NH_3-Plasma Treatment of GaAs Surface at High Temperature in RF Parallel Plate Plasma Reactor

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NH_3-plasma treatment has been used for passivation of native-oxide-contaminated GaAs surface. *Ex-situ* band-gap photoluminescence(PL) measurement shows enhanced intensity for the treated surfaces. Auger electron spectroscopy(AES) shows that the treated surface contains nitrogen atoms but no arsenic atoms, which leads us to speculate that the graded GaN thin layer was formed on the surface. Based on these results, new metal-insulator-GaAs structure is proposed.

I. INTRODUCTION

The poor electronic properties of the GaAs surface have stimulated many researchers to passivate the surface states and unpin the surface Fermi-level. The unpinning of the surface Fermi-level would allow advances in metal-insulator-semiconductor(MIS) capacitor and MIS field effect transistor(MISFET) technology of GaAs. However, controversy remains in their effectiveness of the surface Fermi-level unpinning.

H_2 and NH_3 plasma passivation techniques have been demonstrated to be effective in reducing the surface state density and to provide better control of the processing environment. Although a few case of the surface passivations persist for more than hours, most cases have been reported to be shorter lived. The origin of the deteriorated surface is oxygen incorporation by diffusion through the surface in the air. Therefore, passivation of GaAs surface should involve forming a diffusion barrier for oxygen as well.

In this work, we use the NH_3-plasma at high temperature(550°C) in order to passivate the surface states and form GaN thin layer as a diffusion block layer of oxygen simultaneously. Arsenics are outdiffused into vacuum at temperature higher than 500°C(Fig. 1). Nitrogens from the cracked NH_3-plasma are thought to be incorporated with As-outdiffused GaAs surface to form GaN. After formation of the nitride layer the insulator/GaAs interface in MIS sturcture is now replaced by insulator/GaN/GaAs interface, which results in low defect state density.

II. EXPERIMENTAL AND RESULTS

Samples are nominally undoped n-type ($\sim 10^{15}cm^{-3}$) GaAs thin films grown on the n-type($\sim 10^{18}cm^{-3}$) GaAs wafer by Metal Organic Chemical Vapor Deposition (MOCVD). The thickness of the undoped GaAs layer is 1 µm. These samples were inserted into the plasma reactor (Fig. 2) without any process treatments. NH_3 gas flow at 100 SCCM during the increasing/decreasing the substrate temperature in order to avoid formation of As vacancy and Ga droplet. The operating substrate temperature was 550°C for 5 min. and the net plasma power was 100Watt. The operating chamber pressure was kept at 850 mTorr.

Fig. 3 is a SEM picture of the plasma-treated surface morphology. PL was used to monitor the effectiveness of plasma passivation. The band-gap PL intensity increased by 7 ~ 8 times after the treatment(Fig. 4). Atomic depth profile of the nitride thin film on the treated surface was investigated by AES. The AES results in Fig. 5 show that nitrogen atoms incorporate on the GaAs surface and form the graded GaN thin layer. The thickness of the graded GaN thin film was measured to be ~450 A by using the profilometer(Alpha-step).

III. DISCUSSION AND CONCLUSION

Surface passivation is operationally defined in terms of the enhancement in quantum yield of PL. In this experiment, we attempted to remove all kinds of As atoms on the surface and to replace them with nitrogen atoms in order to reduce the surface states originated from elemental As, As_2O_3, and/or antisite defects. AES results show no As atoms on the surface.

In conclusion, we have shown that the formation of GaN layer is effective in reducing the surface states, although it seems that small Ga droplets were formed and oxygen atoms were incorporated on the treated surface.

[1] J.J. Lee privite communication

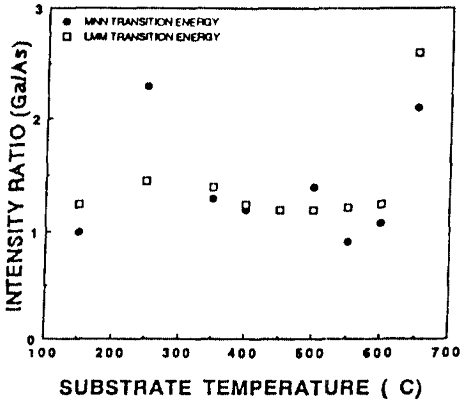

Figure 1. Temperature dependence of relative atomic concentration of GaAs surface from AES[1]

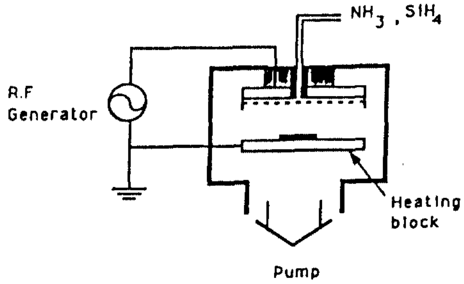

Figure 2. Schematic diagram of the plasma reactor

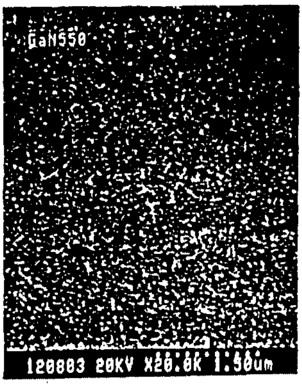

Figure 3. SEM of the plamsa treated surface

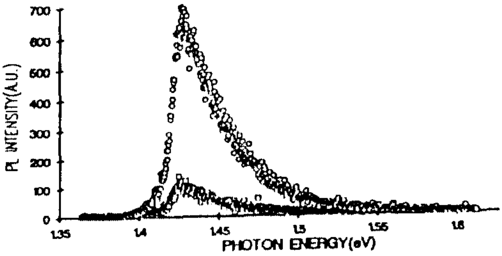

Figure 4. PL intensity spectra (□;for the untreated surface, o ; for the treated surface)

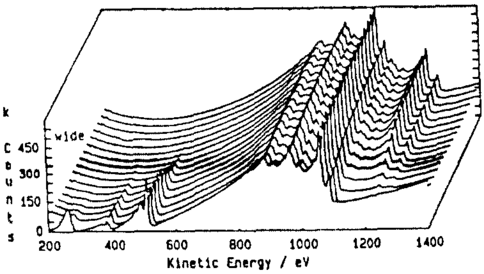

Figure 5. AES depth profile of the treated surface