A Study on Aluminum Gate La$_2$O$_3$ nMISFET with Post Metallization Anneal

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ABSTRACT

The Post Metallization Anneal (PMA) was investigated for Al gate La$_2$O$_3$ nMISFET with equivalent oxide thickness (EOT) of 1.96 nm. Conventional Post Deposition Anneal (PDA) in N$_2$ ambient lead to negative threshold voltage ($V_{th}$). Thus, this gave rise to normally-ON characteristic [1]. However, by using PMA in N$_2$ ambient, we had found that normally-ON characteristic was completely suppressed. Threshold voltage ($V_{th}$) was 0.20 V from extrapolation of $I_d-V_g$ plot. The extracted subthreshold slope of 83.3 mV/decade suggested a fairly good interfacial quality.

EXPERIMENTS

Ultrathin La$_2$O$_3$ films (physical thickness=5 nm) were deposited on silicon substrate with isolation and source/drain structures by molecular beam epitaxy (MBE) system after surface peroxide mixture (SPM) cleaning and HF-dip processes. Pressure and temperature during the deposition were around 10$^{-7}$-10$^{-9}$ Torr and 250°C, respectively. Post Metallization Anneal (PMA) in N$_2$ ambient was performed at 300°C for 1 min after Al gate formation. Source, drain and backside electrodes were then formed. The complete structure of nMISFET had gate length and gate width of 10 µm and 57 µm, respectively.

RESULTS AND DISCUSSION

Figure 1 shows a well behaved $I_d-V_g$ characteristic with high drain drive (0.84 mA/µm at $V_g=2$ V) was observed. Normally-ON characteristic was completely suppressed with PMA annealing condition. This was later proved that $V_{th} = 0.20$ V from extrapolation of $I_d-V_g$. Figure 2 shows the subthreshold characteristics of Al gate La$_2$O$_3$ nMISFET. Good subthreshold slope ($S$) with value of 83.3 mV/decade was obtained from extraction. The small swing is probably due to improved interfacial quality. Electron’s field effect mobility ($\mu_{FE}$) versus $V_g-V_{th}$ was plotted in Figure 3. Maximum mobility of 152 cm$^2$/V-s was obtained. This is not as good as our previous work without PMA [2] and further optimization is necessary.

CONCLUSION

Al gate La$_2$O$_3$ nMISFET with EOT=1.96nm was fabricated and evaluated. Normally-ON characteristic was completely suppressed with the used of PMA in N$_2$ ambient. High drain current was observed. Threshold voltage of 0.20 V was obtained. Relatively good subthreshold swing was obtained. However, field effect mobility needs to be improved.

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REFERENCES


Figure 1. $I_d$-$V_g$ characteristic of Al gate La$_2$O$_3$ nMISFET with PMA at 300°C in N$_2$ ambient for 1 min.

Figure 2. Subthreshold characteristics of Al gate La$_2$O$_3$ nMISFET. Subthreshold slope ($S$) and threshold voltage ($V_{th}$) were 83.3 mV/decade and 0.20 V respectively.

Figure 3. Electron’s field effect mobility ($\mu_{FE}$) of Al gate La$_2$O$_3$ nMISFET. Maximum $\mu_{FE}$ was 152 cm$^2$/V-s.