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A Depletion-Mode $In_{0.53}Ga_{0.47}As$ MOSFET with a Liquid Phase Oxidized Gate

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1. Introduction

There have been efforts to fabricate MISFETs on compound semiconductors in order to take advantages of the MIS gate including a larger gate breakdown voltage and a lower gate leakage current compared with those of the Schottky gate used for MESFETs. Various techniques were studied to form stable insulating films having a low interface trap density on compound semiconductors. Among those techniques, thermal evaporation of $Ga_2O_3(Gd_2O_3)$ on GaAs after the desorption of native oxides in an MBE chamber was successful in producing a high-quality oxide having an extremely low interface trap density, which was used for demonstration of n-channel and p-channel MOSFETs [1]. Recently, a liquid phase oxidation of GaAs at a near room-temperature was reported [2] and was used successfully for demonstrating a GaAs MOSFET [3]. In this paper, we first demonstrate the $In_{0.53}Ga_{0.47}As$ MOSFET utilizing a liquid phase oxidation of the $In_{0.53}Ga_{0.47}As$ layer, which shows the promise of utilizing the better transport property of the $In_{0.53}Ga_{0.47}As$ channel layer compared with that of the GaAs channel layer for MOSFETs.

2. Fabrication and Characterization of $In_{0.53}Ga_{0.47}As$ MOSFET

Liquid phase oxidation of n-type ($2x10^{18}/cm^3$) GaAs and undoped, n-type ($2x10^{17}/cm^3$), and p-type ($2x10^{17}/cm^3$) $In_{0.53}Ga_{0.47}As$ layers was carried out using a gallium-ion-contained nitric acid solution for temperatures between 60-70 °C [1]. Figure 1 shows the thickness of oxides grown at 70 °C for three hours of oxidation as a function of the pH of the solution. $In_{0.53}Ga_{0.47}As$ had a much narrower pH widow for oxidation compared with that of GaAs. It was also observed that the pH window got narrower as the doping density of $In_{0.53}Ga_{0.47}As$ was increased.

Epitaxial layer for the $In_{0.53}Ga_{0.47}As$ MOSFET, shown in Fig. 2, was grown by a V80H chemical beam epitaxy. The heavily n-doped $In_{0.53}Ga_{0.47}As$ cap layer was used for both the oxidation layer and the ohmic layer. The InP oxide stop layer was used for the selective oxidation of the heavily n-doped $In_{0.53}Ga_{0.47}As$ cap layer against the channel layer. Selectivity of oxidation of $In_{0.53}Ga_{0.47}As$ against InP was larger than 100 at the same oxidation condition. Figure 3 shows the leakage current characteristics of the MOS capacitor (area=$100\times100\ \mu m^2$) having the oxide thickness of 500 Å. The breakdown field (>8 MV/cm) of the $In_{0.53}Ga_{0.47}As$ oxide was larger than that (~5 MV/cm) of the GaAs oxides grown by a similar method [2] and that (~3.6 MV/cm) of the evaporated $Ga_2O_3(Gd_2O_3)$ [3].

MOSFETs having a 2x50 μm^2 gate were fabricated using a conventional optical lithography. After mesa was formed, ohmic (Ti/Pt/Au) metallization was deposited and alloyed at 360 °C. The heavily n-doped $In_{0.53}Ga_{0.47}As$ cap layer was oxidized at the solution temperature of 70 °C and the pH of 4.75 using the ohmic metallization as a mask layer. Ti/Pt/Au was used for the gate metallization.

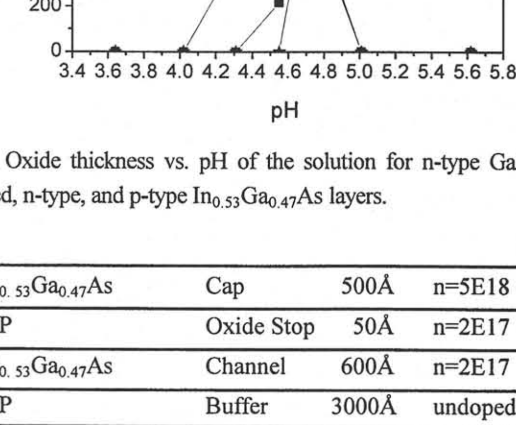

Fig. 1. Oxide thickness vs. pH of the solution for n-type GaAs and undoped, n-type, and p-type $In_{0.53}Ga_{0.47}As$ layers.

$In_{0.53}Ga_{0.47}As$	Cap	500Å	n=5E18
InP	Oxide Stop	50Å	n=2E17
$In_{0.53}Ga_{0.47}As$	Channel	600Å	n=2E17
InP	Buffer	3000Å	undoped
Semi-insulating <100> InP Substrate			

Fig. 2. Epitaxial layer structure of the $In_{0.53}Ga_{0.47}As$ MOSFET.

