*Poster*

# COMPARATIVE STUDY OF GaAs-BASED 1.5 MICRON-RANGE InAs/InGaAs AND InAs/InAlAs SELF-ASSEMBLED QUANTUM DOTS

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## Introduction

It has been previously shown that self-assembled InAs quantum dots can be formed in a metamorphic $In_{0.2}Ga_{0.8}As$/GaAs matrix [1].Such QD structures are promising candidates for an active region of long wavelength (~1.55 micron) lasers for fiber-optic communication systems. Pioneer works in this direction have been already done [2].

This work is a study and a comparison of optical properties of InAs QDs in a metamorphic InGaAs matrix where QDs are capped with either InGaAs or InAlAs quantum well. An objective of the work is to achieve longer wavelength than it has been demonstrated in uncapped QD structures and to study the effect of capping material on luminescence intensity and peak position.

## Experiment

The structures under study were grown in a Riber 32P machine by molecular-beam epitaxy on (001) GaAs substrates. The transient InGaAs buffer was deposited at 400°C, the rest of the structure was grown at 500°C. Indium mole fraction, $x$, in the $In_xGa_{1-x}As$ metamorphic matrix was varied in the 18-31 % range. InAs QDs inserted in the middle of the matrix were capped with either $In_yGa_{1-y}As$ or $In_yAl_{1-y}As$ quantum well ($y>x$), or uncapped.

Photoluminescence (PL) measurements were carried out using a $Ar^+$ laser ($W$=500W $cm^{-2}$, $\lambda$=514 nm) in the 77–300 K temperature range.

## Results

### *Effect of capping material*

First we studied effect of different capping material (no capping, InGaAs QW, or InAlAs QW). We found that InAlAs QW, similar to InGaAs QW, provides a significant long-wavelength shift of QD luminescence with respect to that of uncapped structure (where QDs are formed directly in the InGaAs matrix).

In addition to the peak of QD luminescence, a shorter-wavelength peak of InGaAs QW is observed in InAs/InGaAs structures. In this respect InAs/InAlAs structures have noticeable advantage because no QW peak is observed owing to wider-bandgap material. QD peaks are relatively narrow in both cases being about 50 meV.

### *Effect of matrix bandgap*

Then the effect of indium mole fraction, $x$, in the matrix was studied. InAs mole fraction in the QW was varied following the relation $y=x+0.2$.

PL measurements revealed that QD line in both InAs/InGaAs and InAs/InAlAs structures is red shifted as the In mole fraction in the matrix, $x$, increases (the matrix bandgap decreases). However, the dependence of QD peak on $x$ saturates at ~1.42-1.43 micron in InAs/InAlAs structures when In composition in matrix becomes higher than ~23%. InAs/InGaAs structures demonstrate further shift of the QD peak position.

PL intensity decreases with increasing In composition in matrix, but remains reasonably high up to the highest In composition (~31%). However, this dependence is weaker in InAs/InAlAs structures as compared to that for InGaAs-capped structures.

### Effect of InAlAs QW composition

Then we studied the effect of InAs mole fraction in the capping InAlAs QW ($y=x+\delta$). In this series $x$ was about 23% in the $In_xGa_{1-x}As$ metamorphic matrix. The difference in indium content, $\delta$, between the matrix and the QW was varied between 0-30 %.

It was found that the increase in In composition in InAlAs QW results in strong red shift of QD line. This dependence saturates when In step, $\delta$, becomes higher than ~25%. Blue-shift ("rebound") of QD peak position is observed for higher $\delta$. The longest wavelength of InAs/InAlAs QDs (for $x$=23%) is 1460nm. To reach longer wavelength one should increase simultaneously In composition in matrix and In step δ between matrix and InAlAs QW.

### Correlation between PL intensity and QD wavelength

The next step was to investigate correlation between PL intensity and PL peak position for MM QDs capped with either InGaAs or InAlAs QW.

InAlAs-capped samples demonstrate better PL intensity for the same wavelength being compared with InGaAs-capped structures for the spectral range $\lambda<1.46$ micron. The optimum combination of high PL intensity and long wavelength for $\lambda\sim1.45-1.46$ micron is found for InAlAs-capped samples. Optimum design is: $x \sim 23\%$ (matrix), y~48% (QW).

At the same time, we did not find a method for further shift of QD line to longer wavelength ($\lambda>1.5$ micron) in InAlAs-capped QD samples. The wavelength was limited by the saturation or the rebound as In mole fraction in the matrix and/or the QW increases. As a result, attempt to increase the QD wavelength results in significant drop of PL intensity. The longest wavelength in InAlAs-capped samples is 1.48 micron for the sample with $x$=28% (matrix) and $y$=58% (QW). Contrarily, InAs/InGaAs QDs demonstrates worse PL intensity in shorter-wavelength range ($\lambda<1.46$ micron). At the same time, these structures provide a possibility to shift PL line to longer wavelength (up to ~1.6 micron) while the PL intensity remains quite high.

## Conclusion

To summarize, optical properties of GaAs-based structures with InAs/InGaAs or InAs/InAlAs QDs embedded into an InGaAs metamorphic matrix have been examined. Capping of quantum dots with QW provides a significant long-wavelength shift of QD luminescence regardless the QW material. No QW peak is observed in InAlAs-capped samples.

In both cases higher In content in the matrix results in longer wavelength of QD line. However, this dependence is weaker in InAs/InAlAs structures as compared to that for InAs/InGaAs QD structures. Increase in In content in InAlAs capping QW also results in red shift of QD PL peak position. This dependence saturates when In step becomes higher than ~25%. The longest wavelength in InAlAs-capped samples is 1.48 micron.

InAlAs-capped samples demonstrate better PL intensity for the same wavelength being compared with InGaAs-capped structures for the spectral range $\lambda<1.46$ micron. InAs MM QDs capped with InGaAs QW provides a possibility to shift PL line to longer wavelength (up to ~1.6 micron) as compared with InAlAs-capped samples.

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