Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.686-687

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Improvement of Linearity in Novel InGaAsN-based HEMTs

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1. Introduction

Recently, the high electron mobility transistors (HEMTs) have performed exceedingly well in high speed microwave and digital circuit applications. In order to improve electrical performance, InGaAs channel layer which has been widely used has better carrier confinement due to lager conduction band discontinuity at the interface AlGaAs/InGaAs[1]. However, the lattice mismatch between GaAs and InGaAs material limits Indium incorporation and the thickness in InGaAs layer. Once the InGaAs layer thickness exceeds the critical thickness, the dislocations will induce defects and degrade device performance. Moreover, AlGaAs/InGaAs/GaAs HEMTs have narrower constant transconductions region and lower gate voltage swing (GVS), which may limit the transistor to be used in the applications of digital circuit.

In this letter, excellent performance in extremely large GVS and great linearity of InGaAsN HEMTs are first demonstrated by introducing nitrogen into InGaAs channel layer of HEMTs due to larger conduction band discontinuity and less dislocation[2,3]. In order to improve the poor AlGaAs/InGaAsN interface quality due to the nitrogen-induced defects in InGaAsN channel layer, a very thin GaAs intermediate layer is sandwiched between AlGaAs and InGaAsN layer and rapid thermal annealing (RTA) treatment has been also applied.

2. Experimental

The samples used for this study were grown by metal-organic vapor-phase epitaxy (MOVPE) using dimethylhydrazine (DMHy) as nitrogen source. The carrier gas was H_2. Source materials were trimethylgallium (TMG), trimethylindium (TMI) and AsH_3. The compositions of indium (In) and nitrogen (N) were determined by high-resolution XRC (X-ray rocking curve) and theoretical dynamic simulations. High-resolution XRC measurement was performed using a Bede D1 X-ray diffractometer to determine Al, In and N composition. Fig. 1 illustrates the device structure of InGaAsN HEMT. InGaAsN channel layer with high electron confinement was lattice-matched grown on GaAs substrate. Prior to the AlGaAs layer, the GaAs intermediate layer was grown and n-type heavily doped GaAs was capped on the top.

3. Results and discussion

In inset of Fig. 2, with the increasing RTA temperature, the carrier concentration increases obviously. It drops at 700℃ due to the exceeded annealing temperature and thus results in the quenched crystal quality. In general, H is incorporated alongside N into InGaAs while growing InGaAsN layer. Due to H passivation, some carriers are restricted in material. RTA treatment reduces the H concentration in material, increases the carrier concentration. Furthermore, Fig 2 shows the double-crystal X-ray rocking curve for the InGaAsN HEMTs with and 600℃ RTA. After RTA treatment, the full-width at half-maximum (FWHM) of X-ray rocking curve at 600℃ becomes narrower than that of as-grown sample indicating that thermal treatment also improves the crystal quality. Fig. 3 depicts the three-terminal current voltage characteristics on InGaAsN HEMT as grown and after RTA treatment at 600C. The saturation current density, 370 mA/mm, for the device after RTA treatment is larger than that for the device as grown, 320 mA/mm. This is because there is higher product of carrier concentration and mobility after RTA. The gm characteristics are shown in Fig. 4. The device after thermal treatment shows better device performance; broader GVS and higher maximum gm.

4. Conclusion

Compare to traditional AlGaAs/InGaAs HEMTs with narrow GVS characteristic, extremely large GVS performance of novel InGaAsN-based HEMTs have been first demonstrated. C-V profile and gm characteristic show that the crystal quality and device performance can be improved by applying RTA treatment..

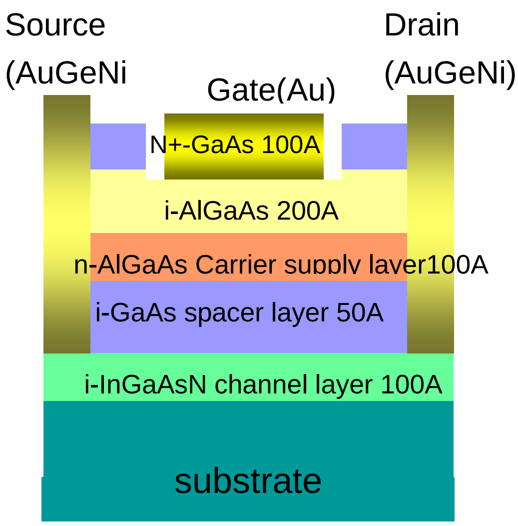

Fig. 1 The structure of InGaAsN HEMT.

