EXPERIMENTAL CHARACTERIZATION OF SOI MOS STRUCTURES TO DETERMINE THE SILICON FILM AND FRONT OXIDE THICKNESSES

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ABSTRACT

Electrical measurements were performed using SOI capacitors and transistors to compare two different techniques used for extraction of the silicon film (t_{si}) and front oxide thicknesses (t_{oxf}). Both techniques exploit the influence of the front/back gate voltages on the conditions of the front and back interfaces.

1. INTRODUCTION

The Silicon-On-Insulator (SOI) technology has grown rapidly during the past years, mainly because this technology presents many advantages over bulk technology [1]. Figure 1 shows a cross section of a SOI transistor and some used notations.

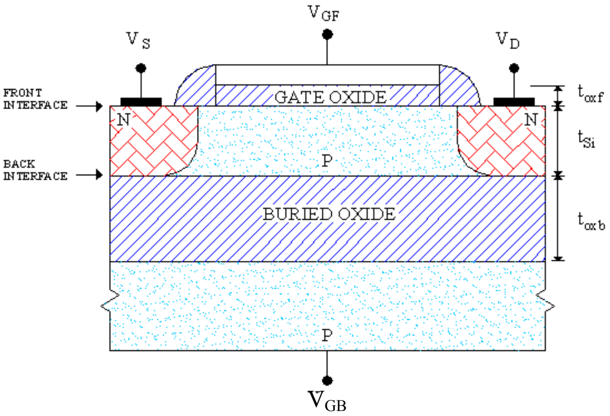

Figure1: Cross-section of the SOI device.

The first technique studied uses a SOI-MOS capacitor structure and C x V curves. The second technique studied uses SOI transistors and I x V curves.

2. C x V MEASUREMENTS AND RESULTS

The extraction method used in this section has been proposed by Sonnenberg et al [2] and is based in SOI-MOS capacitor structure measurements. The capacitance between the front gate and silicon film (C_{FC}) is used as a function of the front gate voltage (V_{GF}) for different values of back gate voltage (V_{GB}), in high frequency. The curves were measured using the HP4280 with 1 MHz. The HP4140 was used to polarize the back gate (V_{GB}).

The electrical measurements were performed in SOI capacitor in inversion mode N type with Area = 7.2×10^{-5} cm^2, poly-gate N+, front oxide thickness (t_{oxf}) of 30 nm, silicon film thickness (t_{Si}) of 80 nm, buried oxide thickness (t_{oxb}) of 400 nm, silicon film doping concentration $N_{af} = 1 \times 10^{17}$ cm^{-3} and substrate doping concentration $N_{ab} = 1 \times 10^{15}$ cm^{-3}. Figure 2 shows C_{FC} x V_{GF} for different values of V_{GB}.

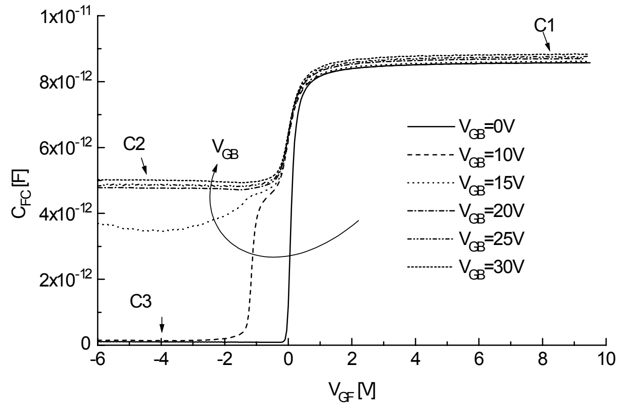

Figure 2: Experimental C_{FC} x V_{GF} curves with different values of V_{GB}.

For sufficiently positive V_{GF}, the capacitance $C_{FC} = C_1$ (front gate oxide capacitance) independent of V_{GB}, because the front interface is inverted. This value can be used to determine the oxide film thickness t_{oxf}, as shown in the equation (1).

$$t_{oxf} = \frac{\varepsilon_{OX}}{C1}.\text{Area} \qquad (1)$$

To determine the silicon film thickness t_{si} the C_{FC} x V_{GB} curve is used (Figure 3). The point A 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.

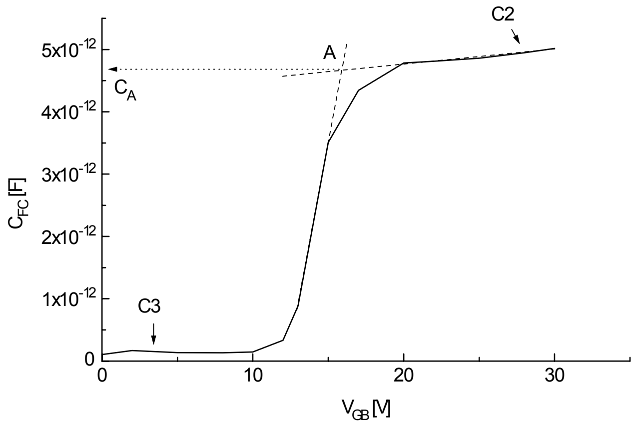

Figure 3: Experimental C_{FC} x V_{GB} curve for V_{GF} = -5V.

