# The Role of Fluorine in Growth Rate Enhancemen and Charge Suppression on a Low Temperature Thermally Grown SiO2 Interface Layer

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*Abstract*— **Integration of CMOS devices on to glass substrates has many process constraints. One of these is the melting point of the substrate, which is much lower than silicon. Normally a thermal oxide is desired for use as the gate dielectric, but at the lower temperature constraints due to the substrate it is not possible. One potential solution to this is they use of fluorine as an oxidation enhancement source is the ambient.**

*Index Terms*—**Thermal Oxide, AR/$F_2$ , Gate Dielecti Thin Film Transistors**

## I. Introduction

A quality thermal oxide at low temperatures, below 700°C is not possible using standard oxidation techniques. To try and promote a higher oxidation rate and create denser and more quality oxide fluorine can be added into the ambient. The fluorine also acts as an etchant to any oxide that has been grown on the substrate already and this effect can override any enhancement and lead to etching at high fluorine concentrations [1]. The balancing of the enhancement and etching needs to be achieved and testing of the dielectric properties of the resulting oxide growths.

## II. Equipment Setup

The experiment was done with the following conditions; a horizontal hot-walled furnace with an 800°C torch was outfitted with a direct injection Ar/$F_2$ inlet with a ratio of 95 to 5. A mass flow controller was used to control Ar/$F_2$ and $O_2$ flow. The experiment used 4" p-type bare Si wafers, and the $O_2$ flow rate was held at 5 Lpm for the experiemtnt while the Ar/$F_2$ was varied from 0 to 330 sccm per minute. The temperature was kept constant at 700°C and the resulting oxide thickness measurements were performed using a Woollam VASE ellipsometer. Oxide quality was investigated using C-V characteristics measured using evaporated Al and sputtered Mo capacitors which had a 2 hour 600°C $N_2$ anneal preformed after the sputter.

## III. Growth Rate Results

The experiment showed that there was a enhancement of up to three times the oxide thickness and a great reduction in the amount of void space in the oxide compared to a run with no fluorine added. Over the range of fluorine flow rates the transition from enhancement to etching dominance starts to occur which decreased oxide thickness as well as oxide density.

| Sample | Ar/$F_2$ Flow (sccm) (5% $F_2$ in argon) | Thickness (Å) | Void Space |
|---|---|---|---|
| 0 | 0 | 66 | 37% |
| 1 | 220 | 176 | 1.6% |
| 2 | 110 | 113 | 16% |
| 3 | 110 | 108 | 10% |
| 4 | 330 | 70 | 40% |

Fig. 1. Experimental results of oxide growths over varying AR/$F_2$ flows

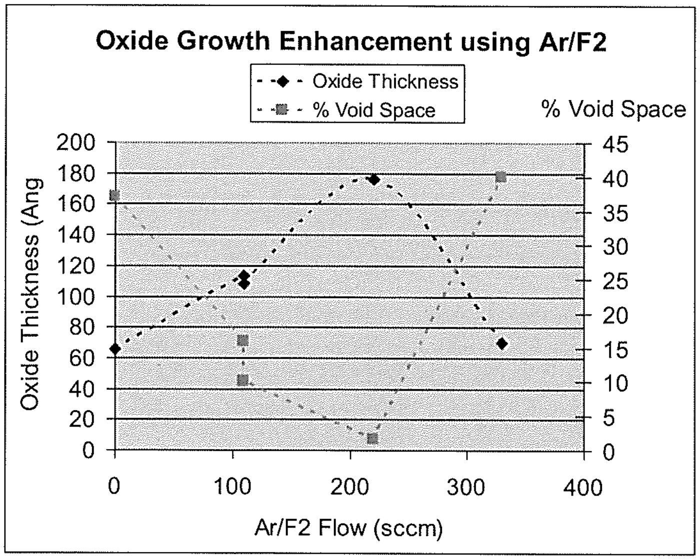


Fig. 2. Graphical representation of results

## IV. IV.C-V MEASUREMENT RESULTS

The C-V testing of the aluminum capacitors shows that the oxide was good quality with sharp C-V curves, with the electrical and optical data matching well. The number of surface states was slightly higher than desired but reasonable. A sinter was prefromed on the capacitors which lowered the charge levels and improved the C-V characteristics some.

| | Optical Thickness (Å) | Electrical Thickness (Å) | Vt (V) | Nss |
|---|---|---|---|---|
| Sample 1 Sinter | 176 | 193 | -0.43 | 3.17 |
| Sample 2 Sinter | 113 | 119 | -0.41 | 4.42 |
| Sample 3 No Sinter | 108 | 115 | 0.67 | -8.8 |

