Polarized Photoluminescence Spectroscopy of HVPE GaN with Different Dislocation Structures

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Along with the near-band-edge photoluminescence (PL) line, which is indicative of the optical quality of GaN, much attention has been paid to the yellow and red PL (YL and RL, respectively). Currently these PL bands are attributed to extended defects and/or vacancies and impurities, probably localized near the defects. However the connections between the PL band properties and the major type of dislocations in GaN still remains unclear. Also the origin of the parasitic bands, especially RL in undoped epilayers, needs additional studies.

The dislocations in GaN have a preferable orientation, therefore linear polarization of the respective PL band is expected, allowing in some cases identification of the dislocation type. In this paper we report on results of polarized PL spectroscopy of the parasitic bands in thick GaN, complemented by detailed x-ray diffraction (XRD) and transmission electron microscopy (TEM) studies performed to elucidate the main features associated with the dislocation structure of the epilayers.

GaN layers were grown on sapphire with undoped and Si-doped GaN templates (sample A and B, respectively) by hydride vapor phase epitaxy (HVPE). Besides direct TEM imaging of the interface and surface regions in the epilayers, the dislocation structures were investigated by XRD analysis of the microdistortion tensor components, derived from different Bragg and Laue symmetrical reflections in two modes of scanning (θ- and θ-2θ), including ones from planes forming a large angle with the basal plane. A strong dependence of grain sizes, strain in the layers, and density of dominant types of dislocations on the templates used was demonstrated, as well as a significant improvement of structural quality of the layers from bottom to top.

We have performed an optical study of the layers in back-scattering geometry by measuring PL from cleaved facets of thick layers. The geometry permits us to analyze the PL polarization along and normal to the c-axis, as well as to measure the PL from the whole cross-section, not only from the near surface area. Both YL and RL bands, well separated due to the excitation of a smaller space, are observed in the facet spectra, while either RL or YL dominate the spectra measured from a surface of the thick layers and templates, respectively. Therefore, the red contribution of the facet PL is ascribed to the top region of the thick layers, whereas the yellow one is provided by regions adjacent to the templates.

The yellow band is mostly polarized normal to the c-axis in the A sample, which is characterized by a high density of dislocations near the interface with the strained buffer. Contrary, the sample B, possessing two times smaller grain sizes with a factor two higher density of dislocations, demonstrates YL polarized along the c-axis. In both samples the polarization sign is opposite for the red bands, being smaller in absolute value, which is consistent with the observed variation of the dislocation structure in the top regions. Chaotically placed vertical edge dislocations predominating in the sample A seem to create polarization along the c-axis, whereas horizontal dislocations forming low-angular boundaries parallel to the surface may be responsible for the lateral polarization in the sample B.

As well known, the dislocations with edge component of the Burgers vector can induce piezoelectric fields in a crystal, which strongly depends on type and orientation of the dislocations being more intensive at dislocation terminations. The fields can modify optical properties through the Franz-Keldysh effect decreasing the energy of transitions. This mechanism is discussed as a possible reason of the observed red emission.

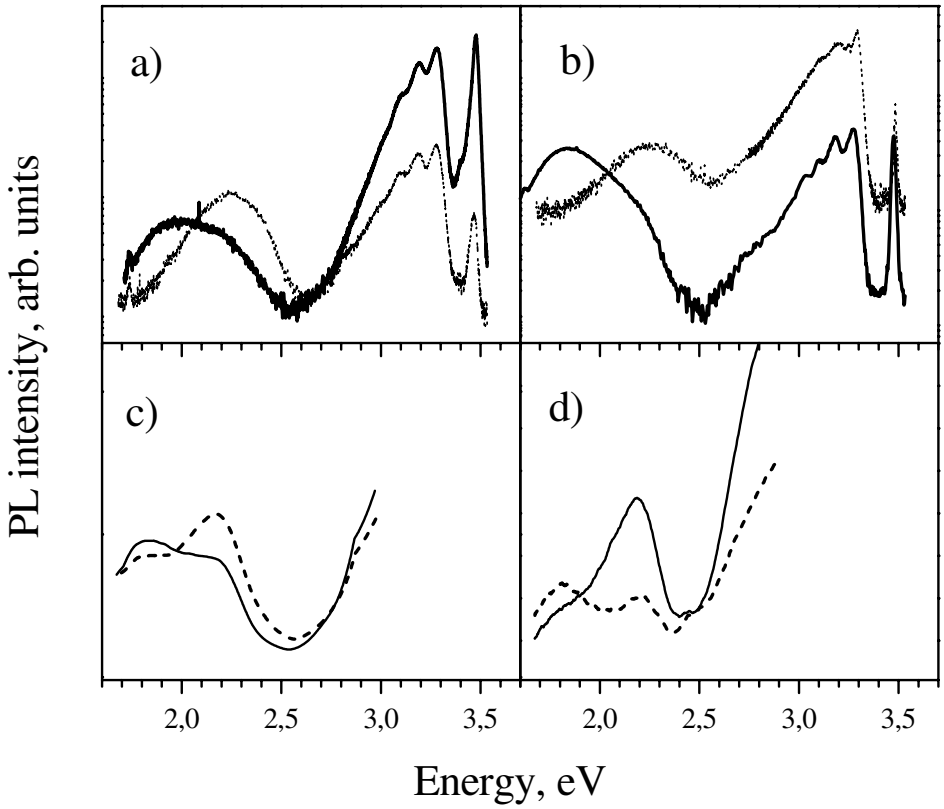

Fig. Photoluminescence (PL) spectra taken from the surface of thick HVPE GaN samples and their templates (solid and dotted curves, respectively in (a) and (b)) and from facets (c), (d). The facet PL spectra are given for both polarizations: E normal to **c**-axis (thin solid curves) and E parallel to **c**-axis (short dash curves). (a), (c) - GaN on a Si-doped template; (b), (d) - GaN on an undoped template.