Fabrication of Low Resistivity p-GaN Contacts and Blue LEDs

A.Ramam[1], Wang Wen[1], Liu Wei[2] and S.J Chua[2]

[1]Institute of Materials Research and Engineering, 3 Research Link, Singapore 117602
[2]National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260
E-mail: ram-akki@imre.org.sg

Abstract

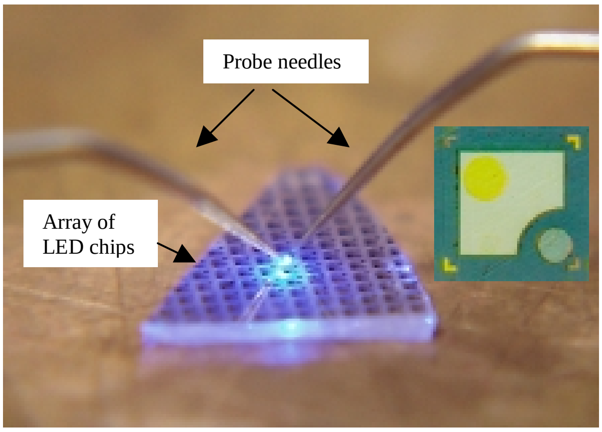
GaN is a promising material for optical and electronic applications owing to its direct, wide band gap property. Major developments in the III-V nitrides have led the commercialization of LEDs in the UV/green/blue regions of the visible spectrum [1-3]. Although the technology has matured, there still exist challenges in optimizing the material growth and in device fabrication aspects. High p-type doping, formation of low-resistance Ohmic contacts and mesa etching profiles are areas of on-going research for blue light emitting devices. We report here on our successful fabrication of blue LEDs using MOCVD grown SQW InGaN layer structures. Low resistance Ohmic contacts on p-GaN were formed by optimizing the surface treatment and post metallization annealing conditions. Dry etching of GaN with minimal damage using ICP etching technique and formation of transparent contact windows on the LED device for efficient light emission were optimized.

The LED structure was grown by MOCVD technique on a c-plane sapphire substrate, with InGaN as the active layer (0.03 μm thick) confined by layers of n and p type AlGaN on either side and finally by p-GaN on the top side for contacts. The total thickness of the layers is about 2.5 μm, including the thick n-GaN contact layer of 2 μm grown on top of the GaN buffer layer.

The LEDs were fabricated using a multiple-level masking process with the conventional lithography techniques. The Ohmic metals used were Ti/Al for n-type and Ni/Au for p-type. The area of p-contact region was maximized to promote current spreading and to maximize the light emission [4] from the device. A transparent window region was thus formed by depositing thin Ni/Au (75Å/50Å) metals. The isolation between n and p GaN was formed by dry etching the p-GaN to a depth of about 1.5μm with BCl_3/Cl_2 chemistry, in the presence of RIE and ICP RF powers. Fig.1 shows the light emission from a single LED chip and in the inset all the masks placed together. Fig.2 shows the SEM cross-section of a fabricated LED diode. The diode I-V characteristics were measured under direct current at room temperature and are shown in Fig.3. The reverse breakdown voltage is > 8V and forward voltage less than 5V. The series resistance is low (25-30 Ohms) indicating the good quality of Ohmic contacts. The LED chips of size 380μm x 380μm were bonded on a TO-8 package to study the spectral response of the emitted blue light. The peak of the spectral response is at 486nm wavelength, although small humps in the curve were observed at 465 and 530 nm.

The formation of low resistivity Ohmic contacts were studied by treating the surface of the p-type GaN with various acid compositions (as shown in Fig.4). Transmission Line method (TLM) was used in determining the contact resistivity of p-GaN layers. The separation of the contacts varied from 5 to 50 um. It is observed that the treatment of surface with conc HCl acid for about 10 min is the most effective condition resulting in low contact resistivity of 4.0E-4 Ohm-cm^2. All other treatments resulted in an order of magnitude higher resistivity. It is interesting to note that treatment of the surface with plasma (of N_2 and Cl_2) resulted in electrically inactive contacts. Even for voltages higher than 10V no current was observed during the measurements. XPS studies were performed on all the treated surfaces. No significant changes were observed in the species lying on the surface of sample, treated with different chemicals. But on the plasma treated samples a significant increase in oxygen and carbon contents were observed. This probably explains the formation of native compounds on the surface, resulting in poor contacts. The contacts were optimized with post annealing treatments also for lowering the resistivity. The temperature of 550^{o}C for 30 Sec, were observed to be the optimum conditions.

