GeO_xN_y 層の挿入による Al_2O_3/n-Ge MOS 界面の遅い準位密度低減

Reduction of slow trap density in Al_2O_3/n-Ge MOS interfaces by insertion of GeO_xN_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_2O_3/GeO_x/Ge and $HfO_2/Al_2O_3/GeO_x$/Ge structures realized by plasma post oxidation (PPO) have been shown to have 1 nm or thinner EOT and low D_{it} of ~10^{11} $eV^{-1}cm^{-2}$ [1,2]. However, one of the remaining critical issues is the existence of a large amount of slow traps [3-5]. We have recently reported that Y-doped Al_2O_3 can decrease the slow trap density of Al_2O_3/GeO_x/p-Ge gate stacks [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_2O_3/GeO_x/n-Ge interfaces by employing post plasma nitridation.

2. Experiment In this study, we have introduced nitrogen atoms by employing plasma post nitridation (PPN) [7] into Ge interfacial layers for suppressing slow trap density in GeO_x. Fig. 1 shows the process flow of Al_2O_3/GeO_xN_y/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_2O_3 were deposited at 300°C by ALD. Here, PPN was performed prior to PPO, because PPN after PPO can significantly increase D_{it}. The PPN process was performed by using ECR plasma of Ar and N_2 with 500 W at room temperature with 1 min. Subsequently, PPO was performed by using ECR plasma of Ar and O_2 at 300 °C under 650 W with changing oxidation time from 25 s to 120 s. PDA was performed for 30 min at 400 °C in N_2 ambient, followed by Au gate electrode and Al back contact formation by thermal evaporation. The slow trap density (ΔN_{fix}) was estimated by the amount of the hysteresis in C-V sweep as a function of the effective oxide field (E_{ox}), defined by $(V_g-V_{FB})/EOT$ [5].

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

4. Conclusions We have investigated the impact of plasma nitridation on slow traps in the Al_2O_3/GeO_x or GeO_xN_y/Ge MOS interfaces by systematically changing the plasma process time. We have demonstrate 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_{it}.

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References [1] R. Zhang et al., APL 98 (2011), 112902 [2] R. Zhang et al., TED (2013) 927 [3] R. Zhang et al., IEDM (2011), 642 [4] J. Franco et al., IEDM (2013) 397 [5] G. Groesenken et al., IEDM (2014) 828 [6] M. Ke et al., MEE 147 (2015), 244 [7] J. Han et al., APEX 6 (2013) 051302

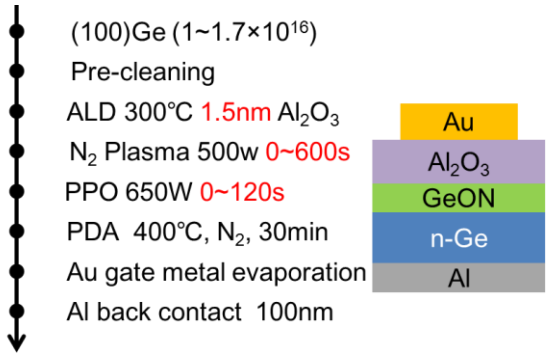

Fig.1: process flow of Al_2O_3/Ge gate stack with PPN-PPO

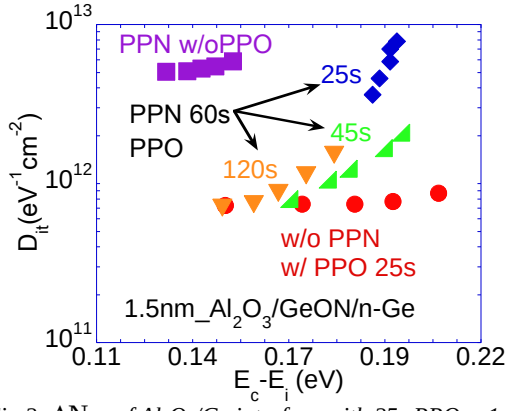

Fig.2: ΔN_{fix} of Al_2O_3/Ge interface with 25s PPO or1min PPN and 0-120s PPO

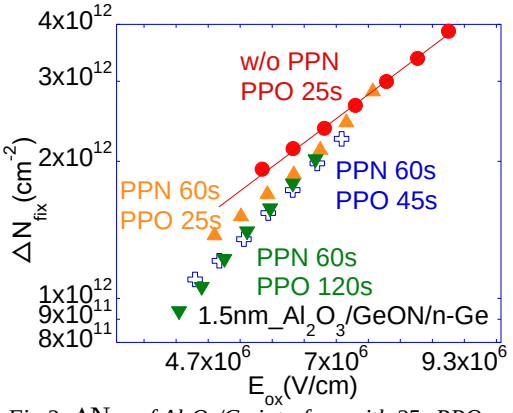

Fig.3: ΔN_{fix} of Al_2O_3/Ge interface with 25s PPO or1min PPN and 25-120s PPO