The point CA = C2, where C2 is the series association between the front oxide (C_{oxf}) and silicon film (C_{Si}) capacitances where the front interface is accumulated and the back interface is inverted. C2 is used in the equation (2) to determine the silicon film thickness t_{Si}.

$$t_{Si} = \varepsilon_{Si} \frac{C1 - C2}{C1C2}.\text{Area} \quad (2)$$

Using C1 = 8.83 pF (Figure 1) with V_{GB} = 0V, it was obtained a toxf = 28.1 nm. The error for this parameter is lower than 10%.

The values got for C1 and C2 in Figures 1 and 2 were used in the equation 2 (C1 = 8.83 pF and C2 = 4.63 pF) to determine t_{Si} = 77.0 nm. The error for this parameter is lower than 5%.

3. I x V MEASUREMENTS AND RESULTS

This method was proposed by Nicolett et al [3] where the I_{DS} x V_{GB} and I_{DS} x V_{GF} curves were used.

The SOI nMOSFET used in this study presents a drawn channel width W_m of 36 µm, drawn channel lengths L_m of 0.8 µm and were fabricated in a 0.5 µm SOI technology on SIMOX substrates. The device has an effective channel doping density of 1×10^{17} cm^{-3}, front gate oxide thickness t_{oxf} of about 15 nm, buried oxide thickness t_{oxb} of 390 nm, and silicon film thickness t_{Si} of about 80 nm. All measurements were done using a HP 4145B parameter analyzer.

Figure 4 shows the I_{DS} and $\delta^2 I_{DS}/\delta V_{GB}^2$ curves as a function of the V_{GB}.

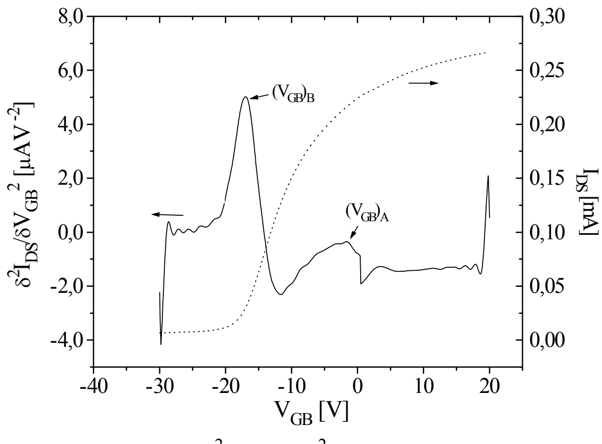

Figure 4: I_{DS} and $\delta^2 I_{DS}/\delta V_{GB}^2$ curves (experimental) as a function of V_{GB} with V_{GF} = 0.6V and V_{DS} = 0.2V.

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 (3).

$$t_{Si} = \frac{\varepsilon_{Si}}{C_{oxb}\left(\frac{(V_{GB})_A - (V_{GB})}{2\phi_{Ff}} - 1\right)} \quad (3)$$

To determine the front oxide thickness t_{oxf}, the I_{DS} vs. V_{GF} curve (Figure 5) 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 (4).

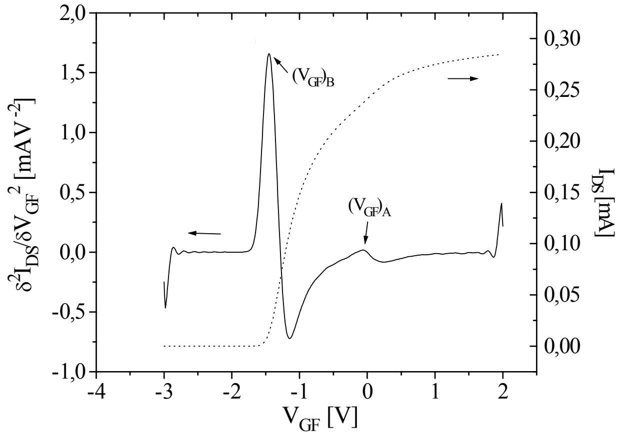

Figure 5: I_{DS} and $\delta^2 I_{DS}/\delta V_{GF}^2$ curves as a function of V_{GF} with V_{GB}=20V and V_{DS}=0.2V.

$$t_{oxf} = \frac{\varepsilon_{ox} t_{Si}\left(\frac{(V_{GF})_A - (V_{GF})_B}{2\phi_{Ff}} - 1\right)}{\varepsilon_{Si}} \quad (4)$$

The points $(V_{GB})_A$ = -1.6 V and $(V_{GB})_B$ = -17.0 V are obtained from Figure 4 and they are used in the equation 3 to determine t_{Si} = 67.5 nm. The error calculated is lower than 15%.

The t_{oxf} obtained is of 15.3 nm, and it is extracted using the points $(V_{GF})_A$ = -0.06 V and $(V_{GF})_B$ = -1.45 V in the equation 4. The error obtained is lower than 5%.

4. CONCLUSION

Electrical characterization of SOI transistor and capacitor were used to compare two different methods for extraction of the silicon film and front oxide thicknesses. The results show that the maximum difference between the experimental and the expected values are lower than 15% in all cases.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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