Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 302-303

**E-3-4**

# Magneto-luminescence of Interdiffused Self-Assembled Quantum Dots.

S. Awirothananon[1,2], W. Sheng[1], A. Babinski[3], S. Studenikin[1] , S. Raymond[1], P. Hawrylak[1], A. Sachrajda[1], M. Potemski[3], G. Ortner[4], and M. Bayer[4].

[1]Institute for Microstructural Sciences, National Research Council of Canada,
Montreal Rd. Ottawa, Ontario K1A 0R6, Canada.
Phone: 1-613-990-9529 E-mail: sunida.awirothananon@nrc.ca.
[2]Department of Physics, The University of Ottawa, Ottawa, Ontario, Canada.
[3]Grenoble High Magnetic Field Laboratory, MPI/FKF and CNRS, Grenoble, France.
[4]Experimentelle Physik II, Universität Dortmund, D-44221, Dortmund, Germany.

## 1. Introduction

Semiconductor self-assembled quantum dots (QDs) are zero-dimensional structures which one can address and tailor. This can have important implications in different fields such as, for example, photonics and quantum information processing. In particular for certain devices, such as lasers, it may be desirable to have the capability to obtain very homogeneous QD emission properties or to tailor the emission energy. To this effect, the process of interdiffusion between QD and surrounding barrier material has been used to tailor the spectrum of QD ensembles, resulting in blueshifting and narrowing of the emission band. [1,2] Here we use magneto-photoluminescence (M-PL) experiments to monitor the evolution of QD properties as a function of increasing interdiffusion.

After growth of a single layer QD sample, a few neighboring pieces typically 5x5 mm in size were cleaved and annealed at different temperatures. Each piece was analyzed using M-PL experiments with magnetic field applied parallel to the growth axis (Faraday configuration).

## 2. Results and discussion

Fig. 1 a), b) and c) show examples of M-PL experiments performed on samples annealed at increasing temperatures, causing increasing amount of intermixing. Fig. 1 (a) shows the typical spectral evolution obtained. The s shell (ground state) emission at 990 nm undergoes a monotonous diamagnetic shift upon application of a magnetic field, while the p shell (first excited state) (950 nm) and d shell (second excited state) (915 nm) emission show clear splitting behavior as the magnetic field is increased (B < ~8T). For higher fields, an overall pattern of splitting and crossing of levels is obtained with one clear region of transition crossings observed at B~17T. This crossing occurs when the cyclotron energy becomes comparable with the QD inter-sublevel spacing. Thus, for samples with greater intermixing with reduced inter-sublevel spacing, the corresponding crossing regions are observed at lower magnetic fields, and an increasing number of crossing regions can be observed. For the samples annealed at 875°C and 900°C, crossing regions occur at 13T, 23T and 11T, 17T, 24T respectively.

The striking pattern of splitting and crossings can be observed due to the small inhomogeneous broadening and reduced inter level spacing of the QD ensemble after intermixing, opening the way for interesting fundamental investigations. Also, one can study the Zeeman-like splitting of excited-state transitions as a function of annealing conditions. In particular, the energy splitting of the first excited state at moderate magnetic fields is given by [3]:

$$\Delta E = \frac{e\hbar B}{\mu_\perp^*}$$

where $\mu^*$ is the in-plane reduced exciton effective mass. This effective mass is related to the Ga content of the QDs, hence in principle one can use this technique to relate the evolution of the interdiffusion process to the annealing conditions.

## References

[1] *R. Leon, Y. Kim, C. Jagadish, M. Gal, J. Zhou and D. J. H. Cockayne, Appl. Phys. Lett.* ***69****, 1888 (1996).*
[2] *S. Fafard and C. Ni. Allen, Appl. Phys. Lett.* ***75****, 2374(1999).*
[3] *P.P. Paskov, P.O. Holtz, B. Monemar, J.M. Garcia, W.V. Schoenfeld, and P.M. Petroff, Phys. Rev. B* ***62****, 7344 (2000).*

