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Strong Linear Polarization of Exciton/Biexciton Photoluminescence from Single Self-Assembled Hexagonal GaN/AlN Quantum Dots

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1. Introduction

Nitride based quantum dot nanostructures are promising candidates for non-classical light sources at room temperature, such as single-photon emission and the generation of polarization entangled photon pairs. Especially with respect to the latter application, we examined the polarization properties of the photoluminescence emission of single quantum dots from the biexciton-exciton decay cascade. For polarization entanglement non-polarized emission is essential. Different from arsenide based systems, in GaN based quantum dots the top three hole bands are mixed. Thus more complex polarization behavior can be expected.

In this contribution we report a strong linear polarization of exciton and biexciton emission from single GaN quantum dots.

2. Sample and Measurement Setup

We investigated samples of self-assembled hexagonal GaN quantum dots grown on 100nm AlN on an n-type 6H-SiC (0001) substrate and capped with another 100nm AlN layer. The growth was done by low pressure metal-organic vapor deposition. The samples were processed as a mesa structure to facilitate single-dot micro photoluminescence (μPL) measurements [1]. We used a frequency-doubled solid-state laser at 266nm to excite the quantum dots with variable power. Polarization dependent μPL spectra were taken using a Berek polarization compensator and a Glan-Taylor polarizer in front of the monochromator. We used three different methods (blinking, pump power dependence and photo correlation) to confirm the origin of the spectral lines as outlined below.

3. Experimental Results

Single Dot μPL

About 100 mesas were investigated by polarization dependent photoluminescence in this study. It was found that most emission lines show a pronounced linear polarization. This agrees with the results recently published in [2]. However, in most cases, we could not observe biexciton emission. Only in three cases, of which we will present one here in detail, clear biexciton and exciton luminescence from a single quantum dot could be observed.

By recording the blinking behavior of individual emission peaks, we can assign them to belong to the same or a different quantum dot (Figure 1). Pump power dependent measurements further indicated that peaks 3 and 4 are the exciton and biexciton emission line of the quantum dot.

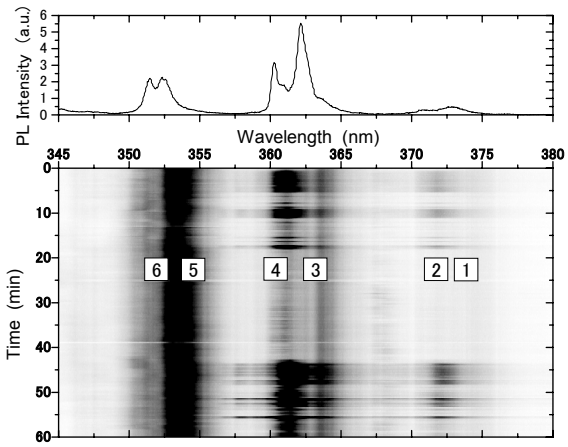

Fig. 1 Blinking of the quantum dot photoluminescence. Notice how peaks 1 to 4 blink in the same rhythm. This is clear evidence that these lines belong to the same quantum dot. Peaks 5 and 6 belong to a different dot.

Finally, we did photo correlation measurements using a Hanbury-Brown&Twiss Setup. The results confirm our peak assignments as exciton and biexciton (Figure 2).

Polarization dependent μPL

We have found that the emission lines exhibit strong linear polarization, with the Stokes vectors of exciton and biexciton lines facing in the same direction (Figure 3). It can be noted that the second quantum dot present in the spectra is also strongly linearly polarized, but in a different direction.

4. Discussion

The strong linear polarization can be explained by an asymmetric dot shape, as has been reported recently by [2,3]. The linear polarization can originate in valence band mixing and should have the same direction for exciton and biexciton [3].

