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InAs/AlGaAs QDs for intersubband devices

M. Schramboeck[a,*], A.M. Andrews[a], P. Klang[a], W. Schrenk[a], G. Hesser[b], F. Schäffler[b], G. Strasser[a]

[a] *Zentrum für Mikro- und Nanostrukturen, TU Wien, Vienna, Austria*
[b] *Johannes Keppler Universität Linz, Linz, Austria*

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Abstract

InAs quantum dots were grown on $Al_xGa_{1-x}As$ surfaces with varying Al concentrations. Atomic force microscopy measurements conducted on surface quantum dots showed that surfaces with higher Al concentrations produce smaller dots compared to GaAs surfaces. Photoluminescence measurements performed on buried quantum dots showed a blue shift and spectral broadening of the luminescence signal for increasing Al concentrations. For Al concentrations of 45% quantum dots with ground state energies above the GaAs bandgap could be achieved. High resolution transmission electron microscopy measurements clearly showed the presence of the dots and were in good agreement with the AFM measurements.

Keywords: Quantum dots; AlGaAs; InAs

0. Introduction

With the advent of semiconductor nanostructures and the discovery of their superior physical properties due to their reduced dimensionality, extensive research has been conducted to exploit these features for next generation device applications. In particular quantum dots (QD) have attracted great attention as they offer the ultimate limit in carrier confinement, which can be exploited for optical devices in the near- and mid-infrared (IR) region. An established way to grow QDs is by the self-assembled Stranski–Krastanow growth mode [1]. Due to the lattice

* Corresponding author. Tel.: +43 1 58801 36227; fax: +43 1 58801 36299.
E-mail address: Matthias.Schramboeck@tuwien.ac.at (M. Schramboeck).

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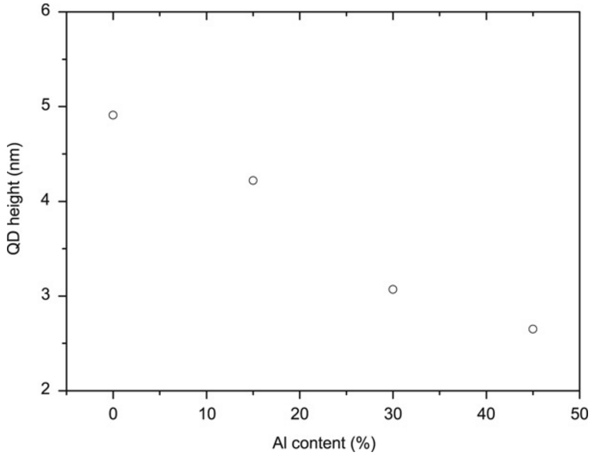

Fig. 1. Graph of the average surface QD height vs. Al content. For higher Al concentration the dot height decreases, thus producing dots with higher ground state energies which is also reflected in the PL measurements.

mismatch of the surface material and the deposited material the formation of QDs is initiated after the deposition of a critical thickness. However, there exists only a narrow growth window for successful QD growth and therefore an exact control of the growth parameters is necessary. Apart from the InAs/GaAs material system, also InAs QDs grown on ternary compound surfaces like AlGaAs have been studied [2,3]. The InAs/Al(Ga)As material system is especially interesting for device applications such as QD mid-IR emitters or detectors [4,5] and it is therefore vital to gain insight into the growth processes and optical properties of InAs QDs on $Al_xGa_{1-x}As$ surfaces.

1. QDs on $Al_xGa_{1-x}As$ surfaces

The QDs were grown using a solid-source molecular beam epitaxy (MBE) system. For the surface QD samples the $Al_xGa_{1-x}As$ was grown at 590 °C while subsequent InAs QDs were grown 490–520 °C. The sample surface, QD size, shape and density were analyzed by atomic force microscopy (AFM) with a Digital Instruments 3100 operated in tapping mode. The QD size evolution was studied for dots grown on surfaces with varying Al concentrations. The Al contents investigated were $x = 0, 0.15, 0.3$ and 0.45. Higher Al concentrations were not investigated as for $x > 0.45$ the $Al_xGa_{1-x}As$ due to the Γ, L, X crossover changes to an indirect gap material. Fig. 1 shows the QD height dependence for increasing Al content at a growth temperature of 500 °C. Compared to a GaAs surface the dot height is reduced almost by half on a $Al_{0.45}Ga_{0.65}As$ surface. A similar behavior was also found for different growth temperatures.

1.1. Photoluminescence measurements

To probe the optical properties of the QDs, the buried dots were characterized by photoluminescence (PL) measurements. The samples for PL consist of 30 layers of self-assembled QDs grown at a surface temperature of 490 °C. To confirm the presence of the dots in the layer structures high resolution transmission electron microscopy (HR-TEM) measurements were performed on the samples. Fig. 2 shows HR-TEM images of single QDs embedded in $Al_{0.45}Ga_{0.65}As$ and in GaAs. For the PL measurements a diode pumped solid state laser operating at a wavelength of 532 nm is used. The emission of radiation from the photo-excited