AlGaN Based High Electron Mobility Transistors

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High electron mobility AlGaN/GaN have been successfully grown on low cost and high challenges AlN/Si substrates. By inserting a thin SiN layer between GaN and AlN to improve the quality of GaN, the result showed that the thin SiN layer could greatly increase the mobility of the two-dimensional electron gas formed at the interface of AlGaN and GaN layers. This suggests that it is possible to grow high-quality GaN on silicon as well as on sapphire for many applications

Keywords: AlGaN/GaN, HEMTs, MOCVD.

1. Introduction

GaN and AlN, and its alloys (AlGaN) heterostructures is a very interesting materials because of their applications in high-power, high-frequency field effect transistors, light-emitting diodes, and high electron mobility transistors (HEMTs) [1-8] than other materials, such as GaAs or GaP [9-11]. To improve the performances of these devices, the electronic properties of the two-dimensional electron gas (2DEG) formed in the AlGaN/GaN quantum well is the most important factor. The formation of the 2DEG are resulted by the polarization of AlGaN and GaN even there is no doping in them but there are spontaneous polarization and piezoelectric polarization in both AlGaN and GaN [12]. The spontaneous polarization is due to the non-coincidence of the centers of cations and anions when they are at their lowest energy positions. Where the piezoelectric polarization is due to lattice mismatch strain and thermal strain caused by thermal expansion-coefficient differences between the AlGaN and GaN layers. When these two materials combine together, there are sheet charges formed at the interface of them. And if the sheet charges are positive, free electrons will compensate them during the cooling process after growth. That is why the 2DEG formed at the interface of AlGaN and GaN can be observed.

Due to the large lattice mismatch, AlGaN/GaN based HEMTs were commonly grown on sapphire substrates. However, Si is a promising substrate for nitride-based devices owing to its low cost and large wafer size [13,14]. Where, AlN layer is commonly used as an intermediate and nucleation layer which can be used to enhance the quality of GaN films greatly. In this paper, we report on the growth and investigations of AlGaN/GaN based HEMTs on a Si substrate using AlN and SiN as intermediate layers by using metal organic chemical vapor deposition (MOCVD) as show in the figure 1. The details of effect of SiN on the 2DEG will be reported below.

2. Experiment

Figure 1 shows the schematic diagram of the three different samples grown for this study. They were all grown by MOCVD on 3-inch Si substrates. Because of the large lattice mismatch and thermal mismatch between Si and GaN, a thin AlN layer was grown as an intermediate layer between Si and GaN in order to reduce the defects due to such mismatch [15-18] before further layer can be grown. After the first AlN layer growth, a thin SiN layer was introduced using silance (SiH_4) flow of 65 sccm diluted to 200 ppm with hydrogen (H_2). The growth pressure is kept at a

pressure of 100 Torr and a temperature of 1040°C. In order to determine the effect of SiN layer on the electrical properties of the HEMT structures, we have fabricated into three devices. Ti/Au/Ni/Au were used as 4-point metal contacts on the surface by evaporating and annealing 500°C in 10 min.

AlGaIn ~ 25nm
GaN ~ 500nm
AlN ~ 20nm
u-GaN ~ 200nm
SiN ~ 0; 3; 8nm
AlN ~45nm
Si Substrate

Fig. 1. The schematic diagram of 3 samples with various thicknesses of SiN: 0; 3; 8 nm.

3. Results and discussion

Fig. 2 shows the measurement of carrier concentration versus the temperature of three samples with different SiN thicknesses. We can see that the carrier concentrations show a slight variation over a wide range of temperature from 0 to 255K. it means that this result demonstrates the formation of a 2DEG in the system at the room temperature.

Fig. 2. Shows the carrier concentration versus temperature.

For further understanding of the transport properties of these samples, we have done a simple setting up for measuring the mobilities of these samples. This is one of the most important values which could directly reflect the sample quality. As show in figure 3, the measured mobilities as a function of temperature. We can easily see that the mobility decreases with increasing temperature from the whole measurement ranging. Thus, this result is totally agreed with the fact that the scattering of electron and phonon increases with increasing of temperature. Especially, from this result we can find out that sample quality is significantly improved after SiN thin film was grown. The mobility of 3 and 8 sec at around 10K is more than 3 times higher than that without a SiN thin film inserted into the structure. In addition, we could confirm that the insertion of the SiN layer leads to an increase of the electron concentration in the HEMT structure.

Fig. 3. Shows the function of mobility versus temperature, where we see the effect of SiN on the mobility.

4. Conclusions

We have successfully grown and measured the AlGaIn/GaN heterostructures on silicon substrates from 0 to 255K. The results show a very slight variation of the carrier concentrations. It confirmed that a 2DEG has been formed in the system at room temperature. Moreover, the mobility was significantly improved with 5 or 10 sec growth of SiN into the structure as compared to the one without SiN. This is really a good technique which can be easily used to improve the performance of HEMTs devices on such low-cost silicon substrates.

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