Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 526-527

P-6-11L

Electroluminescence Characteristics of YellowLuminescence-Like Defects in GaN HEMTS at Off-state Conditions

Hsiang Chen, John Lai, Sheng-Chin Kung, Reginald Penner, Guann-Pyng Li
Phone: +1-949-824-2047 E-mail:hchen5@uci.edu
Univ. of California, Irvine, Dept. of Electrical Engineering
Irvine, CA 92697, USA

1. Introduction

Gallium Nitride is a promising material for optoelectronic and high-power high-frequency electronic devices. The signature of yellow luminescence (YL) has been intensively studied using photoluminescence and cathodoluminescence (CL) methods as one of the most dominant deep level defect related to light emission. For GaN LED, yellow band electroluminescence has been observed both in forward and reverse biased conditions at room temperature [1]. On the other hand, yellow band electroluminescence has only been observed in GaN HEMTs at low temperature [2]. Furthermore, the presence of yellow luminescence-like defects has not been thoroughly investigated in HEMTs at room temperature [3]. In this paper, we studied the light emission characteristics from GaN HEMTs at the off-state conditions, A yellow band electroluminescence characteristic, which might be attributed to the same origin as the YL defects, was observed at room temperature. To further characterize the EL emission spots of YL-like origins, we also performed additional experiments such as photoluminescence (PL), thermal measurements, and electrical characterization on GaN HEMTs.

2. Experimental Results and Discussion

The GaN HEMTs were biased at off-state, i.e. gate voltage below threshold voltage and high drain voltage below device breakdown. While light emission from HEMTs at on-state was continuous throughout the entire gate width, that from off-state showed several light spots illustrated in Fig. 1. Most interestingly, those emission spots at off-state had two distinct features, one being a discrete spot and the other being a continuous section. The temperature distribution along gate width at off-state was measured with a 3μm-5μm wavelength IR. Showing in Fig. 2 (a) is the light emission image and 2(b) is the EL intensity and temperature along the gate width. Several EL spots (1, 2 and 4) had higher temperature than other regions indicating higher current associated with them. However, EL spot 3 did not correlate with high temperature and had temperature similar to that of the non-emitting areas. In order to understand this particular EL spot, we measured EL spectrum of this spot with our spectrally resolved imaging system [4]. PL spectrum on an unbiased device fabricated on the same wafer was also measured. Fig. 3 shows both measurement results, depicting a peak wavelength of around 560 nm with a broad band profile in both EL and PL. This peak is similar to the YL profile reported by others [2,3, 5] suggesting this type of spot related to YL-like origin. To further characterize those YL-like spots, we studied how the EL intensity depends on the electric field. This is done by plotting the normalized emission intensity divided by reverse leakage current versus drain bias voltage. An electric field dependence similar to the YL emission observed on the LED at reverse bias [1] was evident in Fig. 4. To characterize this EL spot dependence on temperature, we measured the EL spectrum at elevated temperature. Fig 5 depicts the measurement results, showing a blue shift characteristic when sample temperature was raised from 24? to 84? [6].

3. Conclusion

A detailed EL emission investigation of GaN HEMTs at off-state including spectrum, temperature and electric field dependence has been presented. The YL-like defect origin has been confirmed by comparing EL and PL results. These YL-like EL spots have been found to be randomly distributed in HEMTs, some with multiple sites and others with none at all. A more detailed discussion of the YL-like origin and its physical characteristics will be presented in the conference. The influences of YL-like defect origins on electrical characteristics and performance of GaN HEMTs will be explored in the future

References

[1] J. Kikawa, S. Yoshida, and Y. Itoh, Solid-state Electron. 47 (2003) 523.

[2] N. Armani, V. Grillo, G. Salviati, M. Manfredi, M. Pavesi, A. Chini, G. Meneghesso and E. Zanoni ,J. Appl. Phys., 92 (2002) 2401.

[3]N. Shigekawa, K. Shiojima, and T. Suemitsu, Appl. Phys. Lett., 79 (2001) 1196. .