It is concluded that the chemical treatment of GaN surface prior to metallisation is the most effective way of forming low resistivity Ohmic contacts. Blue LEDs based on SQW InGaN were successfully fabricated with low forward voltages and low series resistance.



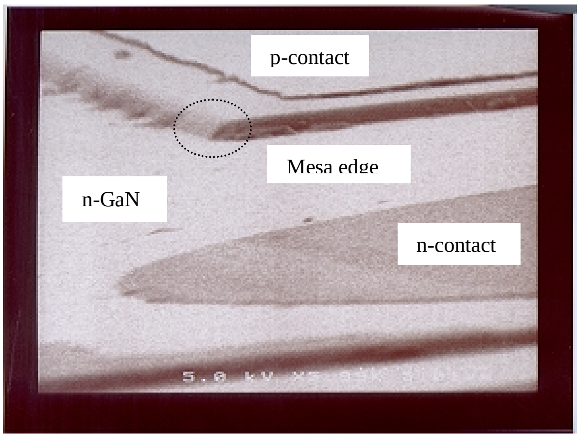
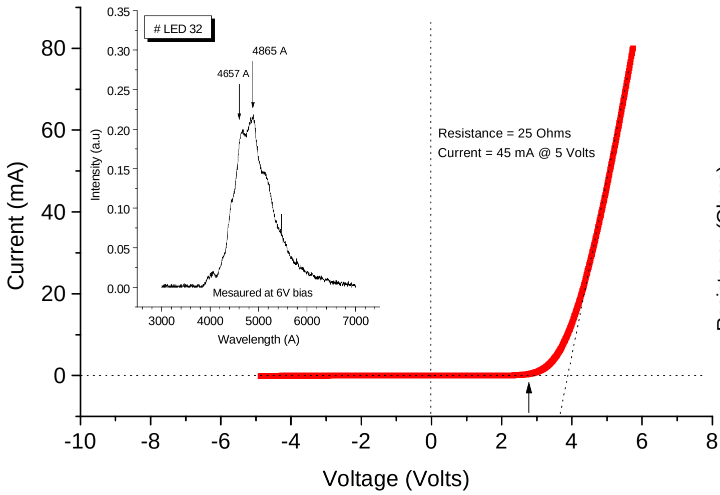


Fig.1 Blue light emission from a single LED device observed under a DC prober assembly. Inset shows geometrical features of the fabricated chip. The round patterns are the n and p bond pads.

Fig. 2 SEM cross-section of a finished LED chip Note the n-contact below the mesa and p contact window above. The mesa was formed by ICP etching technique.



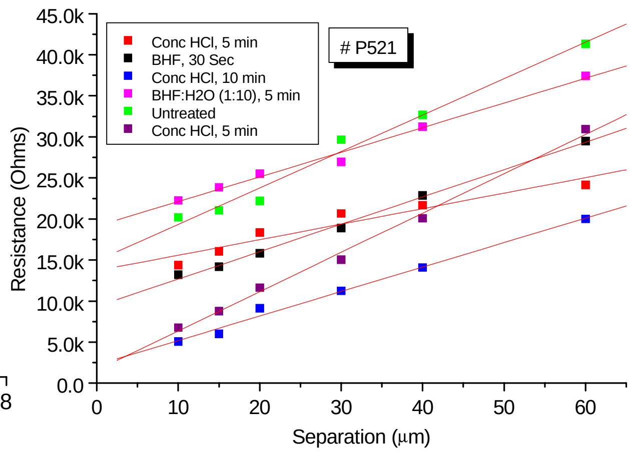


Fig. 3 I-V characteristics of the LED diode. The forward voltage is less than 5 volts, with series resistance less than 30 Ohms. Inset shows the spectral response of the diode with the peak at 486 nm.

Fig. 4 Variation of resistance with separation between the contacts. Various surface treatments given are listed in the figure. The specific contact resistivity was evaluated by TLM technique.

References:

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