Correlation between deep defects and persistent photoconductivity in undoped GaN and AlGaN layers

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The ternary semiconductor alloy AlGaN shows physical properties interesting for applications in solar blind detectors, for short wavelength emitters as well as for high power and high temperature devices. However, many material problems in AlGaN still remain to be solved, e.g. the existence of many deep defect states controlling the compensation mechanisms and the recombination and trapping behavior.
We have characterized deep traps in high resistivity undoped GaN and undoped AlGaN layers and determined their influence on the photoconductivity.
The samples were grown by metal-organic vapor phase epitaxy (MOVPE). The Al-contents of the AlGaN-layers ranges from 7% to 21%. Sputtered Al and Pt layers in coplanar arrangement were used for Ohmic and Schottky contacts, respectively.
The deep defect states were investigated combining temperature dependent conductivity (TDC), thermal stimulated currents (TSC), thermal admittance spectroscopy (TAS), and optical admittance spectroscopy (OAS). Additionally, the temperature dependence of the persistent photocurrent (PPC) is measured between 15 K and 500 K and wavelengths between 250 nm and 3000 nm.
Four regions of thermal emissions from defect states are well distinguished in the TSC-spectra (see Fig. 1): In region 1 two defects with thermal activation energies of 53±10 meV and 80±10 meV, were observed. These peaks were also found in TAS. With increasing Al-content these peaks decrease as shown in Fig. 1. Contrary, at higher Al concentrations, a peak in region 3 dominates the TSC spectra. This region includes at least two different defect emissions with thermal activation energies between 300 and 490 meV. In region 4 a defect emission with a thermal activation energy of 550±55 meV appears as a shoulder of the dominating peaks.
The region 2 is a non-separable continuum of thermal emissions. At higher temperatures above 350K thermal emissions in the TDC appears with activation energies between 570±30 meV and 680±30 meV.
Additionally, the defect emissions of peaks 1 and 3 in the TSC spectra were also observed by temperature dependent OAS. Transitions occur in the near band gap region at E_G- 33 meV and E_G– 85 meV as well as in the blue band with energies at about E_G-(350 – 400) meV caused by the defect levels observed in region 3 of the TSC spectra. The transitions in the blue band become dominant with higher Al-contents.
Further deep trap -to- band transitions in OAS were obtained at 2.3 eV and 0.44 eV. A new near mid-gap- to- band transition at 1.5 eV was found in the GaN and AlGaN samples with low Al- content. Although the sample with a high Al-concentration shows different peak structure in the TSC spectra the 0.35 eV level is dominating at temperatures between 300-400 K where no other peaks are observed.
The thermal emissions observed in the region 3 in TSC dramatically influences the temperature dependent photocurrent as is seen in Fig. 2. In this temperature region the photocurrent and the time constant of the PPC rapidly decrease with an activation energy of 510±30 meV.
Our results directly evidence the control of the persistent photocurrent behavior by emissions of deep defect states observed in the TSC spectra.

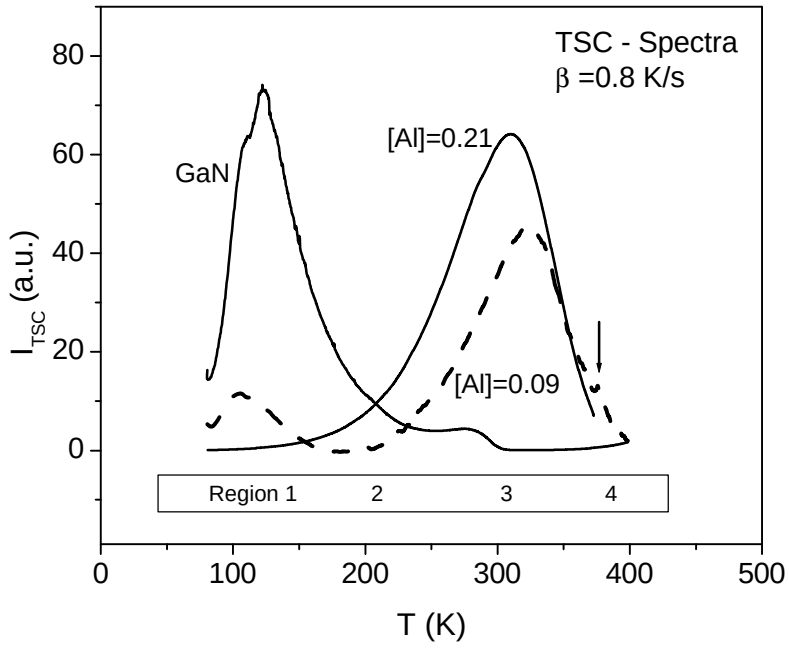

Fig. 1: TSC spectra of different GaN and AlGaN samples. Four regions can be distinguished: The regions 1, 3 and 4 consist of two or more single defect states, which can only be separated with difficulty. The region 2 is a continuum of thermal emissions.

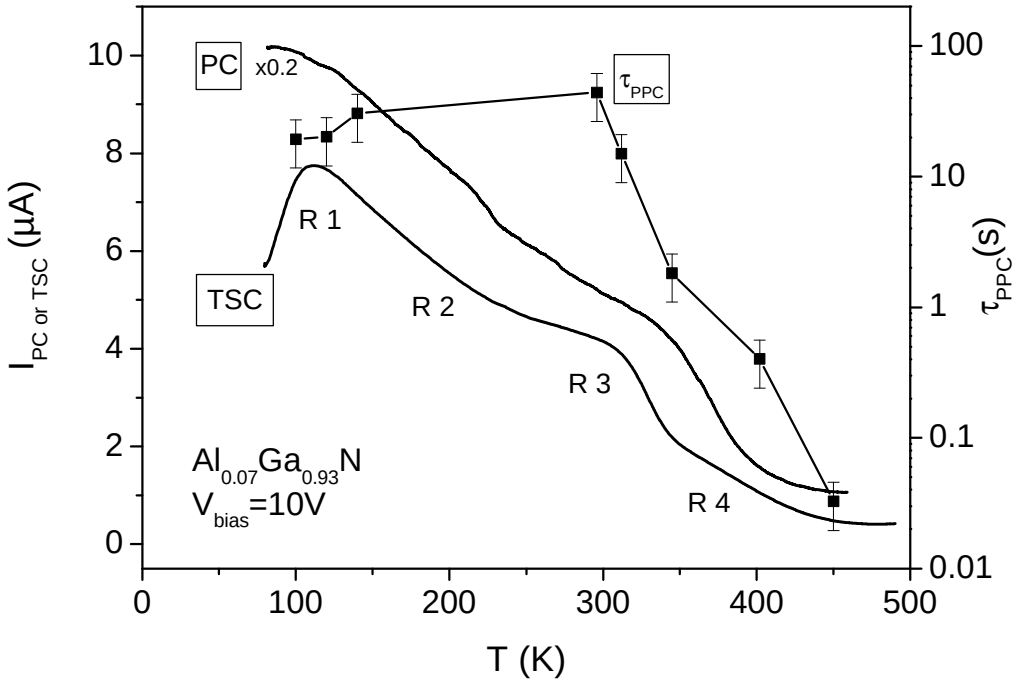

Fig. 2: Temperature dependence of the photocurrent (PC) and the time constant of the persistent photocurrent (τ_{PPC}) of an AlGaN sample with 7% Al-content. In comparison, the TSC-spectrum of this sample (TSC) is shown (R 1 …R 4 are the regions of trap emission in Fig. 1). A strong correlation between the deep defects and the PC is observed.