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High-temperature characteristics of strain in $Al_xGa_{1-x}N/GaN$ heterostructures

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1. Introduction

$Al_xGa_{1-x}N/GaN$ heterostructures have recently attracted intense attention due to their potential for high-electron-mobility transistors suitable for high-voltage, high-power, and high-temperature microwave applications. The high-temperature application is a prominent advantage of $Al_xGa_{1-x}N$ /GaN based devices over $Al_xGa_{1-x}As/GaAs$ ones. It is well known that the strain in the AlGaN barrier layer has an important effect on the formation and transport properties of two-dimensional gas (2DEG) in $Al_xGa_{1-x}N$ /GaN heterostructures. Therefore, the understanding of the high temperature behaviors of strain is one of the key points to understand the high temperature transport properties of 2DEG in $Al_xGa_{1-x}N$ /GaN heterostructures.

In this work, the high-temperature characteristics of strain in a fully strained and a partially strain-relaxed $Al_{0.2}Ga_{0.8}N/GaN$ heterostructures were investigated in the range from room temperature to 800K by means of high resolution X-ray diffraction technique.

2. General instructions

$Al_{0.22}Ga_{0.78}N/GaN$ heterostructure was grown on sapphire substrates by atmospheric pressure metalorganic chemical vapor deposition (MOCVD). Trimethylgallium (TMGa), trimethylaluminum (TMA), and ammonia were the precursors. Following a thin GaN buffer layer grown at 488 ℃, a 2.0-μm-thick unintentionally doped GaN (*i*-GaN) layer was grown at 1071℃. Then, an $Al_{0.22}Ga_{0.78}N$ layer was grown at 1080℃. The thickness of AlGaN layer is 50nm and 100 nm for a fully strained and a partially strain-relaxed $Al_{0.2}Ga_{0.8}N/GaN$ heterostructures, respectively. High resolution X-ray diffraction with a heating stage was exploited to extract lattice parameter c at different temperatures.

Fig.1 shows the temperature dependence of AlGaN lattice parameter c from room temperature to 800K. Fig.2 shows the out-of-plane strain in AlGaN layer after deducting the thermal expansion along the lattice c axes direction at different temperatures. Fig.3 shows the temperature dependence of the in-plane strain in AlGaN layer after deducting the effect of thermal mismatch between GaN and AlGaN layers. It can be seen that the in-plane strain induced by lattice mismatch in AlGaN layer decreases with increasing temperature from room temperature to 680K and then reaches a stable value at temperatures higher than 680K for the partially strain-relaxed $Al_{0.2}Ga_{0.8}N/GaN$ sample. Meanwhile, the strain is almost no change between room temperature and 470K, and then decreases with increasing temperature to 770K, and finally, it reaches a stable value at temperatures higher than 770K for the fully strained $Al_{0.2}Ga_{0.8}N/GaN$ sample. The results indicate that there exists an initial energy barrier to the relaxation of strain for the fully strained $Al_{0.22}Ga_{0.78}N/GaN$ heterostructure. It is interesting to find that the maximum relaxation of the strain in $Al_{0.22}Ga_{0.78}N$ barrier is less than 5% for both fully strained and partially relaxed samples at whole temperature range in our measurement. In addition, the effect of strain relaxation in the high temperature region on the 2DEG concentration of $Al_{0.2}Ga_{0.8}N$/GaN heterostructures is also calculated and discussed.

3. Conclusions

The high-temperature characteristics of strain in a fully strained and a partially strain-relaxed $Al_{0.2}Ga_{0.8}N$/GaN heterostructures were investigated in the range from room temperature to 800K. The results show that the temperature behavior of the in-plane strain in the fully strained AlGaN layer are different to that in the partially strain-relaxed AlGaN layer. There exists an initial energy barrier to the relaxation of strain for the fully strained $Al_{0.22}Ga_{0.78}N$/GaN heterostructure.

Acknowledgments

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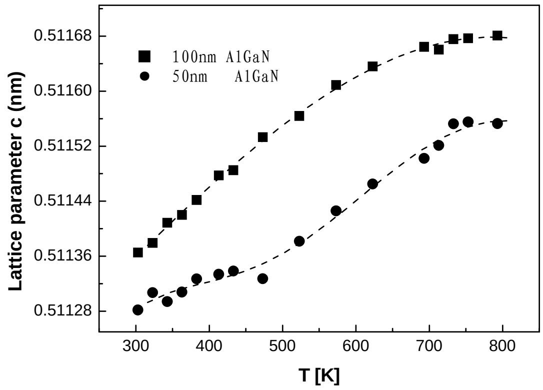

Fig.1 Temperature dependence of AlGaN lattice parameter c

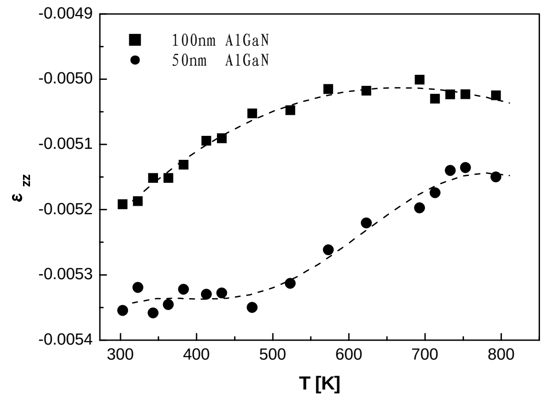

Fig.2 The out-of-plane strain in AlGaN layer after deducting the thermal expansion along the lattice c axes direction

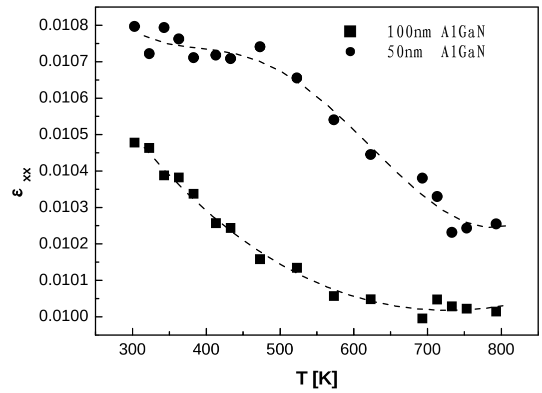

Fig.3 Temperature dependence of the in-plane strain in AlGaN layer after deducting the effect of thermal mismatch between GaN and AlGaN layers