A Study on the Characteristics and Reliability of Dynamic Threshold MOSFETs

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Abstract

We discuss dynamic threshold MOS (DTMOS) operations for nMOSFETs of different dielectric types and thicknesses. We found that, under the DT mode of operation, all devices exhibit a threshold voltage close to 0.7 V, independent of the thickness and gate dielectric type of the device. This is due to the diminished influence of the body effect factor. Formulations of threshold voltage and subthreshold swing of DTMOS are developed to gain insights into this unique phenomenon, and simulation of the subthreshold swing is also provided. Then, we compared the hot carrier effects of T-gate and H-gate SOI pMOSFETs operating under DT-mode and conventional mode at various temperatures. By operating under DT-mode, the threshold voltage shift is reduced. However, enhanced degradations in maximum transconductance and drive current are observed when operating under DT-mode at room temperature, especially for the T-gate structure. The transconductance enlargement effect for devices operating under DT-mode, together with the non-uniform potential distribution in T-gate structure, are believed to be

responsible for the observed enhanced degradations.

The applications of DTMOS with reverse Schottky barrier on substrate contacts for high voltage and high temperature were presented. By this reverse Schottky barrier on substrate contact, DTMOS can be operated at high voltage, and exhibits excellent performance at high temperature in terms of ideal subthreshold slope, low threshold voltage and high driving current. In addition, the characteristics of DT-pMOSFETs using the reverse Schottky substrate contacts are also discussed. Furthermore, the NBTI effects of DTMOS were also reported for the first time. This is because DTMOS could operate just below 0.7V of V_G due to the diode turn-on behavior. It is interesting to note that the shift of the ΔV_{TH} of pMOSFETs under NBTI measurement was significantly alleviated in the DT operating mode.

Furthermore, NBTI effects of pMOSFETs with different nitrogen dose implantation and regions were investigated in the appendix A. High nitrogen dose implantation in the channel or source/drain extension results in serious NBTI degradation. Both the dynamic NBTI effects and substrate hot holes effects were also discussed in this dissertation. Larger nitrogen dose not only results in serious NBTI effects but also serious substrate hot holes effects.. Finally, gate dielectric thickness, carrier mobility, and nitrogen dosage effects on pMOSFETs with ultra-thin gate dielectric on Si-(100) and Si-(111) were investigated in the appendix B. PMOSFETs

on Si-(111) show about 64% improvement of carrier mobility than that on Si-(100) counterparts. We found that the nitrogen incorporation enhances the carrier mobility on Si-(100), but degrades on Si-(111). In addition, compared to Si-(100), pMOSFETs on Si-(111) show a strong dependence with aspect ration effect due to 2-dimensional strain effect. Finally, pMOSFETs on Si-(111) show slightly large sensitive for temperature dependence.