White emission from GaON diode emitter

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1. Introduction

Solid state lighting based on color mixing of plural forms of light emitting diodes or wavelength conversion due to phosphors have become one of the important consideration for energy saving. Plausible solution to the long-standing issues of power efficiency droop was recently suggested by the development of single-crystal phosphors [1] instead of ceramic powder, as well as deployment of diode laser instead of light emitting diode as the pump source [2]. Combination of these approaches has improved the quantum efficiency and thermal stability of white light emission. However, it would be desirable if spectral coverage of the aforementioned white light emission can be extended to the “warm” white region to render better color gamut.

We have previously demonstrated that greenish white emission, without the needs of phosphor conversion, can be observed on n+ gallium nitride nano-wires (GaN NWs) grown on p-type GaN. [3] However, high contact resistance associated with the GaN NW structures depletes its functional applications. In this work, we demonstrated warm-white light emission from 400 to 800nm, with central peak wavelength tunable from 580 to 600nm, on planar i-GaON emitters grown on p-type (100) Si substrates. The current-voltage I-V curves exhibit asymmetric bipolar diode like conduction characteristics with light emission at V_F of 3.5V and 20mA.

2. Device preparation and characterization

Our material preparation began with desositing a low-temperature nitridation layer on p-(100) Si substrate, followed by O_2/NH_3 plasma-assisted GaON film growth. From the x-ray photoemission spectroscopy (XPS) analysis for nitrogen bonding in the GaN film (not shown), a strong 396.4eV peak was assigned to N-Ga bonding whereas a second peak at 393.2 eV to N-O-Ga. The oxygen rate into the GaON is currently under further investigation.

The finished GaON emitter has a 300 mm device size and was capped with a 300nm thick ITO layer to facilitate electron injection and current spreading. Overlaid in Fig.1(a) are the I-V curves measured on a 16- and 24-nm thick-GaON emitters. A first glance of these data reveals bipolar,diode-like conduction characteristics. Rigid shift of the I-V characteristics was noticed as the GaON layer thickness increases from 16 to 24nm. In addition, white light emission only occurs under forward bias as illustrated in Fig.1(b),whereas in the reverse bias the current flow does not cause radiative recombination but joule heating. We further notice that the white emission covers a broad spectral range from 400 to 800nm. Spectral blue shift in the peak position from 610nm to 580nm can be observed with reduced GaON emitter thickness.

These observations highlight a large bias field (~5MV/cm) was needed not only to counteract the polarization field at the GaON/p-Si hetero-structure but also assist in the tunneling processes. Under the conditions of (a) forward bias, white light emission occurs due to radiative recombination between the tunnel carriers with the midgap states. As for (b) reverse bias, valence electron tunneling-from the p-Si substrate to the ITO layer primarily causes joule heating.

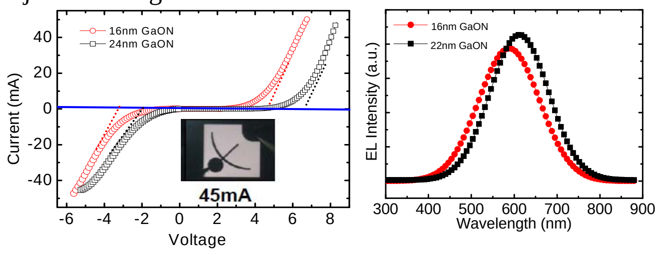

Fig.1(a) overlaid I-V curves of GaON emitters of active layer thickness of 18 and 24nm, and (b) corresponding EL emission spectra under 45mA current injection

3. Conclusions

We demonstrated warm white emission on thin GaON emitter grown on p-Si substrates. The origin for 400 to 800nm emission spectrum was ascribed to the photon-assisted tunneling mechanism with tunnel carriers make radiative recombination with midegap states and subsequent transfer to the valence band of p-Si under forward bias condition.

Acknowledgements

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References

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