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High-Quality Two-Dimensional Electron Gas at Large Scale GaN/AlGaN Wafer Interface Prepared by Mass Production MOCVD Systems

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1. Introduction

GaN-related materials are believed to be very much promising in blue LED/LD applications as well as in future high power electronic devices production. The development of the latter remains, however, at a rather primitive stage at present due to the difficulties of conducting large-scale epitaxial growth of GaN on sapphire or SiC substrates. In order to make large scale (~ 4-inch) GaN template wafers with sufficient quality in mass production style, we recently developed novel MOCVD system which adopted multiple substrate facedown, lamp heating and simultaneous rotation and revolution of the substrates. In this work, we report the results of Hall and magnetoresistance (MR) measurements carried out to estimate the surface (of GaN) or interface between GaN and AlGaN grown by the technique. Since high density two-dimensional electron gas is known to be accumulated at the interface, those electronic properties could reflect the quality of the interface.

2. Sample and Measurements

Layered structure of the sample is very simple. It is composed of >1.2 μm GaN grown on sapphire substrates and ~100 nm $Al_{0.2}Ga_{0.8}N$ layer is deposited further. Electric measurements are done in a van der Pauw sample with 5mm square cut from the 4 inch wafer. The MR measurement is carried out by using He cryostat at 1.5 K with 8 Tesla super-conducting magnet. Table 1 lists room-temperature sheet electron density and electron mobility estimated from Hall measurements for 5 samples investigated. Figure 1 shows results of temperature–dependent Hall measurements of the two samples with lower sheet electron densities (n_s~$9x10^{12}/cm^2$). Both samples exhibit two-dimensional nature that mobility μ, increases as temperature decreases with almost constant sheet electron density, n_s. The mobilities attained at the lowest temperature, ~5 K, are as high as 9,000 and 4,000 cm^2/Vsec for samples C and E, respectively. Especially the former is probably a highest value ever obtained in large scale GaN/AlGaN wafers grown by MOCVD. Another interesting feature observed in Fig. 1 is a mobility "kink" at ~250 K which appears commonly in all samples measured. The reason is an open question at present.

Figure 2 shows Shubnikov de-Haas (SdH) oscillation in sample C and the FFT result. As is seen in Fig. 2(a), the clear oscillation was observed from ~4 (T) and it includes both a rapid and slow components indicating the electron occupation of the ground and first-excited subbands [1]. Peaks indicated by thin and solid arrows correspond to those subbands and the peak fields give the total and threshold (to occupy the first excited subband) sheet electron densities to be ~$1x10^{13}$ and ~$8x10^{12}/cm^2$,

Table 1. Sheet electron density and mobility of the measured samples at room temperature

Sample	A	B	C	D	E
$n_s(x10^{12}/cm^2)$	12.5	11.3	8.6	10.7	9.3
μ (cm^2/Vsec)	1,270	1,080	1,620	1210	1380

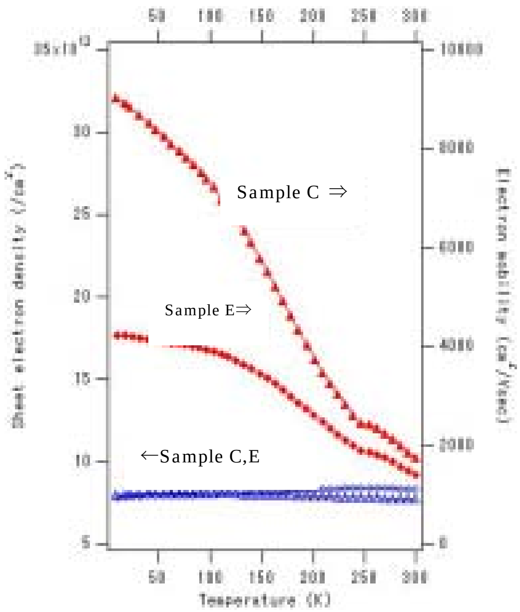
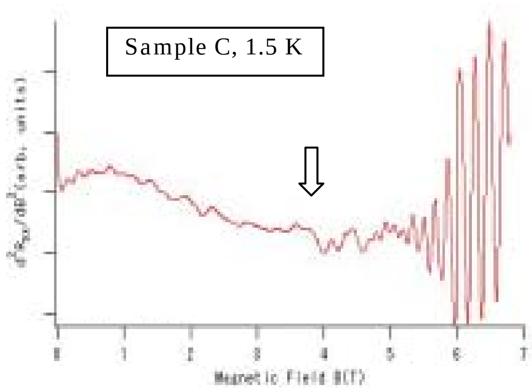
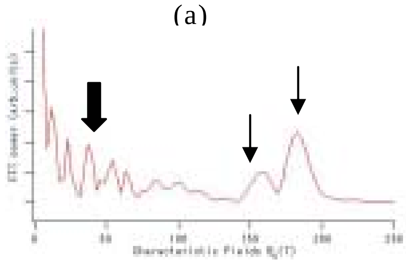


Fig.1 Results of temperature dependent Hall measurement for the two samples with low sheet electron densities

respectively. The latter value is almost equal to that found in Ref. [1]. But, as indicated by thin arrows, there could be a splitting for the peak of the ground subband. Similar result has been reported by Tsubaki et al [2] recently, but the reason is not clear at present. One possible origin is a spin-related one. In other words, the spin degeneracy was lifted by some reasons, i.e., spin-orbit interaction etc. In fact, if we suppose the spin degeneracy is not lifting in this sample, the n_s value estimated from the SdH oscillation does not agree with that from Hall measurement. This problem could be a new and interesting topic in this materials system.



(a)



(b)

Fig.2(a)SdH oscillations (first derivative) of Sample A and (b) corresponding FFT result.

3. Conclusions

We have prepared 4-inch GaN/AlGaN wafer by a new type MOCVD system and estimated the interface qualities by measuring the transport properties of the 2DEG confined at the interface. Electron Hall mobilities increased with decreasing temperature and reached to as high as 9,000 cm^2/Vsec at 5 K (n_s = $9x10^{12}/cm^2$). Moreover, we observed clear SdH oscillations which suggest two subband occupation and possible spin-related subband splitting.

Those electronic estimations suggest excellent in-plane uniformity and high qualitiness (low dislocation density) of the surface of GaN and/or the interface of GaN/AlGaN of those 4-inch wafers prepared by mass production novel MOCVD method.

References

[1] Z. W. Zheng et al., Phys. Rev B62, R7739 (2000)
[2] K. Tsubaki et al., Physica E 13 1111 (2002).