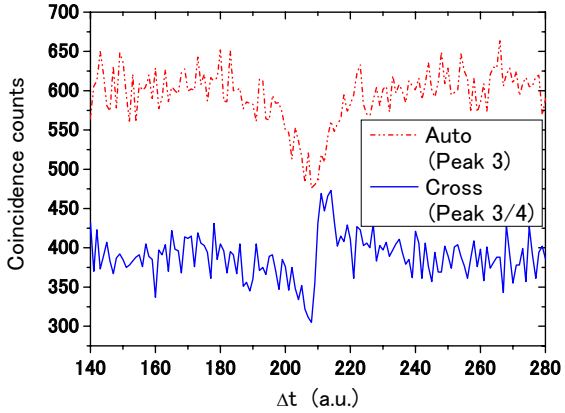

Fig. 2 Autocorrelation and crosscorrelation of Peak 3 and Peaks 3&4 rsp. The autocorrelation shows clear anti-bunching as evidence for single photon emission. The crosscorrelation shows the typical anti-symmetric shape that is characteristic for a two step cascade emission as in the biexciton-exciton emission cascade.

All dots we investigated show such pronounced linear polarization. Although the data presented here shows two dots with a linear polarization axis difference of 30° that could be conveniently explained within a hexagonal symmetry, a correlation between the axis of the polarization and the crystallographic axes could not generally be observed.

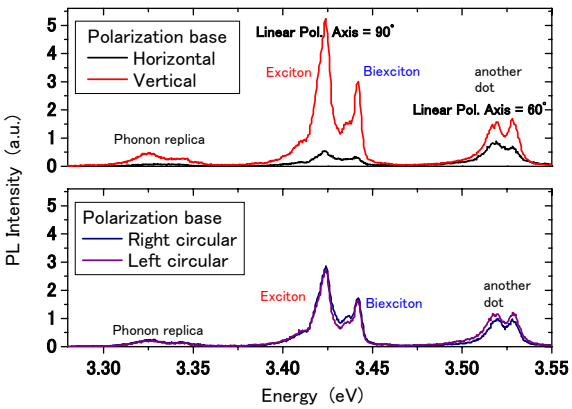

Fig. 3 Polarization dependent μPL spectra from two quantum dots. Exciton and Biexciton line show a strong linear polarization. There is no polarization dependence in the circular base. The "another dot" also shows strong linear polarization, but the axis is different.

Our results agree with the experimental data reported in [2], in the point that all emission lines are linearly polarized. To our knowledge, however, this is the first experimental demonstration of the fact that the polarization vector of biexciton emission line faces in the same direction as the exciton line.

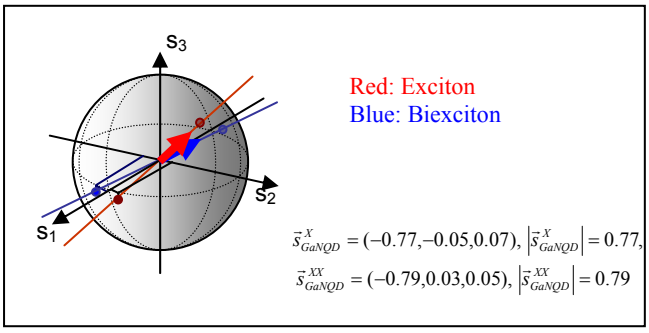

Fig. 4 Stokes vectors of the exciton and biexciton emission line. Both lines are strongly polarized in the same linear direction.

These findings severely limit the prospect of generating polarization entangled photon pairs by GaN quantum dots, as a non-polarized biexciton/exciton emission is required. One report [4] suggests using externally applied stress to compensate for the structural anisotropy of the dots and tune the polarization of the emission, however no experiments have been performed yet.

5. Summary

Micro photoluminescence spectroscopy has been performed on single GaN quantum dots. The nature of the emission lines has been confirmed by blinking, pump power dependence and photo correlation. A strong linear polarization of exciton and biexciton emission was found. The stokes vectors of both emission lines face in the same direction. Our experimental results agree with calculations reported by other groups. For the application in entangled photon pair generation we have to find ways to overcome this strong linear polarization, e.g. via polarization tuning by externally applied stress.

Acknowledgements

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