

COMPARISON OF SILICON DIOXIDE FILMS

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ABSTRACT

This experiment compared oxides grown at 950 C for 135 minutes and 1100 C for 15 minutes in dry O₂. Two different size capacitors were fabricated with gate areas of .0400 cm² and .0225 cm². The films were compared by capacitance - voltage measurements. It was found that the 1100 C process yielded a flat band voltage shift of 1 volt less than the 950 C process.

THEORY [1]

As a high frequency voltage, superimposed on a dc bias, on the gate of a p-type MOS capacitor is swept from -10 volts to +10 volts, the capacitance makes the transition from accumulation, through depletion, and into the inversion region. In accumulation the negatively biased gate attracts majority carriers, holes, to the silicon - silicon dioxide interface. The accumulation capacitance is the maximum capacitance and approximates the actual oxide capacitance (C_{ox}) of the fabricated device. C_{ox} is found below to be,

$$C_{ox} = \frac{(E_o)(\epsilon_{SiO_2})(A)}{X}$$

Where $E_o (=8.85 \times 10^{-14} \text{ F/cm})$ is the permittivity of free space, $\epsilon_{SiO_2} (=3.9)$ is the relative dielectric constant of silicon dioxide, A is the gate area, and X is the silicon dioxide thickness.

Inversion occurs when the positive gate bias is large enough to shift the Fermi-level at the surface from the bulk value, below the intrinsic level, (E_i) to the same position above E_i . In other words, at the surface, the p-Si has a voltage induced n-region. In inversion, the depletion width is a maximum because any further increase in gate voltage is compensated for by minority carrier generation and not increased depletion region width. The observed capacitance is the series combination of the depletion capacitance and the device capacitance. The inversion capacitance is,

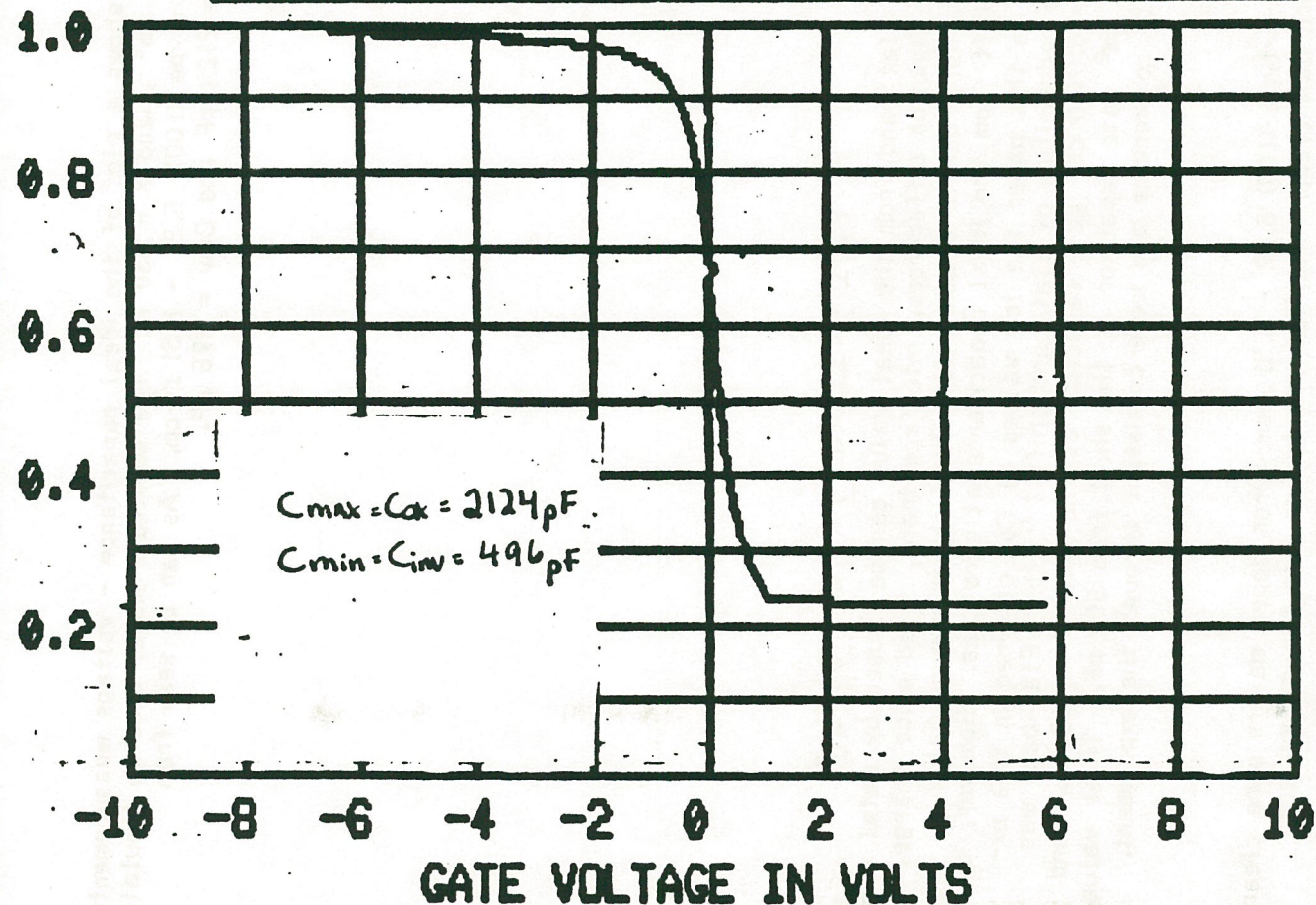
$$C_{inv} = \frac{(C_{ox})(C_s)}{C_{ox} + C_s}$$

