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Studies on the Nature of Deep Level Defects in GaCrN Diluted Magnetic Semiconductor

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1. Introduction

The transition metal Chromium doped Gallium Nitride (GaCrN) had been proved to be a diluted magnetic semiconductor showing room temperature ferromagnetism. Since many of these samples are highly resistive and having high activation energies, photoluminescence is one of the best means to characterize these materials, especially to identify the point defects by the defect induced luminescence. The GaCrN thin films have been grown on sapphire with ECR-MBE system. The excitonic luminescence properties of the GaCrN had been extensively studied. We have reported that the Cr doping induced polymorphism in the grown layers with the increase of Cr doping and also the blue band (BL) centered around 2.9 eV [1, 2].

In this paper we report about the effect of chromium doping on the deep level defects of the GaCrN. In order to understand the nature of the defect induced luminescent bands, their dependence over temperature and excitation intensity has been studied and the results are analyzed.

2. Cr doping and Temperature effect

The Cr doping percentage in the films has been varied from 0.5 to 1.5% by keeping all other growth parameters unchanged. Fig.1 depicts the doping effect over the deep level defects induced luminescence in the GaCrN films. The Cr doping in GaN induced a new blue - band centered around 2.9 eV and it also induced an increase in

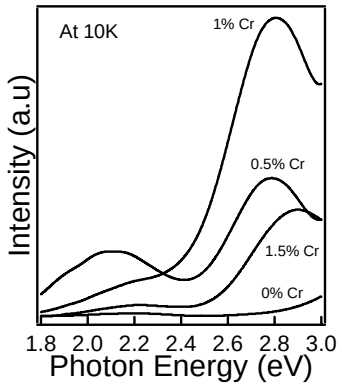

Fig. 1. Cr doping effect over the deep level defect in GaCrN

intensity of the yellow band (YL). With the limited Cr doping percentage, the BL maximum shifted from 2.91 eV to 2.79 eV with increasing Cr doping. Generally acceptor doping provides compensation in n-type materials, to which the undoped GaN crystals usually belongs. In the present case also the lower Cr doping GaN are slightly n-type where as the higher Cr doped samples are resistive because of the increased compensation effect. Yamaguchi et al [6] reported that high doping causes again decrease in resistivity, which may be due to the formation of the compensating donor complexes, possibly the V_N-Cr_{Ga}.

Fig. 2 shows the temperature behavior of both yellow and blue bands observed in GaCrN layers, in the temperature range of 10 to 300 K. It is proposed that blue band is caused due to the transition between a shallow donor and a Cr related deep acceptor, which may be Cr_{Ga}. From the figure it is obvious that the overall intensity of

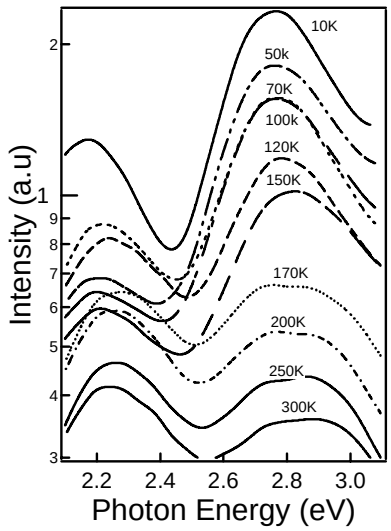

Fig.2. Temperature dependence over the YL and BL of the GaCrN films

both yellow and blue bands decreases with increasing temperature and also shows a blue shift, which are characteristics of DAP. Moreover, the full width half maximum (FWHM) also increases slightly with increasing temperature, which support the argument.

In the case of yellow band its intensity initially decreases with temperature up to 70 K. Above 70k, a sudden increase in intensity has been observed; whereas, the blue band intensity still continue the same trend of decreasing intensity with increasing temperature. It is possible that above 70 K, the band edge luminescence (at 3.47eV), which is a donor bound exciton, completely dissociated and the luminescence is completely by free excitonic transition up to room temperature. Hence a sudden increase in the population of the donors causes an increase in the probabil-

ity of DAP transitions, which in turn increase the intensity of the YL above 70 K.

The next point of interest observed from the Fig. 2 is , at low temperatures the blue band dominates, whereas at room temperature, or exactly above 150k, the yellow band dominates the spectrum. Above 150k, the PL quenching of blue band is attributed to thermal release of the trapped holes from the acceptor level to the valance band, and these redistributed holes attribute to the observed increase in intensity of the yellow band.

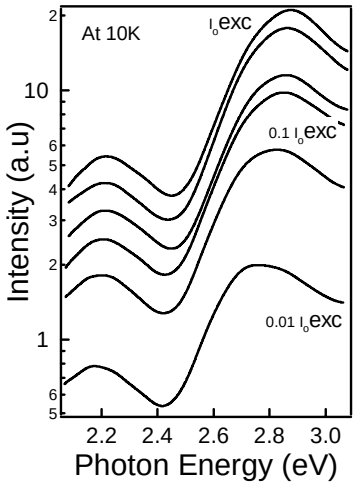

Fig. 3. Excitation intensity dependence of the deep level defects at 10K

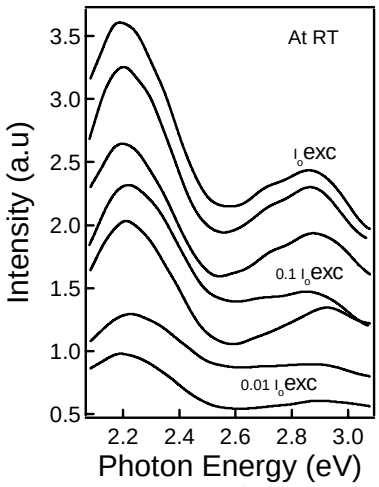

Fig. 4. Excitation intensity dependence of the deep level defects at RT

Figure 3 and 4 represents the effect of excitation intensity, which is changed two order of magnitude, over the YL and BL of high resistive GaCrN films. From the figures it is obvious that for the high resistive samples the BL dominates at low temperature whereas the YL dominates at RT. With excitation intensity both YL and BL shows a blue shift The shift is minimum for YL and for BL it is 70 meV. Hence it is attributed that the BL is caused due to the deep acceptors. The life time of the BL has been measured with the time resolved photoluminescence, which is of the order of micro seconds. The non-exponential decay suggests that the transition involves DAP emission.

Generally the BL band has been observed in undoped, Mg doped and Zn doped GaN, almost with similar shape and spectral position [5]. The reported values of the energy position of the BL vary between 2.7 to 3 eV. Apart from these well known doping species, the BL band has been found in C (Substituted in the N site), Cd, Be, As, P and Mn doped GaN. Surprisingly all the doping species which induce BL band, are acting as acceptor in GaN. From the theoretical study it has been presumed that Cr acts as a deep acceptor in GaN, when it substitutes in Ga site [3]. In the present case also, with EXAFS study it has been confirmed that almost 75% of the Cr has been substituted in the Ga site [4]. Since the BL is predominantly seen in acceptor doped GaN, its origin may be attributed to the transitions involving acceptor related states or acceptor induced defect states.

3. Summary and Conclusions

The influence of the transition metal chromium doping over the deep level defect induced luminescence have been studied. Cr doping induced a new BL which exhibits the nature of DAP, expected to originate from the transition between a shallow donor and a Cr related deep acceptor. It is also expected that there exists a relation between the blue band and the acceptor doping in GaN.

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