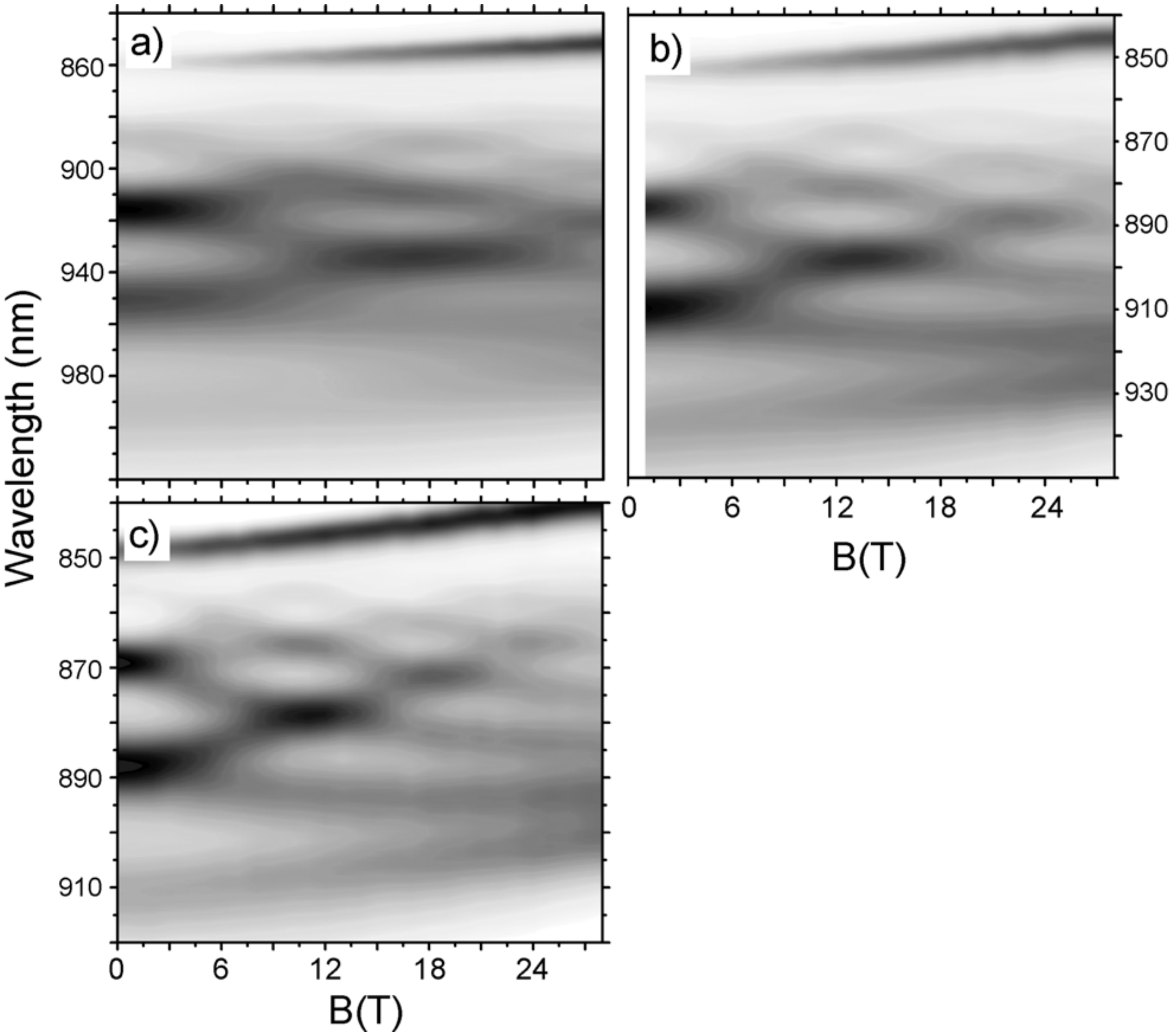


Fig. 1 Results of magneto-photoluminescence experiments for samples annealed during 30s at different temperatures (interdiffusion): a) T=850°C, b) T=875°C and c) T=900°C. Dark shades (light shade) represent region of high (low) photoluminescence intensity. All spectra were recorded at 4.2 K with $Ar^+$-ion laser excitation power of: a) 200 mW, b) 100mW and c) 100mW.