where C_s is the semiconductor capacitance.

RIT C-V PLOT PROGRAM

C/COX

COX = $2.12400\text{E}-09$



INPUTS

TYPE = 0

FREQ = 1

AG = $4.00000\text{E}+06$

PHIMS = 0.0000

QF = $0.00000\text{E}+00$

QM = $0.00000\text{E}+00$

SINTERED

XOX = 650.00

NSUB = 2.00000

TEMP = 300.00

Figure 1 shows a plot of the ideal capacitance - voltage measurements for $A = 0.0400 \text{ cm}^2$, and $X = 650 \text{ \AA}$. The substrate model used to simulate this plot was p-type (100), $6.29 - 8.51 \Omega\text{-cm}$. As can be seen from Figure 1, $C_{ox} = 2124 \text{ pF}$ and $C_{inv} = 496 \text{ pF}$.

Fig1 ; IDEAL , $A = 0.0400 \text{ cm}^2$

Shifts in flat band from the ideal value can be caused by metal semiconductor work function differences, interface traps, fixed oxide charge, and mobile ions. In order to measure flat band shifts one normally measures the shift from the ideal capacitance at zero bias. However, as discussed later in this paper the low values of C_{ox} obtained in this experiment forced redefinition of flat band shift (ΔV_{fb}). Flat band was defined for the 0.0400 cm^2 gate capacitor as the shift from 1200 pF and for the 0.0225 cm^2 gate capacitor as the shift from 600 pF . These values were chosen for convenience and were consistent through the experiment.

EXPERIMENT

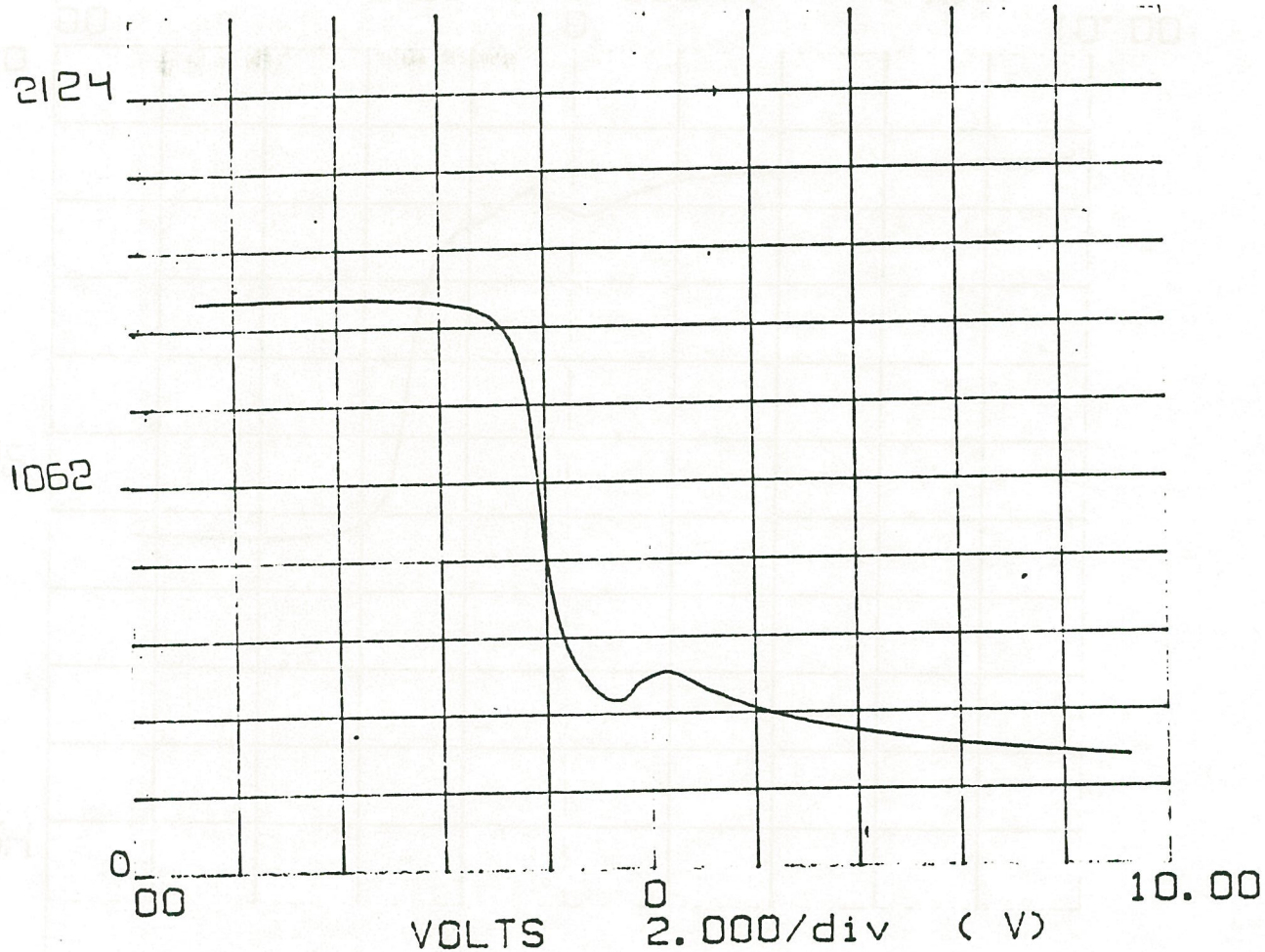
Monsanto p-type (100) $6.29 - 8.51 \Omega\text{-cm}$ boron doped wafers were cleaned using a standard RCA clean. The lot was broken into two groups and thermally oxidized in dry O_2 . Group 1 was oxidized for 135 minutes at 950 C . Group 2 for 15 minutes at 1100 C . Ellipsometry measurements were performed indicating the thickness of both films to be 650 \AA . Next Al was deposited and patterned to form the gate of the capacitors. Two different size capacitors were fabricated, 0.0400 cm^2 and 0.0225 cm^2 . At this point high frequency capacitance - voltage measurements were performed. Problems in obtaining good capacitance - voltage curves led to the decision to add a ohmic back contact. The wafers were next cleaned using a standard RCA clean and stripped of the backside silicon dioxide. Immediately following the oxide strip, the backside of the wafers were coated with Al and sintered in forming gas at 450 C for 15 minutes. Finally, the capacitors were tested using high frequency capacitance - voltage measurements.

