

Development of LTO LPCVD Process for 6" Wafers at RIT

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Abstract--- Low Temperature Oxide (LTO) thin films were prepared using a Low Pressure Chemical Vapor Deposition process. By employing statistically designed experiments, the number of experimental runs required was minimized. The full-factorial experimental design was set up to examine effects temperature, gas flow and pressure had on deposition rate, wafer to wafer uniformity, within the wafer uniformity and within run uniformity. The average deposition rate found to be 112Å per minute. The LTO baseline process conditions optimized based on the results of this project are: Temperature of 410C, pressure of 330mTorr and gas flow ratio of 0.55.

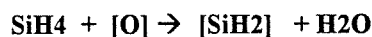
1. INTRODUCTION

Low Temperature Chemical Vapor Deposition of silicon dioxide thin film is used in numerous VLSI manufacturing process. This type of film is typically used as insulation between poly silicon /metal layers, metal layers in multilevel systems, as diffusion and ion implantation masks, or as final passivation layers. At the Rochester Institute of Technology, low temperature silicon dioxide film use as insulation film in multi-layer metallization for CMOS and MEMS integrated circuits. The main objective of this experiment to set up a 150mm (6") wafers process for Low Temperature Oxide (LTO) at RIT's new Low Pressure Chemical Vapor Deposition (LPCVD) ASM system. The process was characterized by applying traditional statistical studies of response surface techniques. By employing statistically designed experiments, the number of experimental runs required was minimized. The experimental design was set up to examine effects temperature, gas flow and pressure had on deposition rate, wafer to wafer uniformity, within the wafer uniformity and within run uniformity. In this design, a two level full factorial screening experiment was conducted where the temperature, gas flow and pressure were varied.

LPCVD system had three zones temperature variables. From preliminary runs and based on some already known facts, first zone temperature was set up constant at 390C, which helped to minimized the number of the runs in this experiment. The total number of runs was 9.

LTO PROCESS CHEMISTRY

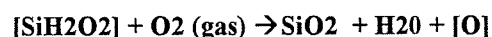
1) Initiation with excited oxygen radical, represented by square brackets, to form silyl radical.



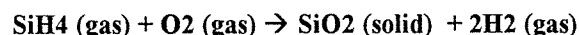
2) Branching to form an intermediates Si-H-O compound:



3) Regenerating and terminating:



4) Overall Reaction is



The oxygen-silane gas ratio is calculated by gas flow of oxygen divided by total flow of the gas (Oxygen +Silane). The gas flow of Oxygen was varied from 96sccm to 117sccm and gas flow of silane kept constant at 81sccm. Mass flow controllers regulated the gas flows.

2. EXPERIMENTAL DESIGN

(a) Full – Factorial Design

The LPCVD system had three zones temperature variables; first zone temperature kept at constant while varies other two zones temperature. Table1 shows the design set up used in this experiment.

Table 1. Experimental Conditions.

Experimental Factor	Range
Deposition Temperature	400 to 420 C
Deposition Pressure	272 to 400 mTorr
Gas Ratio (Oxygen / Silane)	0.54 to 0.59

(b) Responses

At each treatment combination, there were 5 wafers measured to analyze the wafer to wafer, within wafer, and within run uniformity. Deposition time was 15 minutes for all treatment combinations. Thickness measured on Ellipsometer for 9 positions per wafer. The design and data analysis were performed with the RS/6 software at RIT. Table 2 illustrates the response variables for this LTO process. Table 3 was generated from RS/6 software randomly at each treatment combination.

Table 2. Response Variables

Response
Deposition Rate (A/min)
Wafer to Wafer uniformity
Within Wafer uniformity
Within run uniformity

Table 3. Design of Experiment Worksheet

RUN#	TEMP(ZONE2)	PRESSURE(mTorr)	SiH4(sccm)	O2(sccm)	Ratio
1	400	272	81	96	0.54
2	420	272	81	117	0.59
3	420	400	81	96	0.54
4	400	272	81	117	0.59
5	420	400	81	117	0.59
6	410	336	81	106	0.57
7	400	400	81	96	0.54
8	420	272	81	96	0.54
9	400	400	81	117	0.59

3. ANALYSIS

(1) Deposition Rate

Analysis of variance allowed a residual variance (ANOVA) and standard error to be computed. The coefficient with the highest sum of squares was the most significant factor in the design. Non-significant factors were removed, ANOVA was revised and linear regression model equations were obtained for the response variables.

Regression model Equation 1 for the Deposition Rate, equation 2 for the wafer-to-wafer uniformity, equation 3 for within wafer uniformity and equation 4 obtained for the within run uniformity.

