ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title: A Characterization and Process Control Plan for a New Plasma Photo Resist Stripper

Course:
Year: 1993
Author(s): G. Miller

Report No: P93026

ETM OFFICE USE ONLY	
Report No.:	See Above
Type:	Student Project
Note:	This project is in the filing cabinet in the ETM department office.

Abstract: This project developed a characterization and process control plan for a new plasma photo resist stripper as part of the overall continuous improvement effort in the photo resist/ion implant sequence.

Characterization and Process Control Plan For a New Plasma Photo Resist Stripper

Gordon Miller

EMP-P9326

EMGT 510 - TERM PROJECT

SUBMITTED TO: DR. DECKRO
SPRING 1993

SUBMITTED BY: GORDON MILLER

INTRODUCTION

The purpose of this project is to develop a characterization and process control plan for a new plasma photo resist stripper as part of the overall continuous improvement effort in the photo resist/ion implant sequence.

BACKGROUND

Fabrication of integrated circuit wafers involves numerous (30 to 60) processing sequences. The drive to reduce the IC chip size while increasing the active devices results in a need for continuous process improvement and new process development. The specific problem being studied for this project is the trickle down effect of a major process change. Photo resist is used to mask areas of the wafer as various processes are completed in the exposed areas of the circuit. Ion implanters are used to implant precise amounts of atomic elements into device areas. The use of these implanters, however, degrades the protective photo resist layer due to their high energy. Deep UV (ultraviolet) exposure of the photoresist will cause a "hardening" of the top resist surface. This harder surface degrades at a much slower rate than non-hardened resist, giving the required protection during ion implant. The resist, however, is now much harder to remove in the normal wet chemical stripping process. In addition to extending the wet stripping process time, some of the hardened resist can remain in the solution and adhere to the wafer surface as it is removed from the chemical bath. The resulting contamination is not acceptable or easily removed.

A potential solution is to use an oxygen plasma stripping system prior to the wet stripping process, to remove the hardened resist. This process must be carefully controlled to remove all the hardened resist without clearing the underlying softer non-hardened resist from the wafer. Resist contains metallic ions which can not be volatilized. If the resist is cleared completely in a plasma, these mobile ions would be left on the wafer surface. This mobile ion contamination is also unacceptable.

PROJECT PLAN

The first step in the project plan is to develop a plan to characterize the uniformity and etch rate of the new system. Second is to develop a control chart procedure to check for variances in these parameters.

Machine characterization plan.

In order to effectively characterize the plasma stripper, a primary list of key operating characteristics that influence uniformity and etch rate was made.

* System pressure
* Process gas flow rate
* RF power level

Wafer chuck temperature
"O" ring leaks - chamber
"O" ring leaks - loading door
Placement position of wafer on chuck

Since the machine has a robotic wafer loading system and computer controlled settings, the operator variables in operating the equipment were not considered primary.

An L8 experimental design was chosen to evaluate the first three listed machine process variables. The experimental design is listed in the appendix.

A commercial software package was used to aid in the design and evaluation of the experiment. High and low operating values were chosen for each of the machine variables. The experimental design cells were randomized (see design setup table).

Data collection plan.

In order to obtain accurate resist thickness measurement before and after the strip process, the Prometrix (FP-5000) automated measurement system will be used. This system has various standard material measuring programs and automated positioning programs. The positive resist over oxide program with a 9 point measurement pattern will be used. The individual thickness measurements can be stored in a computer file. This raw data file will be converted to a standard spreadsheet format for computation of the individual and subgroup data. Macro's to accomplish this are stored in the "Matr-evl" file.

The data will be used to establish uniformity and etch rate. Uniformity will be calculated as the (Range)/(2*Mean). Etch rate will be calculated as the (Mean)/(Etch time).

Three separate L8 experiments will be conducted. The data will be evaluated using the "Design Cube" software package.

EXPERIMENTAL RESULTS

The initial tests were completed on May 20, 1993. The spreadsheet calculations and L8 design analysis are in the appendix.

The analysis indicates that the low set points for pressure, gas flow and power give the best uniformity. The interactions between the three variables also show the same trends.

The analysis for maximum etch rate indicates that the low pressure but high power give the highest rates. Gas flow has no primary effect. The interactions reveal that pressure is dominate over the power. The best etch rate is obtained at the low set points for pressure and power.

