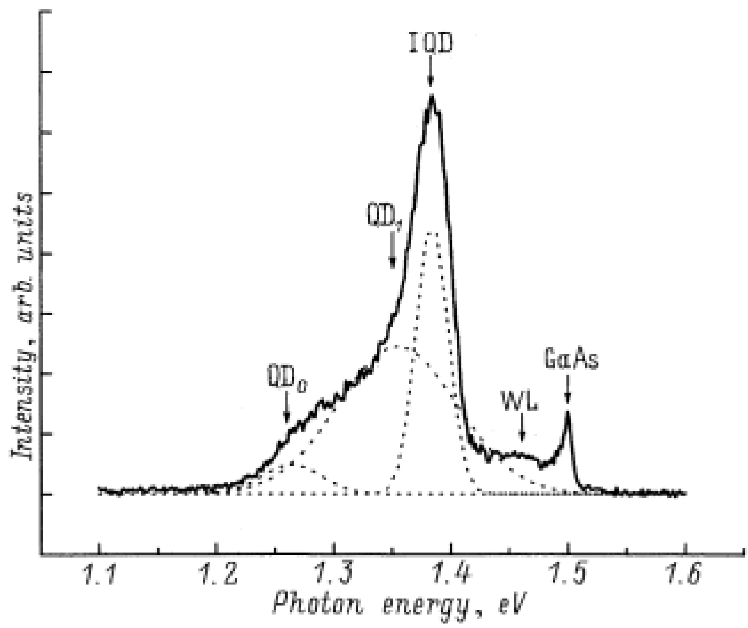

Fig. 2 Photoluminescence spectrum of InP/GaAs 5◦ [011] at T=5 K and its decomposition into Gaussian contours. Excitation by He–Ne laser radiation, power 20 mW.

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Therefore, all studies of the fine structure of InP CT photoluminescence were carried out by us on CT arrays grown in the SMSE mode on vicinal GaAs substrates from an InP layer with a thickness of 1.8 MS. The combination of all these factors allowed us to achieve maximum hardware resolution in the FL spectrum of such CTs and to study its additional fine structure. Experiments with vicinal substrates showed that under equal technological conditions, the dimensions of InP CTs and the dispersion of these dimensions depend on the magnitude and direction of the GaAs substrate disorientation.

Analysis of low-temperature FL spectra suggests a trend common to all studied directions and deorientation angles: short-wave shift of the FL KT maximum, its narrowing, and the appearance of an additional structure in the radiation spectrum. In a series of samples disoriented relative to [011], it was possible to observe a monotonic short-wave shift of the KT radiation maximum (from 1.255 to 1.375 eV) and its narrowing (from 95 to 33 meV) when the degree of vicinality changed from 0 to 7◦ (Fig. 2). Another characteristic feature of the FL CT spectra on substrates with misaligned [011] and [011] directions is the presence of a broad, unstructured wing on the long-wave slope of the main band (Fig. 2). A slightly different evolution of the low-temperature FL spectrum was observed in samples with increased substrate misorientation relative to [001] and [010]. The spectral characteristics of the FL structure changed non-monotonically. The FL band of InAs CT for a vicinal sample reoriented at an angle of 3° corresponded to the radiation band of InP CT on a singular surface of GaAs.

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