Thermal SiO_2 Growth Rate Enhancement at Low Temperatures using an NF_3 Additive

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Abstract—**Thermally grown silicon oxide growth enhancement using small amounts of NF_3 was investigated, examining both growth rate and interface quality. Low temperature results showed noted growth rate enhancement at temperatures above 700° C. Interface quality showed significant improvement. Further enhancement is expected through modified chamber and equipment design.**

Index Terms—**Thermal Oxide, NF_3, Gate Dielectric, Thin Film Transistors**

I. Introduction

THE introduction of a viable thermal oxide process could remedy several current challenges facing high-mobility TFT applications. Studies have shown potential for enhanced oxide growth and interface state reduction using both NF_3 and F_2 additives in an oxidizing ambient [1], [4]. This research project revives this study in a new context where a high-temperature rapid thermal process is not applicable.

II. Equipment Setup

The test setup was constructed as follows; a horizontal hot-walled furnace with an 800°C torch (for pyrogenic steam) was outfitted with a direct injection NF_3 inlet. Figure 1 shows a diagram of the furnace. A mass flow controller rated at 2-8 sccms was used to control NF_3 flow. The experiment used 4" p-type bare Si wafers. Flow rates of O_2 and NF_3 were varied from 2-8 sccm and 2.5-10 lpm, respectively. A temperature range from 600-800°C was investigated. Thickness measurements were performed using a Woollam VASE ellipsometer, a Rudolph ellipsometer, and a Tencor SM300 SpectraMap. Oxide quality was investigated using C-V characteristics measured using an MDC mercury probing station.

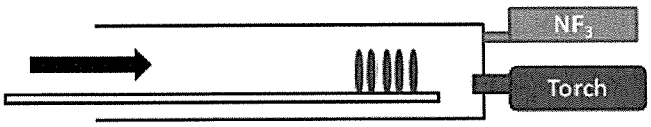

Fig. 1. Diagram of Equipment Setup.

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III. Growth Rate Results

Initial results on screening experiments done at 600°C were inconsistent and non-uniform, and thus further runs were shifted to higher temperatures. Figure 2 shows the dependence of growth rate on NF_3 concentration found from oxide test runs performed at 700°C and 800°C. The greatest enhancement in oxidation growth rate was found at a maximum NF_3 flow condition of 8 sccm; the O_2 flow setpoint at either 5 lpm or 10 lpm showed little effect. Results generally indicated a 2x increase in growth rate. Longer soak runs were performed at 5 lpm O_2 and 8sccm NF_3, with results shown in Figure 3. These results along with literature [2-5] suggest that further rate enhancement may be possible using a different gas mixture configuration, and/or a different chamber design.

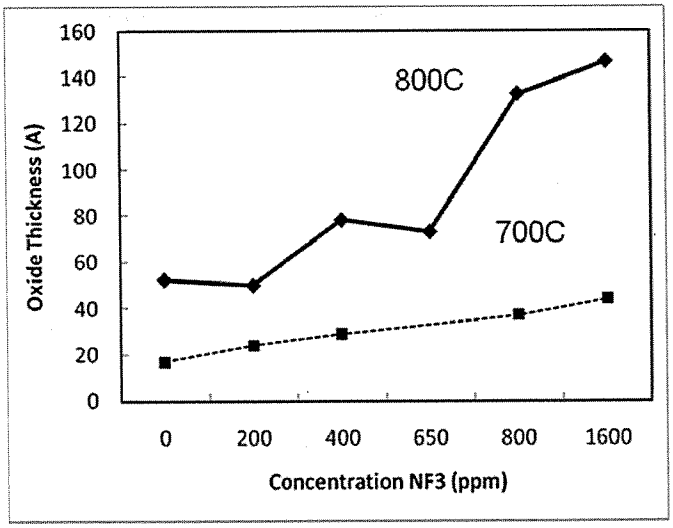


Fig. 2. Growth rate dependence on NF_3 concentration at 800°C and 700° C for 1 hour.

