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Effect of Growth Parameter on InAlN Films Grown By MOCVD For HEMT Application

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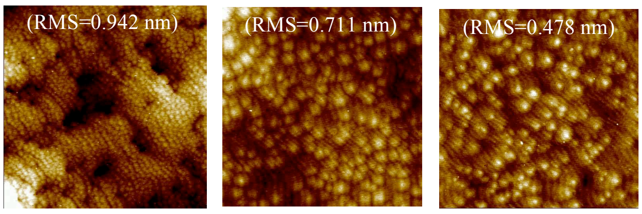
Recently, InAlN/GaN high electron mobility transistor (HEMT) attracts a lot of attentions due to the lattice match of InAlN (In=18%) with GaN and the much larger spontaneous polarization of InAlN as compare to the conventional AlGaN/GaN HEMT. InAlN provided the larger carrier density and better electron confinement in two- dimensional electron gas (2DEG) for the high electron mobility transistor (HEMT). However, it was very difficult to grow high quality InAlN since there were many variables in the growth condition.

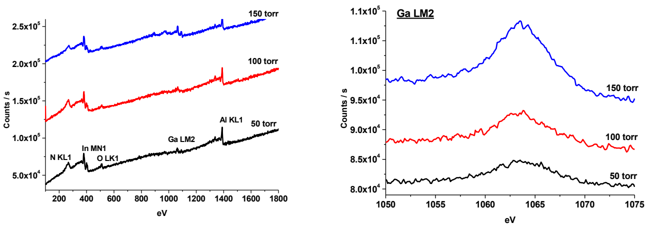
In this study, the influence of growth parameter on $In_{0.18}Al_{0.82}N$ film was investigated. All $In_{0.18}Al_{0.82}N$ layers were deposited on GaN templates, which prepared using identical growth condition. The template consisted of a 30-nm nucleation layer and a 2-μm thick GaN layer. During the InAlN layer deposition, different chamber pressures (50 to 150 torr) were used. In order to keep the In composition at 18%, the growth temperatures were changed accordingly. The In composition was determined by high-resolution x-ray diffraction (HRXRD).

Fig. 1 shows the AFM images (5 x 5μm^2) of $In_{0.18}Al_{0.82}N$ prepared with three different growth pressures (sample A:50 torr, sample B:100 torr, sample C:150 torr). The growth temperatures of these samples were 730, 745 and 775°C, respectively. The AFM results reveal that smoothed surface morphology was achieved for sample grown at higher pressure and higher temperature. This is due to the enhanced lateral mobility of MO species at higher growth temperature. However, the Auger analysis shows that large amount of Ga atoms was found on the InAlN surface. Furthermore the surface Ga composition increased with the increase of growth temperature and growth pressure. This may due to the out-diffusion of Ga from the GaN template. Another sample (100 torr, 745°C), with a thin AlN spacer layer (~1.5 nm) inserted between the InAlN/GaN interface, was also prepared. TEM results on samples prepared without and with AlN spacer are shown in Fig. 3(a) and Fig. 4(a), respectively. As seen in Fig. 4(a), the thin AlN spacer improves InAlN/GaN interface sharpness significantly. The EDS line scans (Fig. 3(b) and Fig. 4(b)) suggest that the interface improvement is due to reduction of Ga out-diffusion. The electrical properties of samples prepared with and without AlN spacer layer were checked using Hall effect measurement. Table 1 summaries the Hall measurement results of these sample. As a result of interface improvement, the electron mobility in the 2DEG channel is improved dramatically on the sample with a thin AlN spacer.



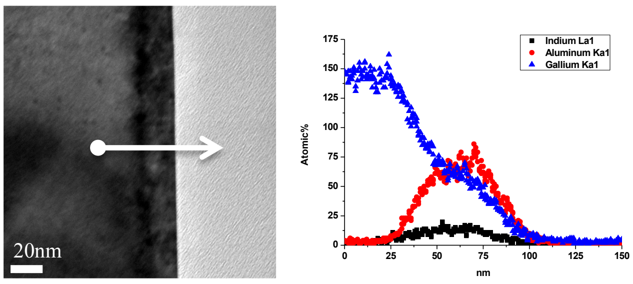
(a) Sample A (b) Sample B (c) Sample C

Fig. 1 AFM images of $In_{0.18}Al_{0.82}N$ for sample grown at (a)50 torr, 730°C (b) 100torr, 745°C and (c)150torr, 775°C



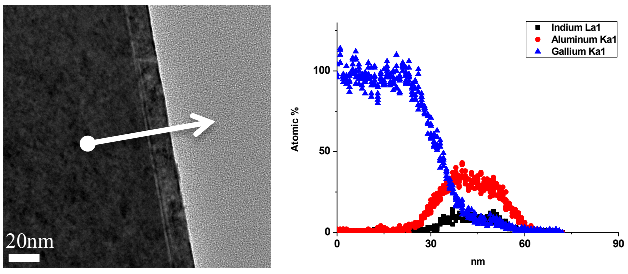
(a) (b)

Fig. 2 Auger analysis on $In_{0.18}Al_{0.82}N$ samples prepare with different growth pressures: (a) Whole spectrum and (b) Ga LM2 signal.



(a) (b)

Fig. 3 (a) TEM image of sample prepared without AlN spacer. White line indicates the EDS line scan direction (b) EDS line scan profile.



(a) (b)

Fig. 4 (a) TEM image of sample prepared with AlN spacer. White line indicates the EDS line scan direction (b) EDS line scan profile.

Table1. Hall measurement results of InAlN HEMT with and without thin AlN spacer layer.

AlN Spacer	Rs(Ω/□)	μ (cm^2/V.s)	Ns (cm^{-2})
Yes	521	888	1.34E13
No	8029	43.3	1.79E13