Equation (1)

$$\text{Dep. Rate} = 88.45 - 1.5(\text{Temp}) - 5.701(\text{Gas}) - 6.5(\text{Temp} * \text{Press}) + 7.7500(\text{press} * \text{Gas}).$$

Equation (2)

$$\text{Wafer to wafer (Unif)} = 0.09700 + 0.02925(\text{Temp}) + 0.02400(\text{Press} * \text{Gas}).$$

Equation (3)

$$\text{Within wafer (Uni)} = 0.1724 + 0.0515(\text{press}) + 0.0362(\text{Gas}) - 0.0422(\text{Temp} * \text{Press}) - 0.0225(\text{Temp} * \text{Gas}) + 0.0195(\text{Press} * \text{Gas}).$$

Equation (4)

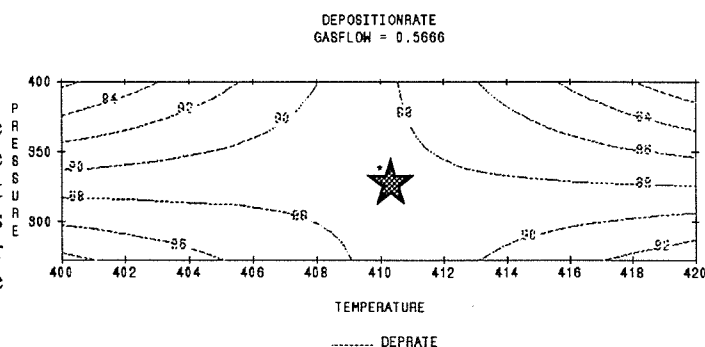
$$\text{Within wafer (Uni)} = 0.1724 + 0.0515(\text{press}) + 0.0362(\text{Gas}) - 0.0422(\text{Temp} * \text{Press}) - 0.0225(\text{Temp} * \text{Gas}) + 0.0195(\text{Press} * \text{Gas}).$$

4. RESULTS

(a) Deposition Rate

The contour plot of figure 1 shows minimal variation and optimum deposition rate can be obtained at a temperature of 410C, pressure of 330mTorr and fixed gas ratio of 0.566. Therefore, temperature will be fixed at 410 C for uniformity analysis.

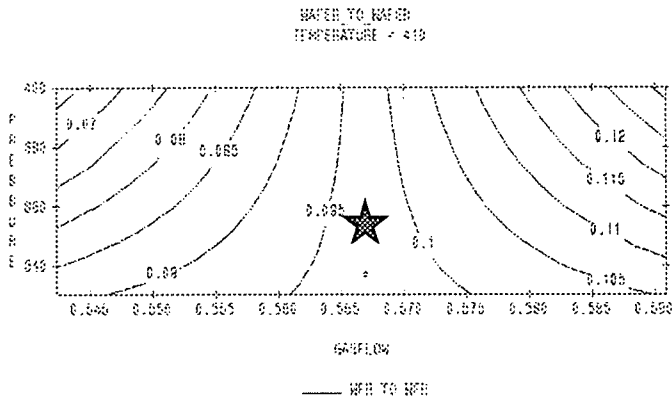
Figure 1. Contour plot of Deposition Rate at a fixed gas ratio.



(b) Wafer to wafer uniformity

The contour plot of figure 2 shows that low gas flow ratio and high pressure give ample variations. Gas ratio ranging from 0.55 to 0.57 and low pressure of (340mTorr) give minimum variation, which would be an optimum point for this process.

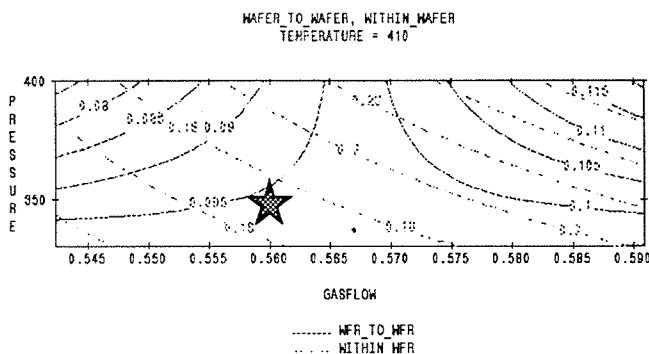
Figure 2. Contour plot of wafer - wafer uniformity at a fixed gas flow ratio.



(c) Within wafer uniformity

The figure 3 shows wafer to wafer and within the wafer uniformity. Low gas flow and pressure give minimum variation and good uniformity.

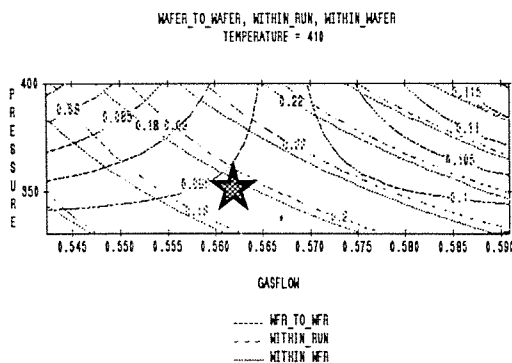
Figure 3. Contour plot of within wafer uniformity.



(c) Within run uniformity

The contour plot shows uniformity of wafer to wafer, within the wafer and within runs. At 0.55 gas flow ratio and low pressure of (330mTorr), minimum variation and good uniformity can be obtained from figure 4.

Figure 4. Contour plot of within run uniformity.



5. CONCLUSION

The objective of this project was to characterize the LTO process at RIT and to create a baseline LTO process. The LTO baseline process conditions recommended, based on the results of this project, are: 410C of deposition temperature, pressure of 300mTorr and gas flow ratio of 0.55. These conditions were obtained from run number six. This optimum result average deposition rate calculated as 112A per minute.

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