Optical study of impurity incorporation in an SAG-ELO GaN by MOVPE

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A high quality GaN with less dislocation density has been achieved with selective area growth (SAG) and epitaxial lateral overgrowth (ELO) technique [1]. A hexagonal pyramidal structure has also been achieved by the SAG on a sapphire substrate [2]. In the ELO region upon the mask material, however, the sample is heavily n-type doped, the properties of which have been left for further studies [3,4]. In this report, we will show the evidence of auto-doping by Si in the laterally over grown region.

The SAG of GaN was performed with atmospheric pressure MOVPE using SiO_2 mask on a GaN templated sapphire substrate. A stripe mask pattern having windows of 1- 10μm wide was formed along $<1\bar{1}00>$ crystal axis of GaN on the (0001) surface. The width of the mask region was equal to that of the window region. TMG and NH_3 were used as the source gases. The growth was performed for 5 - 120 minutes at 1060 ^{o}C. After an enough growth time, depending on the mask width, the ELO GaN with flat (0001) surface was achieved. The Hall measurements showed that the ELO GaN was n-type and the carrier density depended on the mask width. The wider the mask width was, the higher the carrier density was. This suggests that the carrier density is higher in the overgrown region, in agreement with previous results [3].

In order to study the doping properties, the photoluminescence spectra were investigated for samples obtained at various growth times tg. Figure 1 shows SEM image of typical samples with 5μm wide windows. At tg = 5 min, the growth of GaN is mostly on the window region and the ELO is only a small fraction. At tg = 30 min, the overgrowth on the mask region has been proceeded. After 60 min, we achieve coalesced flat (0001) surface. The corresponding PL spectra are displayed in Figure 2. The GaN template layers as well as the coalesced flat (0001) surface exhibit a strong X_B free exciton peak at 354.7 nm. Obviously, we have additional peaks in the spectra for uncoalesced samples with laterally overgrown region. The band peaking at 377 nm followed by LO phonon replicas are attributed to the donor acceptor pair (DAP) emission. The intensity of this band increases as the extension of the overgrown region. Another strong emission (N) band observed in the uncoalesced samples is at around 20 meV below the X_B peak. This band has not been recognized in ELO GaN so far. Judging from the difference energy this is attributed to I_B or A^0X bound exciton. Exact origin of this band is not known, but the presence of this band suggests that the sample has shallow levels which might be the origin of the high carrier density[3]. It is notable that the intensity of this band is in accordance with that of DAP band, and the high carrier density is also achieved in the overgrown region. In Fig.3 the high resolution PL spectrum at 5 K is displayed, which shows that this band consists of two distinct peaks. The assignment of the peaks needs further investigation. Since we can find neither the DAP band nor the bound excitonic band for samples with flat (0001) surface, the incorporation of impurities is strongly related to the facet growth.

The DAP band has been found in various p-type GaN doped with Zn, Mg, Cd, as well as in a nominally undoped GaN, the origin of which is controversial [5]. Khan et al, on the other hand, found out strong correlation of the intensity to the concentration of Si [6].

If this is the case, we may conclude that Si is un-intentionally doped to the overgrown region in the present case. The sauce is probably the SiO_2 mask. We found another peak labeled O in Fig.2, which is attributed to the oxygen related emission [7]. It is notable that the intensity is insensitive to the growth time. These results show that Si is incorporated more in the facet growth mode than the growth along <0001> direction, while oxygen doping is insensitive to the growth direction.

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Fig.1

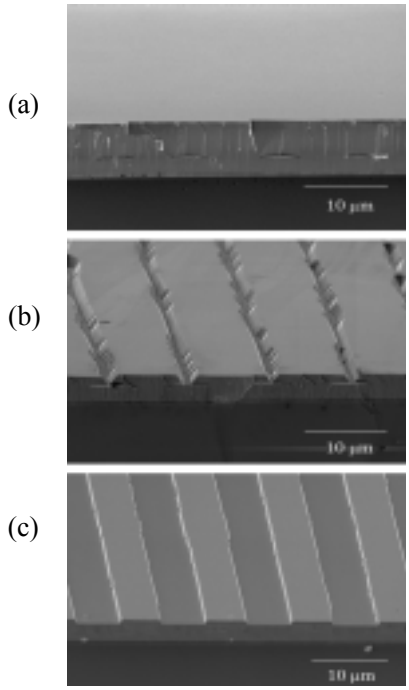

Fig. 1. SEM image of SAG-GaN grown on a GaN templated sapphire. The thickness of the GaN template layer is 2.2μm. (a) tg = 5 min, (b) tg = 30 min, (c) tg = 120 min.

Fig.2

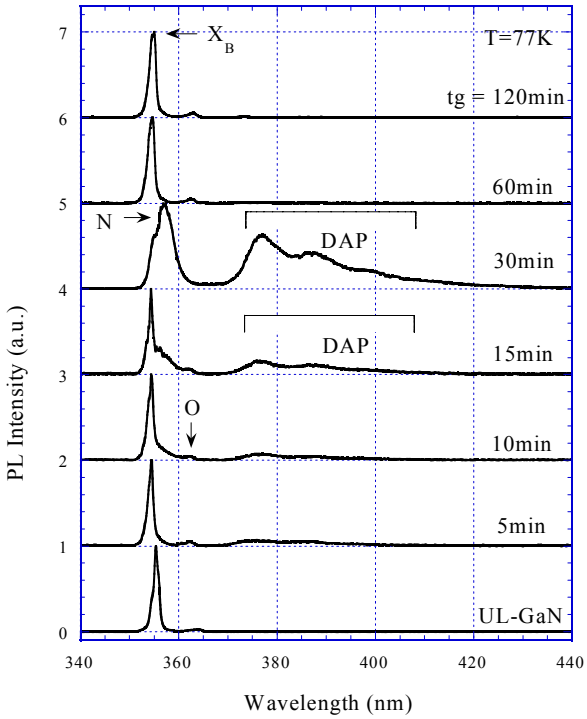

Fig. 2. PL spectra for SAG-GaN grown for several growth times.

Fig. 3

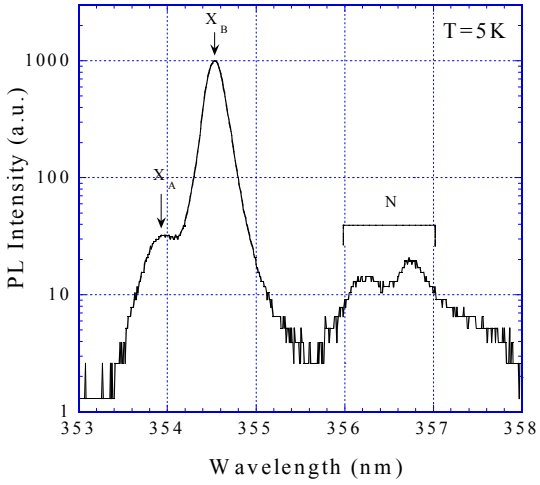

Fig. 3. PL spectrum at 5 K for SAG-ELO GaN for 3 μm windows.