Thermal effects of quantum dots InAs/GaAs with $In_xGa_{1-x}As$ confinement barriers

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Development of self assembled InAs/GaAs quantum dot (QDs) has led an important advance in the optoelectronic technology. One of its main interests comes from the emission of entangled photons [1], and the possibility to integrate such quantum optical active medium with the GaAs technology [2]. However these nanostructures have usually disadvantages, as for example strong decrease of the emission intensity with the temperature or difficulties to obtaining QDs with emission wavelengths over 1 µm [3]. This work studies the effect of growing InAs QDs under $In_xGa_{1-x}As$ confinement layers (CLs) [4] [5], in order to reduce the QD-CL band discontinuities and to achieve a redshift in the emission wavelength. For this purpose self assembled QDs have been grown on a GaAs substrate under 10 nm of an $In_xGa_{1-x}As$ layer. Four samples with different In compositions (x = 0, 0.1, 0.2, 0.3) have been prepared. The final structures were capped by 20 nm GaAs layer. Samples have been characterized by photoluminescence (PL) and time resolved luminescence (TRPL) in function of the temperature.

PL experiments show emission between 1 and 1.4 µm. The exact emission wavelength depends on the barrier composition; being the emission wavelength proportional to the amount of indium in the barrier. All samples have a bimodal size distribution. Temperature dependence of the PLs shows a constant intensity for temperatures lower than 120 K and a double decay time evolution when the temperature is raised. First of all, there is a slow decay for temperatures between 120 and 220 K, and then a fast decay appears when the temperature is higher than 220K. The behaviour can be modelled by Arrhenius dependence with two activation energies, involving two different mechanisms of escape. The second activation energy (fast decay) is always close to the difference between the wetting layer (WL) and QD energy. Thus, this second mechanism has been attributed to escape from the QD to the WL. The exact activation energy depends on the indium content, implying an important role of this barrier into the QD's dynamics.

TRPL's measurements have been realized in function of the temperature at the corresponding emission energies of the two families. As well, the sample with highest indium content (x = 0.3) has been thoroughly studied, covering the whole emission range. TRPL behaviour strongly depends on the emission energy and the barrier composition, but in all cases recombination times increase with temperature before a strong decay when the temperature reaches 220 K. This behaviour is attributed to the appearance of dark states as has been proposed elsewhere [6, 7].

Red-shift and room temperature behaviour obtained in the nanostructures proposed in this work could be helpful in the implementation of new optoelectronic devices, because nowadays there is a great interest of developing quantum optical devices at long wavelengths (in particular the telecommunication windows 1.3 and 1.55 µm).

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