Enhanced Luminescence of GaN-based UV LED With ZnMgO:Al Transparent p-Type Electrode by The Application of a Thin Ni Interlayer

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One of the key issues in recent research and development of vertical GaN-based ultraviolet light emitting diodes (UV LEDs) is improving light extraction efficiency mainly through the p-type electrode modification. In the case of the typical geometry of vertical UV LED, the most common top p-type electrodes to GaN are metallic bilayer of Ni/Au owing to a low specific resistivity and indium tin oxide (ITO) due to a high transmittance in the UV region. However, both solutions have significant drawbacks. The Ni/Au films are opaque in this spectral range, leading to a reduction of the contact surface area with increasing risk of inhomogeneous current flow, local heating and breakdown. In the case of ITO, there is a high demand for indium in electronic and optoelectronic applications leading to its high price due to the limited resources of this element.

Previously we have developed a ZnMgO:Al p-type electrode with 88% transmission at 385 nm and a sheet resistivity of 30 Ω/□ [1]. By applying the full circular ZnMgO:Al electrode we obtained a 250% increase at 385 nm in irradiated power in comparison with the conventional ring Ni/Au electrode. However, the I-V characteristics of the ZnMgO:Al electrode did not exhibit ohmic behavior for low biases.

In this report we consider the influence of inserting a thin Ni film into the ZnMgO:Al/p-GaN interface on the UV LED functional properties, particularly contact electrical characteristics, and irradiated power. We present the technology and comprehensive characterization of full circular ZnMgO:Al p-type transparent electrode to GaN-based vertical UV LED with and without thin Ni interlayer. The ZnMgO:Al contact was obtained by room temperature non-reactive magnetron co-sputtering using ZnO:Al (AZO) and Mg targets. The optimal electrical and optical properties of the electrode were determined by investigating the influence of the sputtering conditions on these properties. The thin Ni films of 2.5 nm, 5 nm and 10 nm were deposited by electron beam evaporation at room temperature. Every contact was annealed in RTP furnace subsequently at 400°C, 500°C, 600°C, 700°C and 750°C. The effect of inserting a thin Ni film into the ZnMgO:Al/p-GaN interface on the electrode performance was investigated by electrical (I-V, resistivity), optical (transmittance), structural (XRD), electron microscopy (TEM, HRTEM, HAADF) and chemical (RBS) characterization. Contact formation analysis was also carried out. We obtained an increase in irradiated power of 9.5% of LED with ZnMgO:Al/2.5 nm Ni contact in comparison with diode with electrode without the Ni interlayer. Furthermore, we reduced annealing temperature from 700°C for previously developed ZnMgO:Al electrode [1] to 600°C for ZnMgO:Al/2.5 nm Ni contact. The role of Ni interlayer in the p-type electrode stack will be discussed.

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[1] M.A. Borysiewicz, M. Wzorek, K. Gołaszewska, R. Kruszka, K.D. Pągowska and E. Kamińska, *Materials Science and Engineering B* 200 (2015) 93-98.