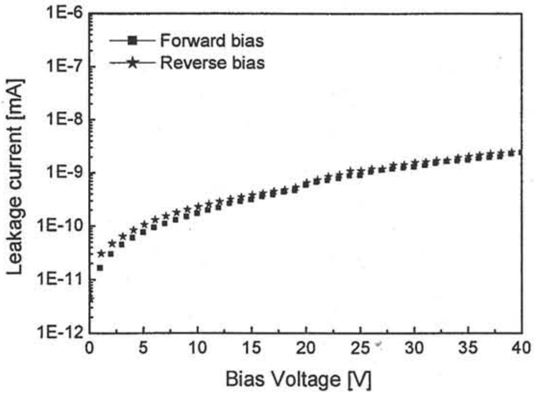

Fig. 3. Leakage current characteristics of the MOS capacitor having a 500 Å thick oxidized $In_{0.53}Ga_{0.47}As$ layer. The area of the capacitor is 100x100 μm^2.

DC characteristics of the $2\times50\mu m^2$ $In_{0.53}Ga_{0.47}As$ MOSFET were measured. Figure 4 shows the normalized drain current-voltage characteristics of the $2\times50\mu m^2$ $In_{0.53}Ga_{0.47}As$ MOSFET for the gate bias voltage from 0 V to –4 V with –0.5 V step. The MOSFET showed complete pinch-off and saturation characteristics without any gate leakage current effect for forward gate biases. Figure 5 shows the normalized transconductance and drain saturation current characteristics of the $2\times50\mu m^2$ $In_{0.53}Ga_{0.47}As$ MOSFET as a function of the gate-source bias voltage measured at the drain-source bias voltage of 5 V.

On-wafer S-parameter measurements were carried out. Figure 6 shows the common-source current gain (h_{21}) and power gain (MSG/MAG) characteristics of the $2\times50\mu m^2$ $In_{0.53}Ga_{0.47}As$ MOSFET measured at V_{gs} of 0 V and V_{ds} of 3.0 V. The current gain cutoff frequency (f_T) and the maximum oscillation frequency (f_{max}) were approximately 9 GHz and 10 GHz, respectively.

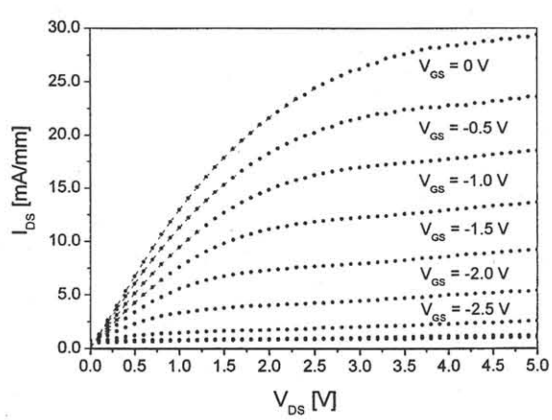

Fig. 4. Normalized drain current-voltage characteristics of the $In_{0.53}Ga_{0.47}As$ MOSFET having a $2\mu m\times50\mu m$ gate.

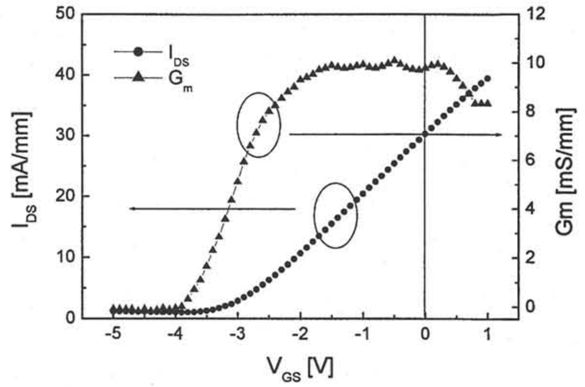

Fig. 5. Normalized transconductance and drain saturation current of the $In_{0.53}Ga_{0.47}As$ MOSFET having a $2\mu m\times50\mu m$ gate.

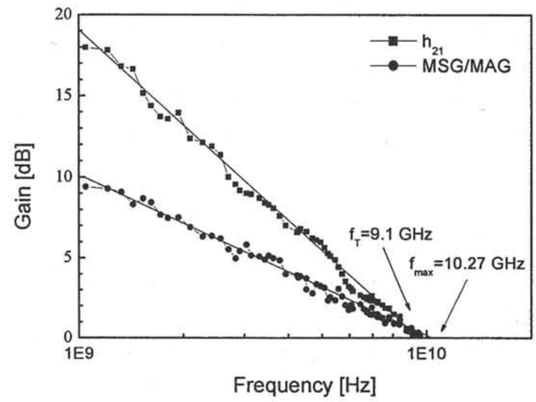

Fig. 6. Current and power gain characteristics of the $In_{0.53}Ga_{0.47}As$ MOSFET having a $2\mu m\times50\mu m$ gate.

3. Conclusions

A depletion-mode $In_{0.53}Ga_{0.47}As$ MOSFET using a liquid phase oxidation of $In_{0.53}Ga_{0.47}As$ has been demonstrated. The quality of the liquid phase oxidized $In_{0.53}Ga_{0.47}As$ was excellent, showing a larger breakdown voltage compared with other III-V compound semiconductor oxides formed by various techniques. The results show the promise of utilizing the excellent transport property of the InGaAs lattice-matched to InP for MOSFETs having improved device performances.

Acknowledgments

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References

[1] F. Ren, et al., Tech. Dig. of the 19th GaAs IC Symp. 18(1997)

[2] H.-H. Wang, et al., Jpn. J. Appl. Phys. **37**, L67(1998)

[3] J.-Y. Wu, et al., IEEE Elec. Dev. Lett. **20**, 18(1999)