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Highly uniform sheet resistance of the double-channel AlInN/GaN heterostructure

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ABSTRACT

A high uniformity of sheet resistance was achieved in the double-channel (DC) $Al_{0.82}In_{0.18}N$/GaN heterostructure by lowering the interface roughness scattering effect. The variation of the AlInN/GaN interface roughness as a key factor influenced the uniformity of the sheet resistance. In the DC heterostructure, the distribution of the two dimension electron gas (2DEG) was modified to reduce interface roughness scattering effect. As a result, the uniformity of the sheet resistance was enhanced, and the nonuniformity of the sheet resistance in the DC $Al_{0.82}In_{0.18}N$/GaN could be reduced to 0.7% after structure optimization.

1. Introduction

GaN-based high electron mobility transistors (HEMTs) have attracted great interest due to their important applications in high power and high frequency electronic devices [1]. Among the nitride materials, the AlInN system is the most promising option to improve the HEMT performance especially for the $Al_{0.82}In_{0.18}N$ which is lattice-matched (LM) to GaN [2]. The LM AlInN/GaN HEMT demonstrates an outstanding reliability in harsh environments, due to absence of mechanical stress. Although only exiting spontaneous polarization between the $Al_{0.82}In_{0.18}N$ and the GaN, the LM AlInN/GaN HEMT still has a high sheet electron density. Furthermore, AlInN/GaN HEMTs contribute to improve the device performance by reducing the sheet resistance, which is as an important factor to limit the high frequency performance of HEMTs [3]. Many studies have been performed to reduce the sheet resistance. For example, one AlGaN layer was inserted between AlInN and AlN in order to improve the

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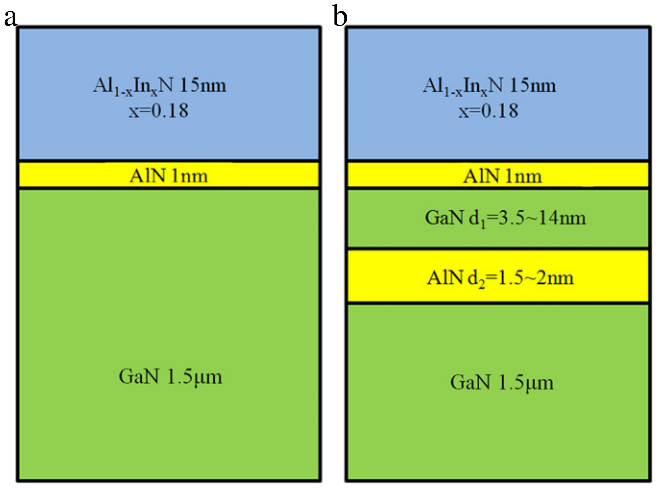

Fig. 1. Structure of the samples. (a) SC AlInN/GaN for sample A, (b) DC AlInN/GaN for sample B (d_1 = 3.5 nm, d_2 = 2 nm), sample C (d_1 = 14 nm, d_2 = 2 nm) and sample D (d_1 = 7 nm, d_2 = 1.5 nm).

surface morphology of the AlInN/AlN/GaN HEMT structure [4]. Recently, we have reported a double-channel (DC) AlInN/GaN heterostructure with high electron mobility and low sheet resistance [5]. In this structure, the 2DEG in AlInN/GaN DC heterostructure was divided into two channels by an AlN/GaN/AlN interlayer, and then the sheet electron density in each channel was decreased. Following the lowering of the sheet electron density in both the channels, the electron mobility was enhanced, and the sheet resistance was reduced. This work reported another advantage for the DC AlInN/GaN heterostructure, high uniformity of the sheet resistance. Further, the reasons for improving the uniformity were investigated in detail.

2. Experimental

In this study, one single-channel (SC) heterostructure sample and three DC heterostructure samples with different values of d_1 (the distance between the dual channel) and d_2 (the thickness of the bottom AlN insert layer) were prepared as shown in Fig. 1. All the heterostructures were grown on 2 in. sapphire substrates by metal organic chemical vapor deposition (MOCVD). The growth was initiated with a 20 nm GaN buffer layer grown at 550 °C, and then a 1.5 μm high-resistance GaN buffer was deposited at 1050 °C. For a conventional LM AlInN/AlN/GaN SC heterostructure, an AlN and $Al_{0.82}In_{0.18}N$ layer was directly deposited following the GaN buffer layer. Their corresponding thickness is 1 nm and 15 nm, respectively. But for the DC AlInN/GaN heterostructure, AlN, GaN, AlN and $Al_{0.82}In_{0.18}N$ layers were deposited following the GaN buffer layer in sequence. The corresponding thickness is 1.5–2 nm, 3.5–14 nm, 1 nm and 15 nm, respectively. The morphologies of the AlInN films were studied by atomic force microscopy (AFM). The sheet resistance of the 2DEG was analyzed using the eddy current technique. The electron mobility and sheet density of the 2DEG were characterized by the van der Pauw Hall method. All the measurements were carried out at room temperature.

3. Results and discussion

Fig. 2 shows the sheet resistance maps of the samples, plotted at the same contour interval of 2 Ω. It is obviously noted that the contour line density of sample A is high, and the highest sheet resistance value of 312 Ω/squre is obtained at the center. Additionally, the average sheet resistance for the A sample is 294.4 Ω/squre with a standard deviation of 3.5%. However, the maps from the samples with