SILICON FILM AND FRONT OXIDE THICKNESS EXTRACTION ON SOI DEVICES USING TWO DIFFERENT TECHNIQUES

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ABSTRACT

This work presents two different techniques used for extraction of the silicon film and front oxide thickness. The first of them was developed for SOI transistors and the second for SOI capacitors. Both techniques exploit the influence of the front/back gate voltages on the conditions of the front and back interfaces. The comparison between the methods was done using numerical bidimensional simulations.

1. INTRODUCTION

Silicon-On-Insulator (SOI) technology has grown rapidly during the past years, mainly because this technology presents many advantages over bulk technology [1]. The SOI MOSFETs behavior is dependent on the silicon film thickness and the channel doping concentration. Three different types of devices exist: thick-film, medium thickness film and thin-film devices [2]. In thin-film devices, the silicon film can be fully depleted and in this case there is an interaction between the front and back interface charges.

2. PROPOSED TECHNIQUES

The first method studied in this work was proposed by Nicolett [3]. To determine the silicon film thickness t_{Si}, the I_{DS} vs. V_{GB} curve is obtained for a constant V_{GF} larger than Vth_{Facc2} on SOI transistors. Figure 1 shows the I_{DS} and $\delta^2 I_{DS}/\delta V_{GB}^2$ curves as a function of the V_{GB}.

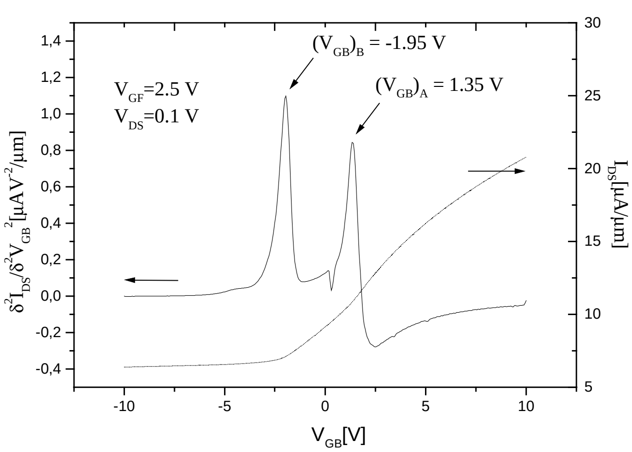

Figure 1: I_{DS} and $\delta^2 I_{DS}/\delta V_{GB}^2$ curves as a function of V_{GB} for a constant $V_{GF} > Vth_{F,acc2}$.

The second order derivative curve of I_{DS} presents two peaks (maximum points) related to the condition changes of the back interface as a function of the back gate voltage. Using the values of the points $(V_{GB})_A$ and $(V_{GB})_B$, the silicon film thickness t_{Si} can be obtained by equation (1).

$$t_{Si} = \frac{\varepsilon_{Si}}{C_{oxb}\left(\frac{(V_{GB})_A - (V_{GB})}{2\phi_{Ff}} - 1\right)} \quad (1)$$

To determine the front oxide thickness t_{oxf}, the I_{DS} vs. V_{GF} curve is determined for a constant V_{GB} larger than $Vth_{B,acc1}$. For these conditions, two maximum points can be found in $\delta^2 I_{DS}/\delta V_{GF}^2$. Using these two points the front oxide thickness can be extracted by equation (2). The point $(V_{GF})_A$ represents the voltage where the front interface under the channel becomes inverted. The point $(V_{GF})_B$ represents the voltage where the front interface under the channel becomes accumulated.

$$t_{oxf} = \frac{\varepsilon_{ox} t_{Si}\left(\frac{(V_{GF})_A - (V_{GF})_B}{2\phi_{Ff}} - 1\right)}{\varepsilon_{Si}} \quad (2)$$

The second method was proposed by Sonnenberg [4]. The Figure 2 shows the SOI-MOS capacitor structure and the capacitance between the front gate and silicon film (C_{FC}) that will be analyzed.

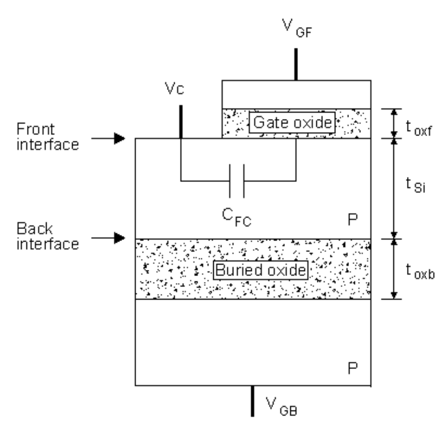

Figure 2: SOI-MOS capacitor and the capacitance between the front gate and silicon film (C_{FC}).

This method uses the C_{FC} x V_{GF} curves for different values of t_{oxf} like showed in Figure 3.