Fig. 3. C-V test summary

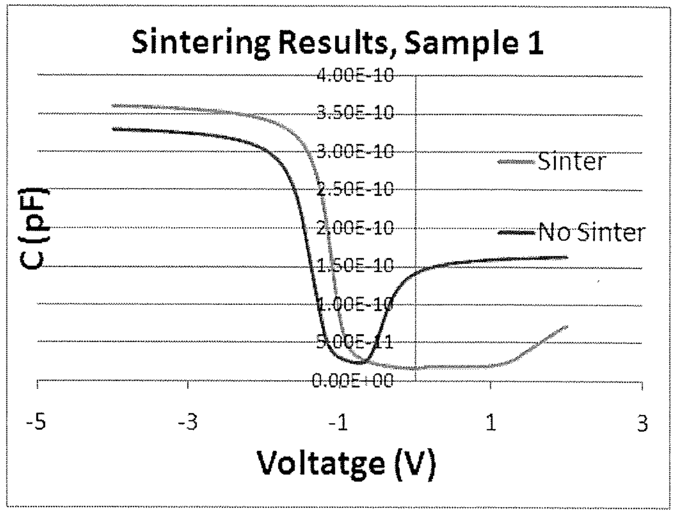


Fig. 4. C-V test results and sinter comparison

The molybdenum sputter was done in order to determine the feasibility of directly sputtering Mo as a gate onto the oxide. The results show that there was a large positive shift in the threshold voltage which is most likely due to damage the plasma introduced. Other than the increase of fixed charge there was only a slight degradation of the C-V characteristics and if the $V_t$ shift is predictable the process could be viable. A sinter was preformed on the Mo sample, but for a yet undetermined reason it appeared to only degrade the C-V results.

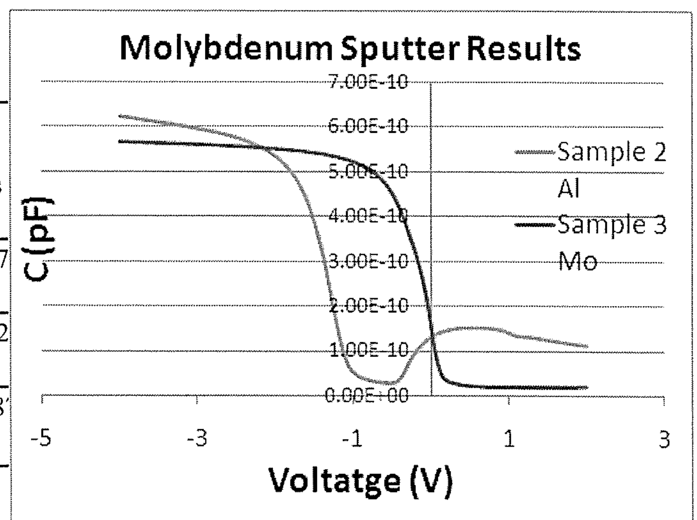


Fig. 5. Al Comparison of Al and Mo samples

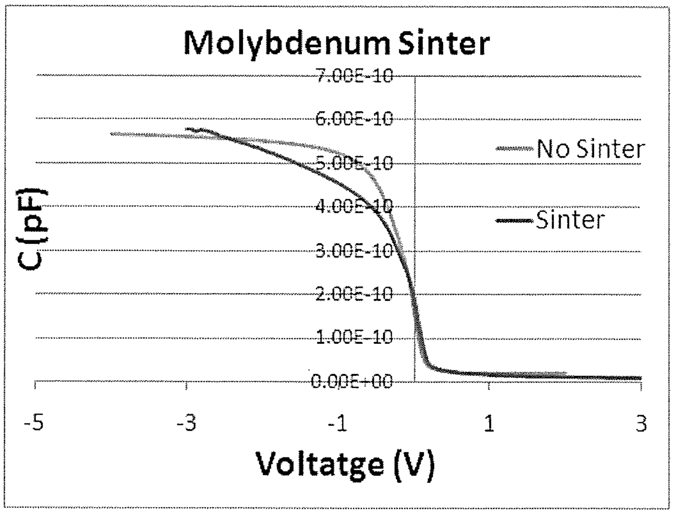


Fig 6. Mo sinter C-V results

## V. V.Conclusions/Future Work

Growth rate enhancement was observed in the process window, and further oxidation runs should be completed to more precisely find the optimal fluorine concentration for oxide enhancement. Also a study into the effects of different soak time and temperatures should be conducted to see the its effects on the optimal fluorine concentration.

The Mo sputter still needs work to be useful for device fabrication. First the sintering process needs to be better understood and the process improved. The anneal should also be improved upon to improve the quality of the Mo process.

## VI. References

1. M. Morita, et al., "A New Si02 Growth by Fluorine-Enhanced Thermal Oxidation," IEDM., vol. 84., pp. 144-147, 1984.