Abundant Acceptor Luminescence from p-doped ZnO Films Grown under Oxygen-Rich Conditions

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The stable *p*-type conductivity of zinc oxide has still encountering problems and is the main obstacle in a wide application of this material in optoelectronics. Regardless a considerable number of papers reporting *p*-type conductivity in ZnO films, in many cases the obtained results remain controversial. It has been reported that doping ZnO with group V elements results in enhancement of luminescence intensity around 3.30-3.32 eV. However, this emission line is commonly observed in a ZnO material irrespective on the chemical nature of dopant or even in a ZnO material without any intentional doping. It has been shown that in epitaxial films the 3.31 eV luminescence is related to structural defects as it is emitted from distinct lines on sample surfaces and cross-sections representing intersections with basal planes of wurzite hexagons [1]. Even in this case the 3.31 eV emission is unambiguously related to a shallow acceptor state located 130 meV above the valence band.
Intentionally undoped and nitrogen doped ZnO films were grown by thermal Atomic Layer Deposition (ALD) under oxygen rich conditions. Low temperature photoluminescence spectra reveal a dominant donor-related emission at 3.36 eV and characteristic acceptor-related emissions at 3.302 and 3.318 eV. Annealing at 800^{o}C in oxygen atmosphere does not increase any acceptor-related emission in the undoped sample, while in the ZnO:N it leads to a considerable enhancement of the photoluminescence at 3.302 eV. The high resolution cathodoluminescence cross-section images show different spatial distribution of the donor-related and the acceptor-related emissions, which complementarily contribute to the overall luminescence of the annealed ZnO:N material. Similar spatial areas of both emissions indicate that acceptor emission comes neither from the grain boundaries nor from structural defects called stacking faults. Moreover, in ZnO:N the acceptor-emission regions are located along the columns of growth, which shows a perspective to achieve a ZnO:N material with homogeneous acceptor conductivity at least at the micrometer scale. The homojunction based on a ZnO:N fabricated by ALD at 100^{o}C shows a very good rectification characteristic ($I_{ON}/I_{OFF} = 10^5$ at ±2V).

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References

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