GeO\textsubscript{x}N\textsubscript{y} 層の挿入による Al\textsubscript{2}O\textsubscript{3}/n-Ge MOS 界面の遅い準位密度低減

Reduction of slow trap density in Al\textsubscript{2}O\textsubscript{3}/n-Ge MOS interfaces by insertion of GeO\textsubscript{x}N\textsubscript{y}

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1. Introduction

Ge has become more and more attracting as a next generation MOSFET channel material because of the higher electron and hole mobility than Si. As one of the promising gate stacks, Al\textsubscript{2}O\textsubscript{3}/GeO\textsubscript{2}/Ge and HfO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3}/Ge\textsubscript{2}O\textsubscript{3}/Ge structures realized by plasma post oxidation (PPO) have been shown to have 1 nm or thinner EOT and low D\textsubscript{it} of \textasciitilde10\textsuperscript{11} eV\textsuperscript{-1} cm\textsuperscript{-2} \cite{1,2}. However, one of the remaining critical issues is the existence of a large amount of slow traps \cite{3-5}. We have recently reported that Y-doped Al\textsubscript{2}O\textsubscript{3} can significantly decrease the slow trap density of Al\textsubscript{2}O\textsubscript{3}/GeO\textsubscript{2}/p-Ge gate stacks \cite{6}. However, significant reduction in slow trap density near the conduction band edge is still strongly needed. In this study, in order to reduce the density of these slow traps, we examine the effects of incorporating nitrogen into Al\textsubscript{2}O\textsubscript{3}/GeO\textsubscript{2}/n-Ge interfaces by employing post plasma nitridation.

2. Experiment

In this study, we have introduced nitrogen atoms by employing plasma post nitridation (PPN) \cite{7} into Ge interfacial layers for suppressing slow trap density in Ge\textsubscript{2}O. Fig. 1 shows the process flow of Al\textsubscript{2}O\textsubscript{3}/GeO\textsubscript{N}/Ge gate stacks by the combination of PPN and PPO. (100) Ge wafers were cleaned by de-ionized water, acetone and HF. After the pre-cleaning, 1.5-nm-thick Al\textsubscript{2}O\textsubscript{3} were deposited at 300°C by ALD. Here, PPN was performed prior to PPO, because PPN after PPO can significantly increase D\textsubscript{it}. The PPN process was performed by using ECR plasma of Ar and N\textsubscript{2} with 500 W at room temperature with 1 min. Subsequently, PPO was performed by using ECR plasma of Ar and O\textsubscript{2} at 300°C under 650 W with changing oxidation time from 25 s to 120 s. For 30 min at 400°C in N\textsubscript{2} ambient, followed by Au gate electrode and Al back contact formation by thermal evaporation. The slow trap density (\Delta N\textsubscript{fix}) was estimated by the amount of the hysteresis in C-V sweep as a function of the effective oxide field (E\textsubscript{ox}), defined by \((V\textsubscript{g}-V\textsubscript{FB})/E\textsubscript{ox}\).

3. Results and Discussion

Fig. 2 shows the energy distributions of D\textsubscript{it} for PPN only and PPN/PPO samples with the different PPO time. It is observed that sufficiently-long PPO significantly reduces D\textsubscript{it}, while only PPN sample exhibits quite high D\textsubscript{it}. Fig. 3 shows \Delta N\textsubscript{fix} of the MOS interfaces with only PPO and PPN/PPO. It is found that \Delta N\textsubscript{fix} decreases and the slope of the \Delta N\textsubscript{fix}-E\textsubscript{ox} line increases by introducing 60 sec PPN, attributable to passivation of defects in GeO\textsubscript{2} with N atoms.

4. Conclusions

We have investigated the impact of plasma nitridation on slow traps in the Al\textsubscript{2}O\textsubscript{3}/GeO\textsubscript{2} or GeO\textsubscript{N}/Ge MOS interfaces by systematically changing the plasma process time. We have demonstrated the reduction in the slow trap density near the Ge conduction band edge by introducing N atoms by combining the PPN/PPO process under a limited expense of the increase in D\textsubscript{it}.

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References


Fig. 1: process flow of Al\textsubscript{2}O\textsubscript{3}/Ge gate stack with PPN-PPO

Fig. 2: \Delta N\textsubscript{fix} of Al\textsubscript{2}O\textsubscript{3}/Ge interface with 25s PPO or 1min PPN and 0-120s PPO

Fig. 3: \Delta N\textsubscript{fix} of Al\textsubscript{2}O\textsubscript{3}/Ge interface with 25s PPO or 1min PPN and 25-120s PPO

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