ICAM2009

11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Electronic States of InAsP Self Assembled Quantum Dots

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Abstract – In the present work we investigate the optical properties of InAsP quantum dots in order to determine the electronic states (ground and excited levels) of these nanostructures as a function of their growth parameters. For a progressive incorporation of As in the ternary alloy quantum dot emission shifts to lower energies [Fig. 2(a)], as well the wetting layer starts to be visible only at high temperatures [Fig. 2(b)]. A hint on a first excited state is seen only for samples with higher As contents (Fig. 3) and modulation techniques will be used in order to clarify this issue.

Self-assembled quantum dots (QDs) present great potential for application in commercial devices, as well as they are considered one of the most promising building blocks for performing quantum computation in solid state devices. Some time ago it was showed that the presence of a QD plane near a two-dimensional electron gas (2DEG) does modulate some basic transport properties of the gas, and even induced a metal-insulator transition on a 2DEG [1-2]. On this light, a proposal has been made to employ a plane of self-assembled QDs nearby a 2DEG in order to artificially modify the hopping regime, characteristic of low density electron gas transport. These randomly distributed QDs would modify the potential fluctuations of the interface to which the 2DEG is confined; by presenting lower energy confined states, the dots might act as the electron reservoirs from which the carriers would hop. Thus it is of fundamental importance to characterize the QD electronic states (specially the excited levels) so that the desired effect on the 2DEG is achieved. The tunable InAsP QD system is used for this purpose since by changing the As contents on the ternary alloy the QD energy emission can be controlled [3].

Samples were grown by metal-organic chemical vapor deposition [3] and Figure 1 shows a growth map where the As contents on the different QD samples were achieved by varying both the growth rate and the phosphine flux. Photoluminescence (PL) spectra were taken as a function of the temperature (10 K to 300 K) and excitation power (10 µW to 10 mW, 532 nm laser), and analyzed by a 30 cm monochromator-CCD setup. Figure 2 shows the emission spectra of five different samples (marked in green in the map of Fig. 1). For lower temperatures [Fig. 2(a)], a single emission band is observed and assigned to the fundamental QD recombination. No signal of excited states was found, even for the highest excitation power. As temperature is increased, however, the PL spectra changes: a second structure arises, as well as the GaAs substrate emission at around 1.46 eV. The first can be attributed to the wetting layer (WL), since it is narrower than the QD emission (as expected) and also shifts in energy as a function of the As contents in the alloy. When fitting the PL spectra with Gaussian line shapes, an additional structure between QD and WL emission is needed for a perfect description. This is an indication that an excited state is present on the samples with higher As contents. For other samples, QD and WL structures are overlapped and it is likely that the QD confining potential is too shallow to allow a second electronic level. Since it is difficult to explore this behavior with PL only, we will perform photoreflectance measurements on the set of samples in order to accurately identify the appearance of excited QD states as a function of the ternary alloy composition.

We acknowledge financial support from Fundação Araucária and CNPq.

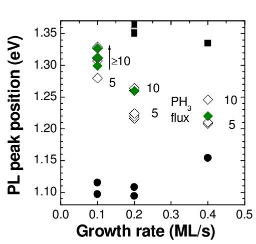

Figure 1: Growth map for InP (full squares), InAsP (open diamonds), and InAs (full circles) quantum dots grown on different conditions.

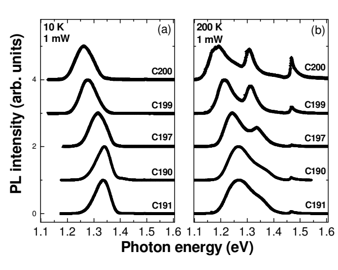

Figure 2: Photoluminescence spectra for different InAsP samples taken at (a) 10 K and (b) 200 K.

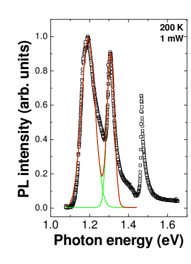

Figure 3: Fitting procedure for sample C200: QD and WL structures only.

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