Pressure	3.60 Torr
Gas Flow	45%
Power	450 Watts

This result establishes the base line machine operating parameters to be used for the second step of the project plan. The second step will use a standard X-bar & R chart to evaluate the process variation.

PLAN FOR CONTINUOUS IMPROVEMENT

Since time has not permitted the completion of the second step, the establishment of the machine variability using the X-bar & R charts for both uniformity and etch rate must be done.

Using this baseline data, the next step is to run paired etch tests between non-deep UV hardened resist wafers and deep UV hardened wafers. Comparison of the etch rate and uniformity offsets between the two sets of charts will indicate variations in the thickness and hardness of the deep UV layer.

The next phase of the process evaluation is to expand the cause and effect relationships and process control charts to the process steps preceding the resist strip step. Implementation of this phase involves expanding the project team to include the engineers and operators at the preceding steps. The same style of equipment characterization and control charting will need to be done.

If the etch rate for the deep UV hardened resist goes out of control, but the non deep UV chart remains in control, then a process shift outside the resist strip step is indicated.

Perhaps the deep UV system is unstable and not curing the resist to the same degree of hardness. If both charts move out of control, then the resist system is out of control.

CONCLUSIONS

The results of the project could be improved by plotting each of the individual measurement locations to look for trends across the wafer.

A better technique for measuring the actual thickness of the deep UV hardened layer is needed, rather than relying on the correlation between hardened and non hardened resist etch rates.

One conclusion from the project is that the same techniques used to solve problems can effectively be used to characterize new equipment and process changes to prevent problems upon implementation. Using sensitivity and optimization experimental design to establish baseline data for control charts is very useful.

APPENDIX

This appendix contains the L8 experimental design matrix with the experimental data.

Process Flow Steps for Photoresist/Ion Implant

The "spreadsheet" raw data is also listed.

Key tools used include:

Design Cube software by QINAS, INC., for Design of Experiments utilizing Taguchi Concepts. Copyright 1986.

Prometrics FP-5000 Automated Resist measurement system. Standard positive resist over oxide program plus standard 9 point measurement.

Matrix 10X Downstream Plasma Photo Resist Etcher.

Symphony Software, release 2.0, with custom macro's "Matr-evl".

Process Flow Steps for Photoresist/Ion Implant

Dehydration Baking and Priming
Resist Coating
Resist Soft-Bake
Resist Exposure
Resist Development
Resist Post Bake and Deep UV Hardening

Ion Implant

Resist - Oxygen Plasma Resist Strip
Resist - Wet Strip
Resist - Spin, Rinse & Dry

ATD - MATRIX PHOTO RESIST STRIPPER EVALUATION
L8 DESIGN

Grp.	Factor	Name	Level 1	Level 2
I	1 P	Pressure	3.60	4.40
II	2 GF	Gas Flow	30	45
II	3 PxGF	PxGF		
III	4 W	Power	450	500
III	5 PxW	PxW		
III	6 GFxW	GFxW		
III	7 e			

2 way Interactions

2x3	4x5	6x7
1x3	4x6	5x7
1x2	4x7	5x6
1x5	2x6	3x7
1x4	2x7	3x6
1x7	2x4	3x5
1x6	2x5	3x4