[4] Z.Y. Wang, J.Y. Qian, Li-Jen Cheng, G.P. Li , Y.C. Chou, R. Lai, D.C. Streit, *IEDM* (1998) 239.

[5] T Ogino, M Aoki, Jpn. J. Appl. Phys.,19(1980) 2395.

[6] R. Seitz, C. Gaspar, T. Monteiro, E. Pereira M. Leroux, B. Beaumont, Pierre Gibart, " Temperature behaviour of the yellow emission in GaN," MIJ-NSR, 5(1997) art. 36,.

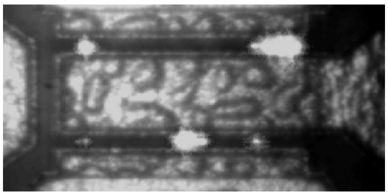

Fig. 1 A typical 2D electroluminescence image at off-state.

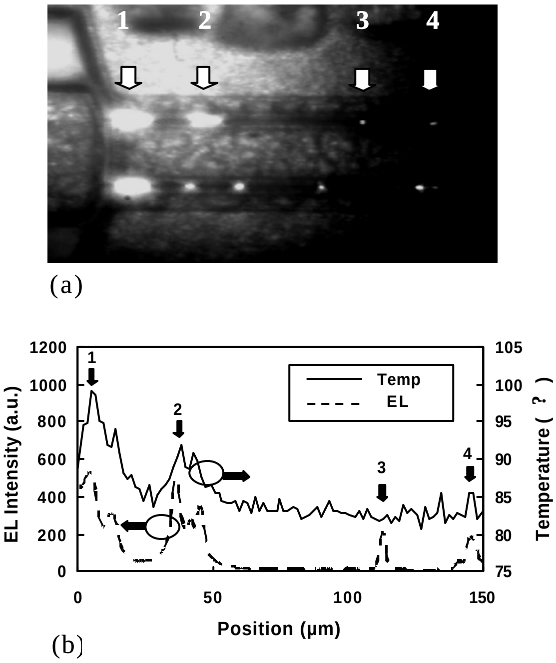

Fig. 2 (a) Another electroluminescence image at off-state (b) Electroluminescence intensity and temperature distribution along the upper gate. EL spot 1,2,3 and 4 are labeled on the upper gate.

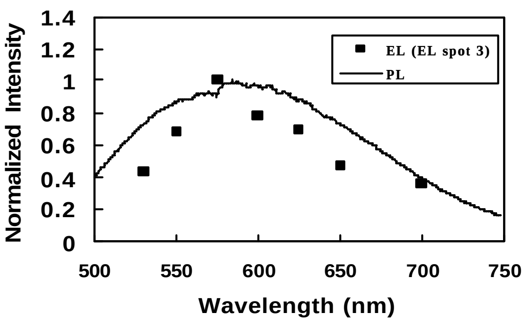

Fig. 3 PL spectrum of an unbiased device fabricated on the same wafer and EL spectrum of EL spot 3.

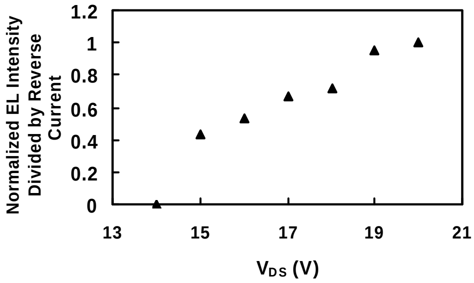

Fig. 4 The normalized electroluminescence intensity divided by reverse leakage current of a YL-like spot versus drain bias voltage.

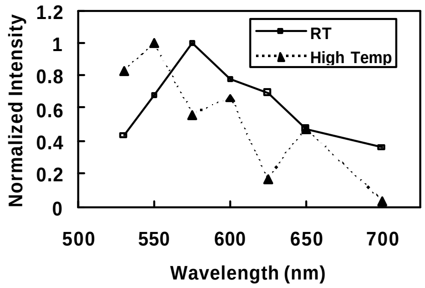

Fig. 5. EL spectrum of a YL-like spot at 24? (RT) and 84? (High Temp).