

The role of vacancies in the red luminescence from Mg-doped GaN

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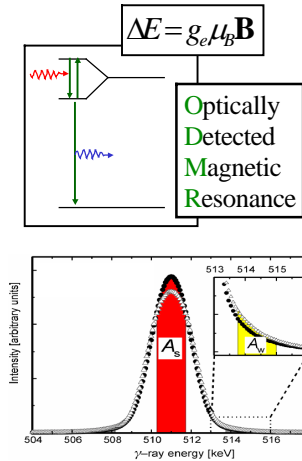
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Introduction

- Deep defects restrict improvement of carrier concentrations and play a key role in the performance and aging effects of GaN devices.
- The red (1.8 eV) luminescence band in Mg doped GaN has been suggested to be deep defects related [1-3].
- Vacancy-dopant complexes have been proposed as origins of deep defects based on indirect evidence [1-2]. Further experimental confirmation is needed.

Experimental Methods



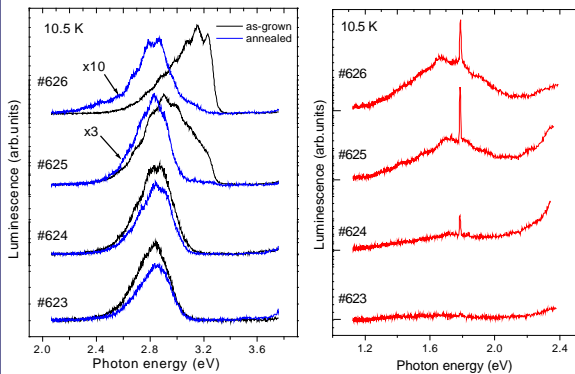
ODMR: the excited states of defects are investigated by monitoring microwave-induced changes in the photoluminescence (PL) of GaN.

Positron Annihilation Spectroscopy: positron trapping in vacancy-type defects leads to a decrease in the Doppler broadening of the annihilation radiation and a value of S higher than that for the defect free lattice sites

$$S = A_S/A_0$$

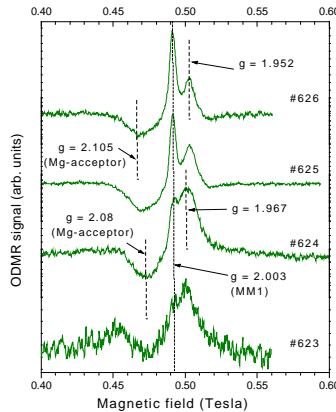
A_0 is the total area under the peak

PL Results



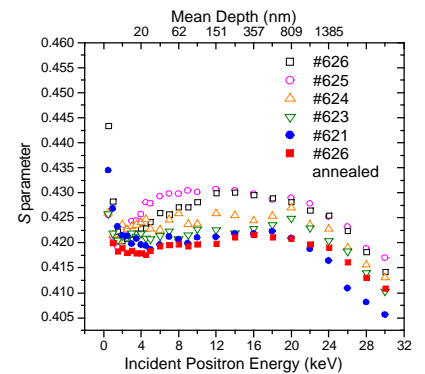
PL spectra from the GaN:Mg samples grown with different Mg precursor flow rates increasing from #626 to #623. The sharp peak at 1.79 eV is the ${}^2E(E) - {}^4A_2$ (or R_1) line of Cr^{3+} in Al_2O_3 emitted from the sapphire substrate [4].

ODMR Results



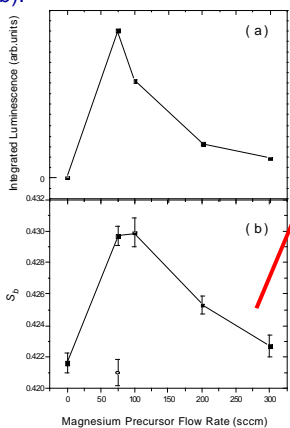
ODMR studies carried out at 13.7 GHz, monitoring the intensity of the 1.77 - 1.91 eV red band, with $B||c$.

PAS Results



The low momentum S parameter versus incident positron energy for an undoped sample (#621) and for the range of Mg doped GaN samples.

A correlation has been found between the integrated intensity of the red PL (a) and mid-range parameter (S_b) of the PAS data (b).



The observation of higher S_b s for all the Mg doped samples than the undoped one suggests the existence of a second vacancy related defect in the samples, most probably V_N-Mg_{Ga} , besides V_{Ga} .

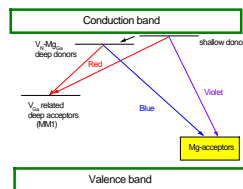
The decrease of S_b in the high Mg concentration end is dominated by the concentration decrease of V_{Ga} .

Model

• ODMR results suggest that the red emission involves electrons from both EM and deeper donors and holes from deep acceptors.

• PAS experiments show the existence of two types of vacancies, V_{Ga} and V_N-Mg_{Ga} .

• The correlation between the ODMR and PAS spectra provides strong evidence that V_{Ga} and V_N-Mg_{Ga} together lead to the red emission.



Conclusions

The red emission in Mg doped GaN is due to recombination between electrons from both EM and deeper donors with holes from deep acceptors, with the deeper donors being V_N-Mg_{Ga} (in a neutral charge state) and the deep acceptors V_{Ga} (or related complexes).

References:

- [1] U. Kaufmann *et al.*, Phys. Rev. B 59, 5561 (1999)
- [2] D. M. Hofmann *et al.*, phys. stat. sol. (a) 180, 261 (2000)
- [3] M. W. Bayerl *et al.*, Phys. Rev. B 63, 125203 (2001)
- [4] F. Varsanyi *et al.*, Phys. Rev. Lett. 3, 544 (1959)