Free and bound exciton recombination in AlGaN/GaN epitaxial films

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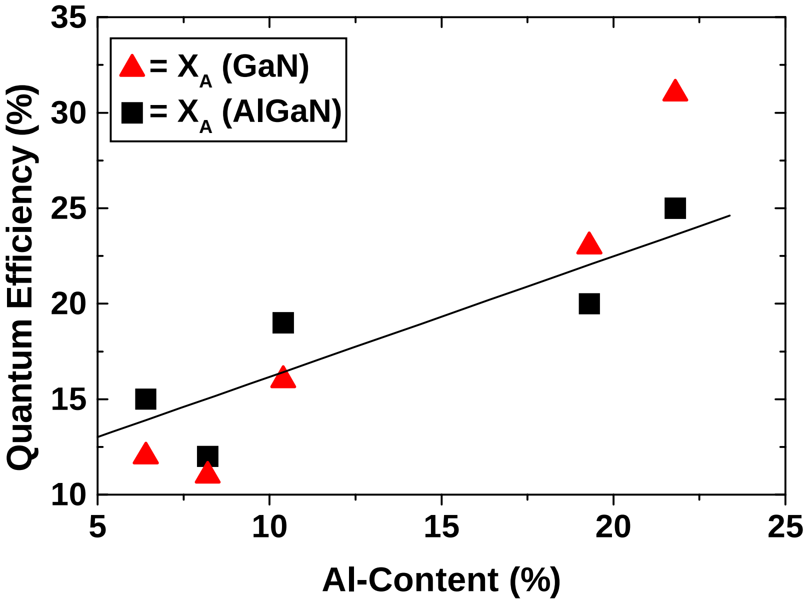
In order to realize electronic and opto-electronic devices such as field effect transistors or light emitting diodes heterostructures of the ternary nitrides InGaN and AlGaN are sandwiched between GaN layers. If they can be grown coherently on GaN the ternary layers are either under tensile (AlGaN) or compressive (InGaN) stress. The strain also enters into the energy positions of free and bound excitons and modifies the non-linear contribution of the band gap of AlGaN as a function of alloy composition (bowing parameter). We investigated AlGaN/GaN heterostructures by calorimetric absorption, transmission and reflection spectroscopy (CAS/CTS/CRS) at 47 mK.

The films were grown by MOVPE on sapphire (0001) substrates using a low temperature deposited AlN buffer and were undoped. $Al_xGa_{1-x}N$ films with thicknesses between 350 and 650 nm were grown on a 2 μm thick GaN film. The AlN molar fraction varied between 0 and 0.76 %.

The AlGaN film on a 2 μm thick GaN layer adds additional compressive strain on the GaN layer. A blue shift of the A- and B-exciton line positions in GaN is observed, which goes linear with the Al molar fraction in the films. The amount of strain in the GaN layers is quantified by micro-Raman experiments. We can demonstrate by CAS with a very high precision that for unstrained films the bowing parameter is -0.05 eV and for strained films it is 0.31 eV. Compared to photoluminescence where usually at low temperature bound excitons are monitored, CAS measures directly the transitions from the free excitons in GaN and AlGaN.

It was also possible to detect by CAS the absorption of the neutral donor bound exciton in the series of AlGaN films. Its position as a function of alloy composition coincides with the results presented recently by Steude et al [1], and serves as an important aspect as to the nature of the residual donors in these epitaxial films. Firstly, it confirms that in photoluminescence indeed neutral donor bound excitons are observed, and alloy fluctuations are small and do not contribute to localisation. Secondly, for alloy compositions smaller than 22 % the localisation energy increases from 7 meV (GaN) to appr. 28 meV in AlGaN. Applying Haynes rule would predict that the donor binding energy increases from 35 meV to 140 meV. Extrapolating to higher Al-contents the energy level approaches the DX level position of the oxygen donors in AlGaN as measured by McCluskey et al. [2]. The DX level of the oxygen donor enters into the band gap for an alloy composition of 27 %. The quantum efficiency of the A-exciton in AlGaN as measured by CAS shows a linear increase as a function of the alloy composition. This increase is also a consequence of the increasing localisation energy of the neutral donor bound exciton (see figure). Implications of these findings will be discussed at the conference.



[1] G. Steude et al, phys. stat. sol. (b) **205** (1998) R7; G. Steude et al, phys. stat. sol. (b) **165** (1998) R3

[2] M.D. McCluskey et al. Phys. Rev. Lett. **80**, 4008 (1998)