The influence of growth direction on electrical and optical properties of GaN:Mg single crystals grown by High Nitrogen Pressure Solution method

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Single crystals of Mg doped GaN grown by High Nitrogen Pressure Solution (HNPS) method in different crystallographic directions were characterized to determine thermal stability of their electrical and optical properties. Hexagonal platelets grown spontaneously mostly in semi-polar $[10\bar{1}1]$, $[10\bar{1}\bar{1}]$ directions, and a set of crystals deposited homoepitaxially on substrates with (0001), (11-10), (10-10), (10-11), (10-1-1) orientations were analyzed.

The hexagonal GaN:Mg platelets grown spontaneously were of excellent structural properties (TDD < 10^3 cm^{-2}) and of extremely high electrical resistivity ($\rho > 10^9$ Om·cm) [1, 2]. However their electrical properties were unstable at high temperature which was assigned to dissociation of Mg-H complexes at T > 600 K [2]. I this paper, it was shown that the change of the orientation of crystallization front especially the growth in polar [0001] direction can lead to significant improvement of thermal stability of GaN:Mg crystals and extension of the electrical stability range up to at least 900 K.

Both electrical and optical properties of crystals grown in different directions in their "as-grown" state and after annealing at temperature up to 900K have been compared. In the crystals grown in semi-polar $[10\bar{1}1]$, $[10\bar{1}\bar{1}]$ directions the annealing induced a drastic change of both electrical and optical properties. Electrical resistivity decreased by 5-6 orders of magnitude whereas blue Mg-related PL peak shifted towards low energy by 50 meV. In contrast, for crystals grown on polar (0001) surface both electrical resistance and the PL spectra were not changed after the annealing. It is therefore suggested that the formation of Mg-H complexes at growth on (0001) surface of GaN is drastically suppressed.

The observed behavior of electrical properties especially $\rho(T)$ and $R_H(T)$ obtained in the temperature range below the annealing temperatures were discussed within the model assuming three impurity states: Mg-related shallow acceptor (E_a = 150 meV). O-related shallow donor (E_a = 30 meV) and deep acceptor with activation energy of l eV above the valence band.

[1] S. Porowski, M. Bockowski, B. Lucznik et al. *Acta Phys. Pol. A*, **92**, 958 (1997)
[2] R. Piotrzkowski, E. Litwin-Staszewska, T. Suski, I. Grzegory *Physica B* **47-50**, 308 (2001)