Fabrication of a heterostructure field-effect transistor using AlGaN/GaN

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Wide band-gap semiconductors, such III-V nitrides, are very important for electronic devices that can operate under high-temperature, high-power, and high-frequency conditions. That is, GaN and related materials have large figure of merits for these purposes compared with conventional Si or GaAs devices, since these materials have a wide band gap, a high breakdown electric field, and a high saturation velocity[1]. High-temperature devices and high-frequency devices using GaN and related materials have recently been reported. We have also demonstrated a GaN metal-semiconductor field-effect transistor (MESFET) and a bipolar junction transistor (BJT) which can be operated at 673K and 573K, respectively[2]. The high-temperature reliability of these GaN electronics was also confirmed. We could obtain high-quality GaN using gas-source molecular beam epitaxy (GSMBE)[2]. However, we have not yet reported an AlGaN/GaN heterostructure using GSMBE.

In this paper, we report on the fabrication of an AlGaN/GaN heterostructure FET grown by GSMBE[3]. In our growth system, GaN and related materials were grown using ammonia gas. A GaN buffer layer was grown using DMHy at substrate temperatures of 973K, since DMHy was easily decomposed at lower temperatures (below 873K) compared to ammonia. The Ga beam-equivalent pressure (BEP) was $5x10^{-7}$Torr and the BEP of DMHy was $4x10^{-5}$Torr. A thick film of GaN was grown using Ga ($6x10^{-7}$Torr) and ammonia gas ($5x10^{-6}$Torr) on the GaN buffer layer at 1123K. An $Al_{0.2}Ga_{0.8}N$/GaN heterostructure was also grown using ammonia gas at 1123K. The thickness of undoped $Al_{0.2}Ga_{0.8}N$ was 30nm and that of undoped GaN was 2000nm. We measured the hole mobility using the Van der Pauw method. The mobility was about 1160cm$^2$/Vs at room temperature; this value was relatively higher compared with a previously reported value using GSMBE. Furthermore, a C-V (Capacitance-Voltage) measurement was carried out to investigate the concentration of two dimensional electron gases (2DEG). Figure 1 show the C-V profile of an $Al_{0.2}Ga_{0.8}N$/GaN heterostructure. A very high carrier concentration due to 2DEG was obtained. That is, the carrier concentration was over $5x10^{19}cm^{-3}$ at the interface of AlGaN/GaN. In order to form an electrode on the AlGaN surface, we measured the sheet resistivity of an $Al_{0.2}Ga_{0.8}N$/GaN heterostructure, giving about 370ohm/cm$^2$. This value was comparatively lower and corresponded to that of a GaN surface with a high carrier concentration above $5x10^{18}cm^{-3}$. In the case of an $Al_{0.2}Ga_{0.8}N$/GaN heterostructure, it was found that the sheet resistivity of the surface was inclined to reduce without the surface contact layer with the high carrier concentration.

We next fabricated an FET using an AlGaN/GaN heterostructure. A dry etching technique using an electron cyclotron resonance (ECR) plasma was used for device fabrication[4]. The etching gas was a mixture of $CH_4$ (5sccm), Ar (7sccm), and $H_2$ (15sccm). The Al/Ti/Au was used for the source and drain electrodes. Pt/Au was also used for the Schottky gate. The gate length was 2000nm and the gate width was 0.1mm. Figure 2 shows the current-voltage (I-V) property of the gate and source. The breakdown voltage was over 50V. Figure 3 shows the I-V property of a HFET. The maximum transeconductance ($g_m$) of the HFET was about 140mS/mm, and the breakdown voltage was also over 50V. This HFET was operated at a high temperature above 573K. It was therefore confirmed that the undoped $Al_{0.2}Ga_{0.8}N$/GaN heterostructure had a high electron mobility and that the HFET was operated at high temperature.

References

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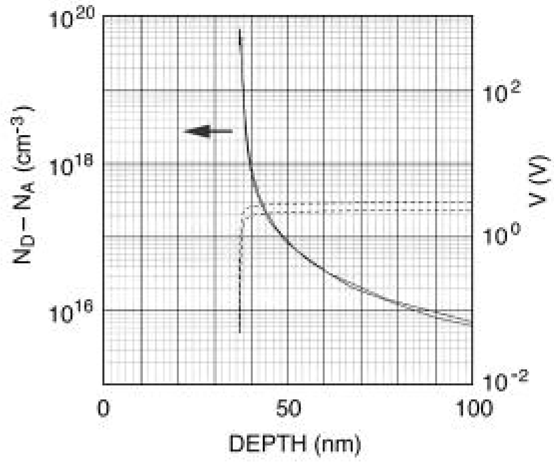


Figure 1 C-V profile of AlGaN/GaN heterostructure.

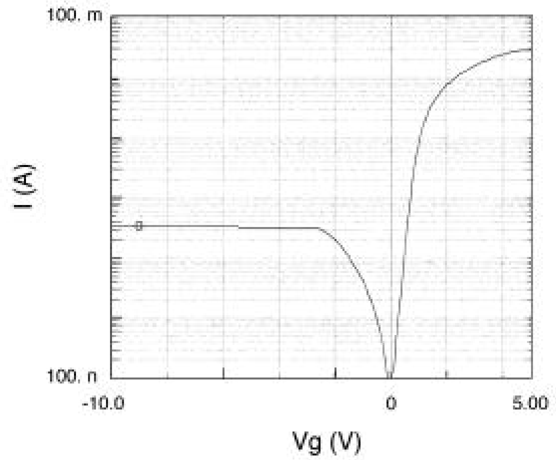


Figure 2 I-V property between the source and gate of AlGaN/GaN HFET.

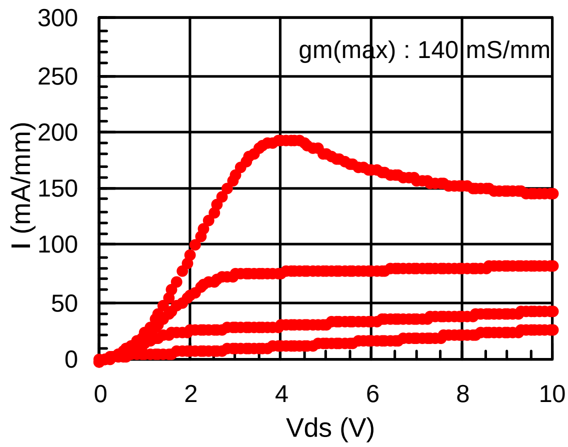


Figure 3 I-V property of AlGaN/GaN HFET