Characterization of Effective Electron Mobility in nMOSFETs with Direct Contact La-silicate/Si Structure

Takamasa Kawanago¹, Yeonghun Lee¹, Kuniyuki Kakushima², Parhat Ahmet¹, Kazuo Tsutsui², Akira Nishiyama², Nobuyuki Sugi², Kenji Natori¹, Takeo Hattori¹, Hiroshi Iwai¹
¹ Frontier Research Center, Tokyo Institute of Technology
² Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, E-mail: kawanago.t.ab@m.titech.ac.jp

Introduction

Scaling in an equivalent oxide thickness (EOT) with high-k/metal gate stacks is indispensable for suppression of short-channel effect and threshold voltage variability in state-of-the-art MOSFET [1-2]. The removal of SiO₂ interfacial layer is essential for reduction of EOT since SiO₂ interfacial layer is typically prepared for recovery from reliability or mobility degradation prior to high-k deposition [3]. A direct contact high-k/Si structure is necessary to continue the EOT scaling. La₂O₃ can easily achieve the direct contact high-k/Si structure for gate dielectrics owing to material nature of La-silicate formation at La₂O₃/Si interface [4]. Since reduced effective mobility with decreasing the thickness of SiO₂ interfacial layer is one of serious issues in high-k/metal gate stacks [3], it is of great importance to investigate the effective mobility in MOSFET with direct contact La-silicate/Si structure. The objective in this study is to investigate scattering mechanisms in La-silicate nMOSFET with wide range of EOT.

Experimental Procedures

La₂O₃ was deposited on HF-last Si (100) substrate by e-beam evaporation in an ultra-high vacuum chamber, followed by in-situ W (tungsten) metal deposition by RF sputtering. nMOSFETs were fabricated by gate last process using source and drain pre-formed p-Si (100) substrates with a substrate doping concentration of 3x10¹⁶ cm⁻³. TiN and Si were deposited on W metal by RF sputtering for Metal Inserted Poly-Si (MIPS) stacks. The thickness of Si, TiN and W were 100nm, 10nm and 5nm, respectively. Post-metallization annealing was performed at 800 °C for 30 min in forming gas ambient with various gate structures. Finally, recovery annealing was conducted at 420 °C for 30 min in forming gas ambient. Split-CV method was employed to measure an effective electron mobility of nMOSFET [5].

Results and Discussion

Figure 1 shows the relationship between effective electron mobility and effective field (E_{eff}) as a function of EOT with various gate structures. The effective electron mobility is monotonically decreased with decreasing EOT in entire effective field. The scattering mechanisms in Si-MOSFET can be divided into three mechanisms (namely Coulomb, Phonon and Interface Roughness) [6]. It was found that all of scattering processes in La-silicate nMOSFETs are strongly dependent on EOT. It can be speculated that carriers in inversion layer interact with top metal/high-k interface by scaling down the EOT [3]. Moreover, E_{eff} dependence of mobility in La-silicate nMOSFET is weaker compared with universal mobility curve at both middle and high E_{eff} region [6]. This weaker E_{eff} dependence of mobility may be inherent feature of La-silicate gate dielectrics in directly contact with Si substrate. It indicates that Phonon scattering associated with high-k gate dielectrics affect on effective mobility and roughness at direct contact La-silicate/Si interface is quite different in the case of SiO₂/Si interface [3].

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References