Losses via Excited States in Green InGaN/GaN Quantum Wells

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Abstract

We studied green-emitting InGaN/GaN quantum wells of high structural quality by means of (time-resolved) photoluminescence and photoluminescence excitation spectroscopy. The optical properties are governed not only by the well-known quantum-confined Stark effect (QCSE), but also by a strong and very fast decaying "Blue Luminescence" (BL) in high excitation power density conditions, that we tentatively attribute to excited states of the quantum wells. We discuss the impact of these two processes on device performance as well as implications for optimal device design.

1. Introduction

Commercially available green InGaN quantum well (QW) LEDs are usually grown on c-plane sapphire. To achieve green luminescence, thick QWs or high Indium contents are required. In the former case the quantum-confined Stark effect (QCSE) leads to band bending in the active region which results in an increasing electron-hole separation in growth direction[1,2]. This reduces the radiative recombination rate and hence IQE. In the latter case the crystalline quality of the active layers often suffers when the In content is increased, which also reduces IQE. As such the optimal growth strategy for a given wavelength is not obvious.

2. Experiment

We investigate a series of high-quality nominally undoped samples with 5-fold InGaN/GaN QWs on c-plane sapphire substrates. In high excitation power density photoluminescence measurements we observe a strong Blue Luminescence (BL) originating from the green-emitting QWs. With time-resolved photoluminescence we show that the BL decays – independent of temperature - extremely fast (<30ps). This suggests a non-radiative process is involved.

Further we compare the IQE (as obtained from temperature-dependent photoluminescence) of a series of samples with an emission maximum of 510 nm (but varied QW thickness and In content) under low excitation power density conditions. For thick QWs the IQE drops due to the increasing electron-hole separation (QCSE). For very thin (2.2nm) QWs however, the IQE also drops. This is accompanied by an increase in observed BL under high excitation power density.

3. Conclusions

From our results, we conclude that the states involved in the BL are likely excited states of the

QW and the non-radiative loss observed is escape of carriers due to overflow of the QW, resulting in a decrease of IQE. The optimal design (thickness, Indium content) of a QW for a given wavelength is therefore a compromise of losses due to QCSE (thick QWs) and losses due to excited states (high In QWs).

4. Acknowledgment

We gratefully acknowledge the financial support of the European Union FP7-ICT Project NEWLED, No. FP7-318388 and the German Science Foundation (DFG) Collaborative Research Centre SFB 787.

5. References

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