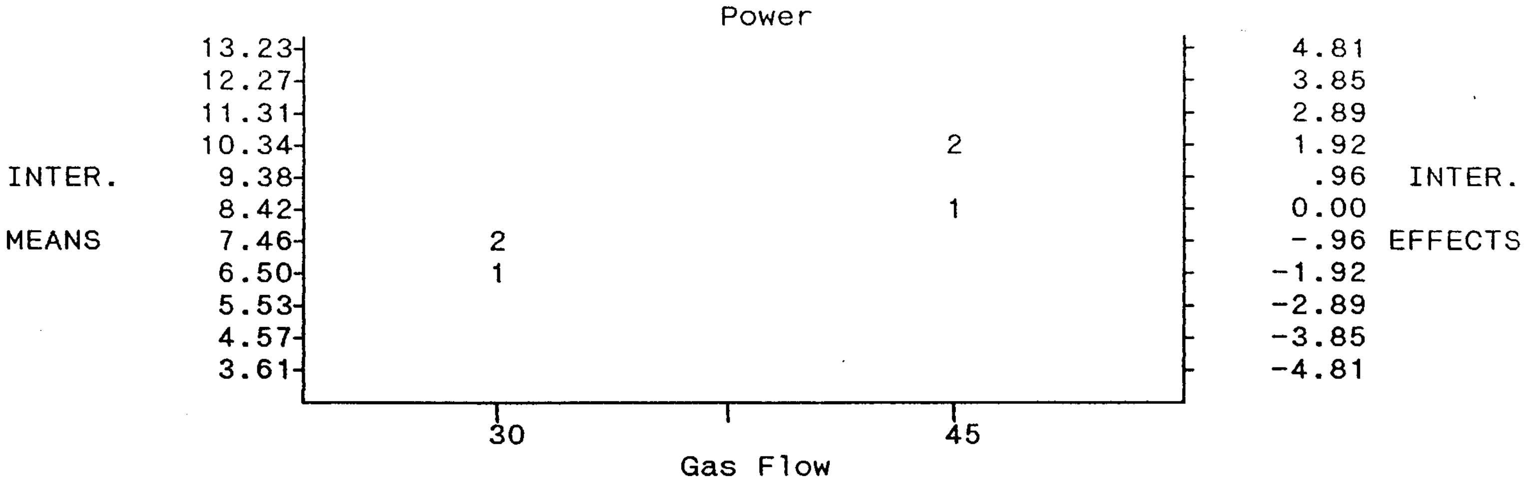
Trial Order	Design No.	FACTORS 1	2	3	4	5	6	7	Uniformity 1	2	3
1	1	1	1	1	1	1	1	1	4.40	5.70	8.20
3	2	1	1	1	2	2	2	2	7.60	7.50	8.30
6	3	1	2	2	1	1	2	2	7.90	8.40	8.90
2	4	1	2	2	2	2	1	1	8.30	6.70	7.20
8	5	2	1	2	1	2	1	2	8.00	8.70	6.60
5	6	2	1	2	2	1	2	1	7.50	8.20	7.00
4	7	2	2	1	1	2	2	1	8.40	8.50	8.70
7	8	2	2	1	2	1	1	2	7.70	14.60	19.10
								Averages	7.48	8.54	9.25

Grand Average 8.42 (REFERENCE)

FACTOR	NAME	LEVEL	LEVEL MEANS	LEVEL EFFECTS	TOTAL EFFECTS
1 P	Pressure	1 3.60	7.42	-1.00	1.99
		2 4.40	9.42	1.00	
2 GF	Gas Flow	1 30	7.31	-1.11	2.22
		2 45	9.53	1.11	
3 PxGF	PxGF	1	9.06	.64	-1.27
		2	7.78	-.64	
4 W	Power	1 450	7.70	-.72	1.44
		2 500	9.14	.72	
5 PxW	PxW	1	8.97	.54	-1.09
		2	7.88	-.54	
6 GFxW	GFxW	1	8.77	.34	-.69
		2	8.08	-.34	
7 e		1	7.40	-1.02	2.04
		2	9.44	1.02	

DESIGN CUBE
INTERACTION PLOTS

Gas Flow x Power



	Gas Flow	Power	MEANS
LEVEL 1x1	30	450	6.93
LEVEL 1x2	30	500	7.68
LEVEL 2x1	45	450	8.47
LEVEL 2x2	45	500	10.60