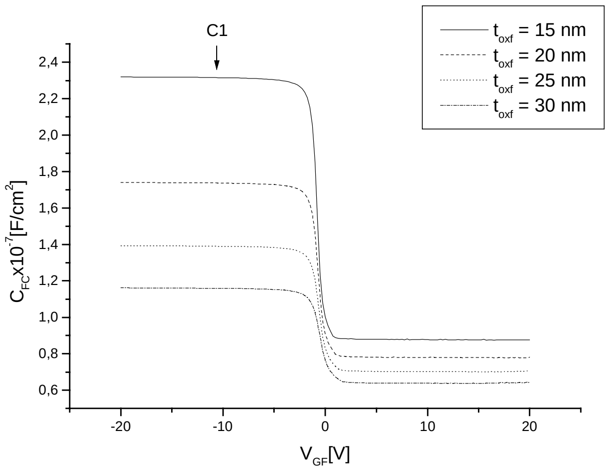

Figure 3: C_{FC} x V_{GF} curves with different values of t_{oxf} .

For V_{GF} sufficiently negative, the capacitance C_{FC}=C_1 is the front gate oxide capacitance, independent of V_{GB} because the front interface is accumulated. This value C1 can be used to find the oxide film thickness t_{oxf} as shown in equation (3).

$$t_{oxf} = \frac{\varepsilon_{OX}}{C1} \tag{3}$$

To determinate the silicon film thickness t_{si} the curve C_{FC} x V_{GB} is used, Figure 4. The point C_2 is obtained as the intersection of the straight lines extrapolated on the back accumulation and the transition, between accumulation and depletion of the back interface regions. This point C2 is used in the equation (4) to determinate the silicon film thickness t_{Si}.

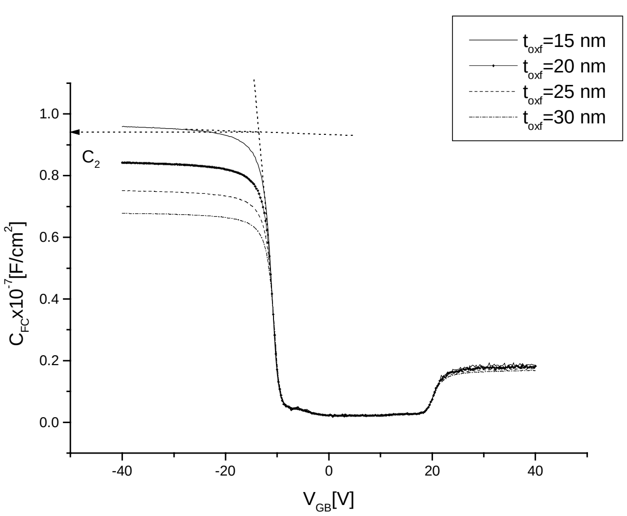

Figure 4: C_{FC} x V_{GB} curves with different values of t_{oxf} .

$$t_{Si} = \varepsilon_{Si} \frac{C1 - C2}{C1C2} \tag{4}$$

3. SIMULATIONS AND RESULTS

To compare the both techniques used for extraction of the silicon film and front oxide thickness, bidimensional numerical simulations were done with MEDICI [5]. The process parameters were: t_{oxf} from 15 to 30 nm, t_{Si} from 70 to 100 nm.

For the 1st method: t_{oxb} = 80 nm, silicon film doping concentration N_{af} = $1x10^{17}$ cm^{-3}, substrate doping concentration N_{ab} = $1x10^{15}$, front and back oxide charge densities Q_{ox1} = $5x10^{10}$ cm^{-2} and Q_{ox2} = $1x10^{11}$ cm^{-2}.

For the 2nd method: t_{oxb}=400 nm, N_{af} = $1x10^{17}$ cm^{-3}, N_{ab} = $1x10^{17}$ cm^{-3}, Q_{ox1} = 10^{10} cm^{-2} , Q_{ox2} = $5x10^{10}$ cm^{-2} .

Table I shows the results obtained of t_{oxf} and t_{Si} using the both methods.

Table I: Calculated values using the both methods

Simulated		1st method		2nd method	
t_{Si} [nm]	t_{oxf} [nm]	t_{Si} [nm]	t_{oxf} [nm]	t_{Si} [nm]	t_{oxf} [nm]
70	20	68,26	21,24	67,70	19,84
70	25	69,46	27,82	68,22	24,79
70	30	68,26	31,49	67,67	29,74
80	20	79,24	21,76	75,55	19,84
80	25	77,68	26,38	75,51	24,79
80	30	79,24	32,38	75,47	29,74
90	20	90,11	17,42	82,23	19,85
90	25	88,10	27,41	82,84	24,80
90	30	90,11	32,06	82,63	29,74
100	20	99,20	21,60	88,77	19,85
100	25	101,70	27,11	88,92	24,80
100	30	101,70	31,66	89,02	29,74

The maximum error for t_{Si} is 2.48% using the 1st method and 11.23% for the 2nd method. On the other hand, the maximum error for t_{oxf} is 12.9% % using the 1st method and 0.86% for the 2nd method.

4. CONCLUSION

It has been presented two different techniques for extraction of the silicon film and front oxide thickness. The results were analyzed by bidimensional numerical simulations and they showed that the values obtained for t_{Si} using the 1st method are closer to the used in the simulations and that the values obtained for t_{oxf} using the 2nd method are closer to the simulations characteristics.

5. REFERENCES

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