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# Pillar Diameter Dependence of the Carrier Response Time in a Surrounding Gate type MOS Capacitor

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Abstract: It is reported that carrier response time of a Surrounding Gate type MOS capacitor strongly depends on the pillar diameter for the first time. This important result is clarified by the effect of measurement frequency on the Capacitance-Voltage (C-V) characteristics of the Surrounding Gate type MOS capacitor.

Introduction: In order to realize future ULSI's, the Surrounding Gate Transistor (SGT) is proposed [1]. However, the Capacitance-Voltage (C-V) characteristics of the Surrounding Gate type MOS capacitor which has the gate oxide around the cylindrical silicon pillar have not been studied. This paper describes the pillar diameter dependence of the minority carrier response time of the Surrounding Gate type MOS capacitor, by the effect of measurement frequency on the C-V characteristics of Surrounding Gate type MOS capacitor.

Structure: Fig.1 (a) and (b) show the schematic cross-sectional view and the TEM photograph of Surrounding Gate type MOS capacitor, respectively. In order to measure the capacitance of the gate oxide around the cylindrical silicon pillar, thick oxides are formed both on the top of pillars and on the bottom of trenches compared with the gate oxide. From Fig.1 (b), the thicknesses of gate oxide, top oxide and bottom oxide are 15.0nm, 757.9nm and 133.7nm, respectively. The silicon trenches are filled up with the gate electrode poly silicon. The diameter of silicon pillar is 680nm and the height is 820nm. This structure is fabricated on (100) p-type silicon substrate with a doping concentration of $2.5\times10^{15}$ $cm^{-3}$. In a planar type MOS capacitor, the thickness of gate oxide is 9.8nm and the area of gate oxide is $3\times10^{-4}$ $cm^{2}$.

Measurements & Results: The capacitance between the gate electrode poly silicon and the substrate is measured. The C-V characteristics are measured at 0.1Hz and 20Hz. The DC bias is swept from -3V to +3V in the dark and at room temperature.

Fig.2 shows the effect of measurement frequency on the C-V characteristics of the Surrounding Gate type MOS capacitor. When the surface along the cylindrical silicon pillar is in accumulation, the capacitance value agrees well with the oxide capacitance calculated from oxide thicknesses and areas. When the gate voltage increases over -0.5V, the capacitance value at 0.1Hz is recovered and saturated to the same value as that of accumulation. On the other hand, the capacitance value at 20Hz is constant. From Fig.2, the minority carrier response time of the Surrounding Gate type MOS capacitor is 10sec. Fig.3 shows the comparison of C-V characteristics of the Surrounding Gate type MOS capacitor with the planar type MOS capacitor at the same frequency of 0.1Hz. When the surface along the cylindrical silicon pillar is in inversion, it is clear that the carrier response time of the Surrounding Gate type MOS capacitor is smaller than that of the planar. In applying small signal voltage to the gate electrode, the carrier response time of MOS capacitor depends on the current from substrate to Si-SiO2 interface per unit area of gate oxide. The current per unit area of gate oxide of Surrounding Gate type MOS capacitor is larger than that of the planar. The planar type MOS capacitor is considered as the Surrounding Gate type MOS capacitor which is the infinite pillar diameter. Therefore, the carrier response time of the Surrounding Gate type MOS capacitor strongly depends on the pillar diameter.

Conclusions: In this paper, the effect of measurement frequency on the Capacitance-Voltage (C-V) characteristics of the Surrounding Gate type MOS capacitor is analyzed. It is clarified that carrier response time of a Surrounding Gate type MOS capacitor strongly depends on the pillar diameter for the first time.

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References:

[1]H. Takato et al., IEDM Tech.Dig., p.222, 1988.

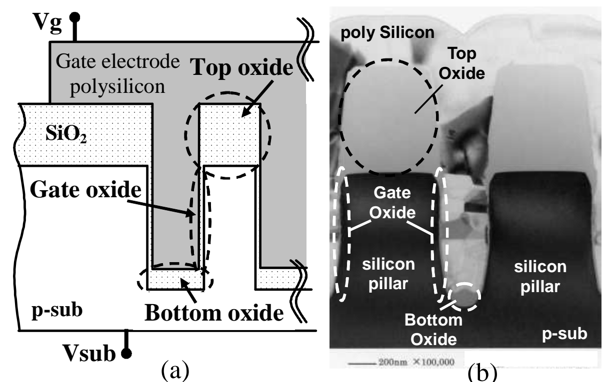


Fig.1 (a)Schematic cross-sectional view and (b)TEM photograph of Surrounding Gate type MOS capacitor

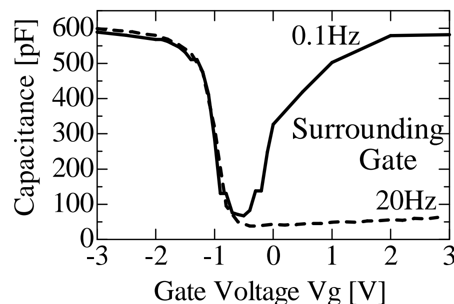


Fig.2 Effect of measurement frequency on the Capacitance-Voltage(C-V) characteristics of the Surrounding Gate MOS capacitor

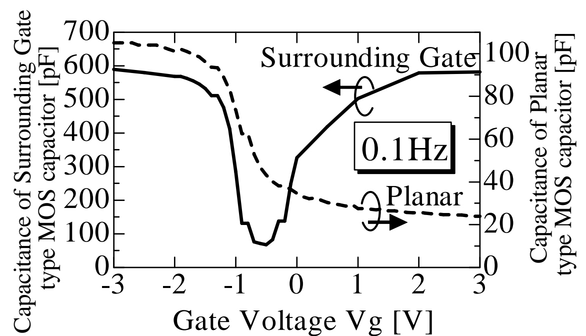


Fig.3 The comparison of C-V characteristics of the Surrounding Gate type MOS capacitor with the planar type MOS capacitor at 0.1Hz