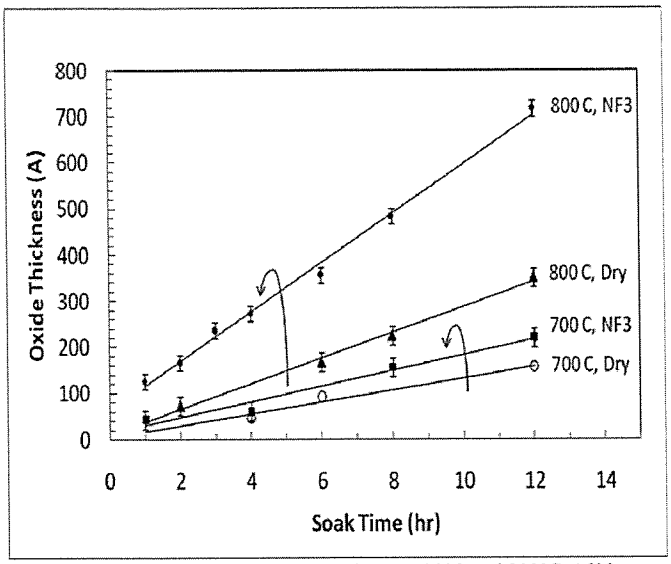


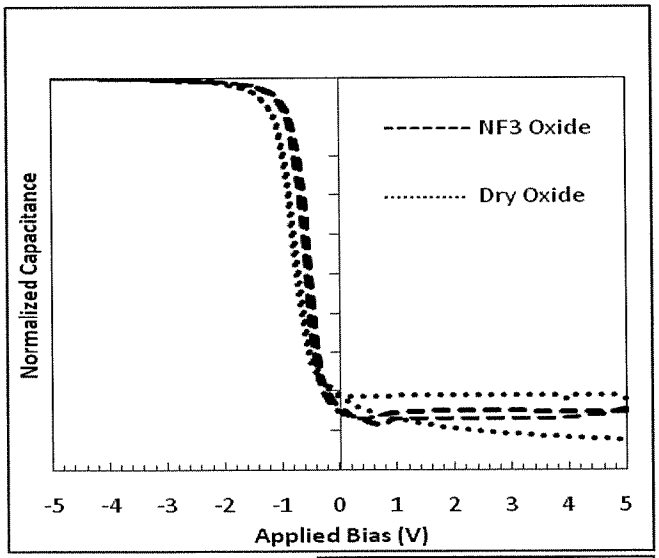
Fig. 3. Oxide Thickness dependence on time at 700°C and 800°C, 1600 ppm NF3.

IV. C-V Measurement Results

Initial electrical measurements were performed using an MDC mercury probe capacitance voltage station. Figure 4 shows a sample of C-V measurement sweep using the Hg probe station. No significant shift in oxide quality was observed between dry and NF_3 enhanced growth runs. Derived electrical thickness showed some deviation from optically measured results.

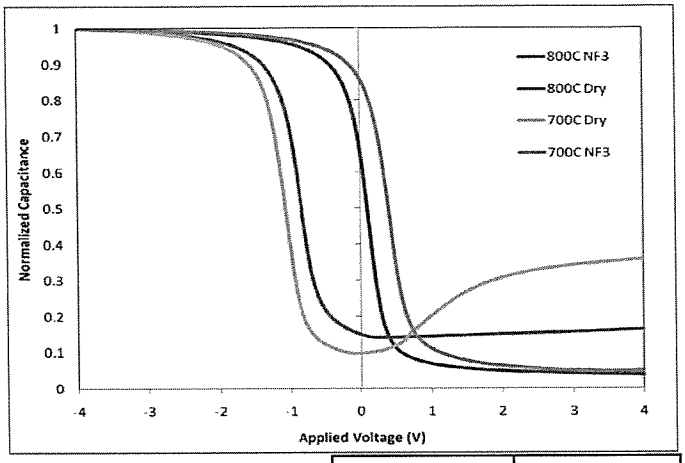
Aluminum capacitors were then fabricated to verify results. Sample wafers were coated with aluminum using a CVC evaporator, patterned, and etched using wet etch chemistry. The wafers were then sintered at 450° C in an N_2/H_2 ambient.

Measurements were preformed on an MDC probing station. Figure 5 shows a sampling of the C-V results.



	Electrical Oxide Thickness	Surface State Density
800C, 2 hour, 1600 ppm NF3	256	4.56e10 cm^-2
800C, 4 hour, Dry Oxidation	293	3.41e10 cm^-2

Fig. 4. Hg-probe electrical characterization results.



	Electrical Oxide Thickness	Surface State Density
800C, 2 hour, 1600 ppm NF3	194 Å	4.51e10 cm^-2
800C, 4 hour, Dry Oxidation	203 Å	1.33e11 cm^-2
700C, 4 Hour, 1600 ppm NF3	209 Å	5.18e10 cm^-2
700C, 12 hour, Dry Oxidation	227 Å	1.32e11 cm^-2

Fig. 5. Al capacitor C-V measurement results. Tests performed at 30° C.

Significant interface state reduction is observed in the NF_3 enhanced growth runs. This is thought to be caused by the influence of fluorine during the growth process; F atoms are suspected to tie up Si dangling bonds as a placeholder for O_2 molecules [4].

V. Conclusions/Future Work

Growth rate enhancement was observed for temperatures greater than 700° C. However, results from less than 700° C runs were inconclusive. C-V measurement data shows a substantial improvement in oxide quality through the use of NF_3. This has significant importance to proposed TFT applications. For this work to be applicable, oxide quality must match or exceed currently available techniques.

Optimizations to chamber design based on previous studies and data from this study are expected to further improve growth rate. By plumbing the NF_3 source through the torch, the molecules are expected to dissociate, freeing up the fluorine to interact with the oxide growth.

References

[1] D. N. Kouvatsos, F. A. Stevie, R. J. Jaccodine, " Interface State Density Reduction and Effect of Oxidation Temperature on Fluorine Incorporation and Profiling for Fluorinated Metal Oxide Semiconductor Capacitors," *J Electronchem. Soc.*, **Vol. 120, No 4**, April 1993.

[2] D. N. Kouvatsos, J. G. Huang, R. J. Jaccodine, "Fluorine-Enhanced Oxidation of Silicon," *J Electronchem. Soc.*, **Vol. 136, No 6**, June 1991.

[3] A. Kazor, C. Jeynes, I. W. Boyd, "Fluorine enhanced oxidation of silicon at low temperatures," Appl. Phys. Lett. 65 (12) Sept. 1994

[4] J. G. Huang, R. J. Jaccodine, D. R. Young, "Improvement of the SiO_2 interface of metal-oxide-semiconductor devices using gate dielectrics formed by NF_3-aided oxidation and N_2O post-annealing," *J Applied Physics*, 75 (5) March 1994

[5] J. G. Huang, R J Jaccodine, "Fast Growth of Thin Gate Dielectrics by Thermal Oxidation of Si in N_2O Gas Ambient with Low Concentration of NF_3 Addition," *J Electronchem. Soc.*, **Vol. 140, No 2**, February 1993.