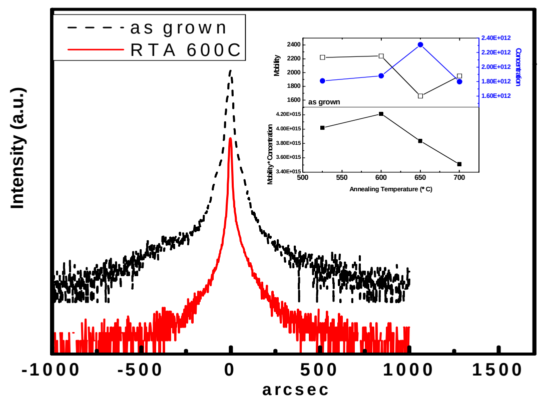

Fig. 2. Analysis of XRD and Hall measurement

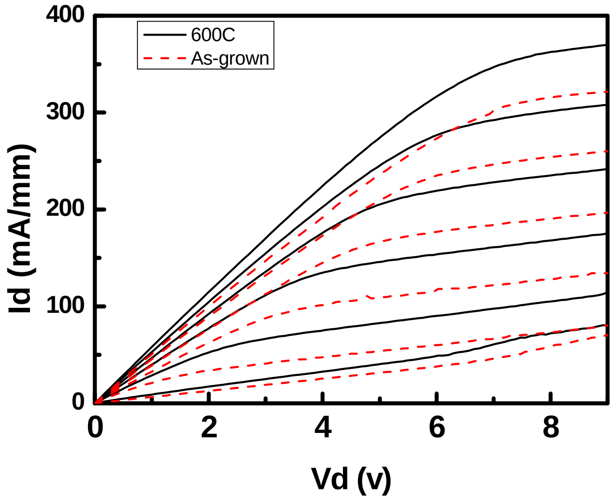

Fig. 3 The three-terminal current voltage characteristics on InGaAsN HEMT with and without RTA treatment at

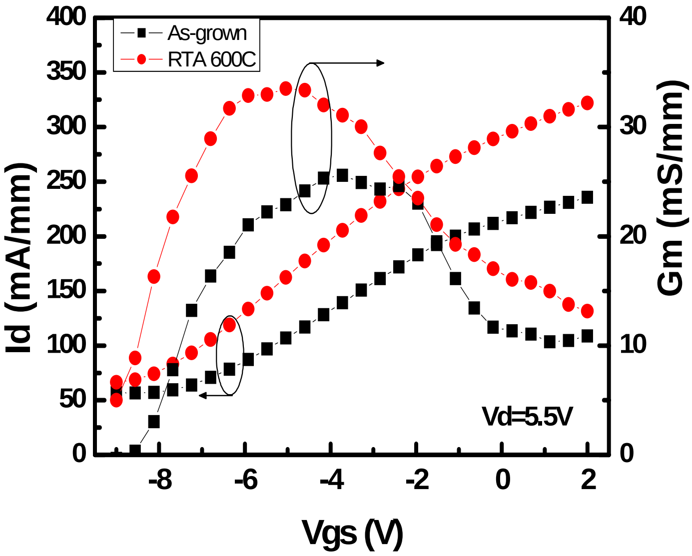

Fig. 4 Gm characteristics of InGaAsN HEMTs with and without RTA treatment

Reference

[1] YUJI ANDO and TOMOHIRO, IEEE Trans. Electron Devices, VOL 35, No. 12, DECEMBER 1988

[2]S. R. Kurtz, A. A. Allerman, E. D. Jones, J. M. Gee, J. J. Banas, and B. E. Hammons, Appl. Phys. Lett. **74**, 729 (1999)

[3]J. F. Geisz, D. J. Friedman, J. M. Olson, Sarah R. Kurtz, and B. M. Keyes, J. Cryst. Growth **195**, 401 (1998)