***** GRAPHICS PLOT *****

CAP(PF)

Variable1:
 VS2 -Vs2
 Linear sweep
 Start .0000V
 Stop 1.0000V
 Step .0040V

Constant:



***** GRAPHICS PLOT *****

CAP (PF)

2124

1062

0

00

VOLTS

0

2.000/div (V)

10.00

Variable1:

VS2 -Vs2

Linear sweep

Start .0000V

Stop 1.0000V

Step .0040V

Constants:

Fig 2 ; $A = 0.0400 \text{ cm}^2$
 $T = 950 \text{ C}$

Fig 3 ; $A = 0.0225 \text{ cm}^2$
 $T = 1100 \text{ C}$

RESULTS

Figures 2 and 3 show typical high frequency capacitance - voltage curves for the $A = 0.0400 \text{ cm}^2$ 950 C and 1100 C capacitors. Comparing these plots with the ideal curve (fig. 1) indicates that Cox experimental was considerably less than Cox theoretical and that the 1100 C process yielded a larger flat band shift than the 950 C capacitor.

The fact that Cox experimental was less than Cox ideal is unexplained at this time and requires further investigation. Because of the Cox discrepancy, ΔV_{fb} had to be redefined (see the experimental section) so that measurements could be obtained on the straight line portion of the curve between the accumulation and inversion regions.

Table 1 compares Cox, Cinv and V_{fb} with the ideal, 950 C, and 1100 C capacitors for $A = 0.0400 \text{ cm}^2$ and $A = 0.0225 \text{ cm}^2$. As can be seen from these results the 1100 C process had a smaller flat band shift for both the large and small capacitors. By using the 1100 C oxide over the 950 C oxide the flat band voltage shift was observed to decrease by 1.01 volts and 1.81 volts for the large and small capacitors respectively. This observation indicates that the 1100 C oxidation is preferred over the 950 C oxidation.

	$A = 0.0400 \text{ cm}$			$A = 0.0225 \text{ cm}$		
	IDEAL	950 C	1100 C	IDEAL	950 C	1100 C
Cox (pF)	2124	1322	1522	1194	808	976
Cinv (pF)	496	355	422	274	224	250
V_{fb} (V)	0	-3.39	-2.38	0	-3.86	-2.05

TABLE 1

CONCLUSIONS

Preliminary results show the 1100 C oxidation superior to the 950 C oxidation. However, problems with Cox experimental versus Cox theoretical shows that more research is needed in this area.

ACKNOWLEDGEMENTS

Thanks to Michael Jackson for advice rendered.

REFERENCE

[1] --- MODULAR SERIES ON SOLID STATE DEVICES.