ATD - MATRIX PHOTO RESIST STRIPPER EVALUATION
L8 DESIGN

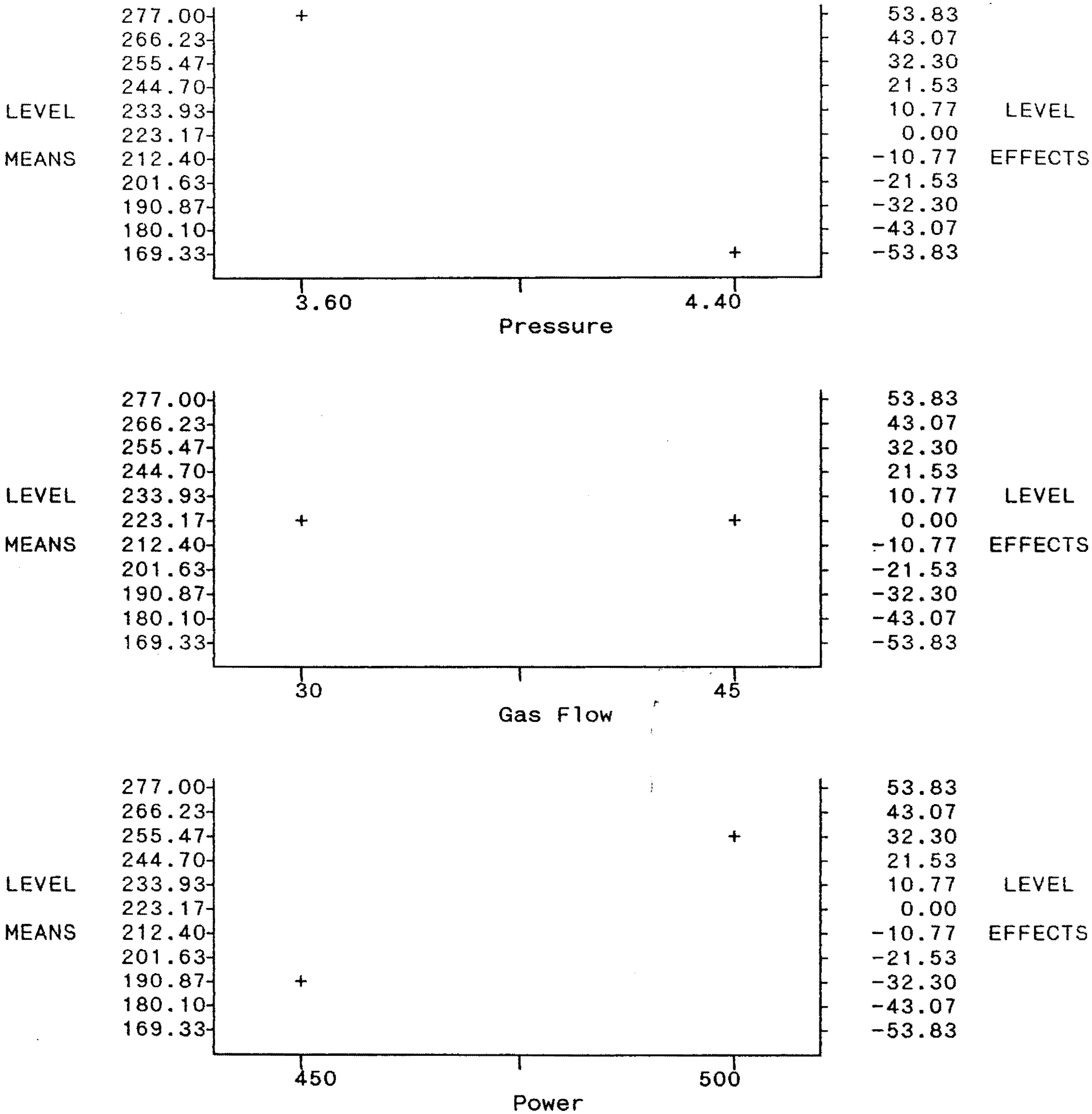
Grp.	Factor	Name	Level 1	Level 2	2 way Interactions		
I	1 P	Pressure	3.60	4.40	2x3	4x5	6x7
II	2 GF	Gas Flow	30	45	1x3	4x6	5x7
II	3 PxGF	PxGF			1x2	4x7	5x6
III	4 W	Power	450	500	1x5	2x6	3x7
III	5 PxW	PxW			1x4	2x7	3x6
III	6 GFxW	GFxW			1x7	2x4	3x5
III	7 e				1x6	2x5	3x4

Trial Order	Design No.	FACTORS 1	2	3	4	5	6	7	Etch Rate (45 sec) 1	2	3
1	1	1	1	1	1	1	1	1	246.00	263.00	273.00
3	2	1	1	1	2	2	2	2	295.00	312.00	305.00
6	3	1	2	2	1	1	2	2	242.00	270.00	255.00
2	4	1	2	2	2	2	1	1	271.00	292.00	300.00
8	5	2	1	2	1	2	1	2	118.00	121.00	128.00
5	6	2	1	2	2	1	2	1	188.00	218.00	219.00
4	7	2	2	1	1	2	2	1	137.00	136.00	137.00
7	8	2	2	1	2	1	1	2	182.00	221.00	227.00
								Averages	209.88	229.12	230.50

Grand Average 223.17 (REFERENCE)

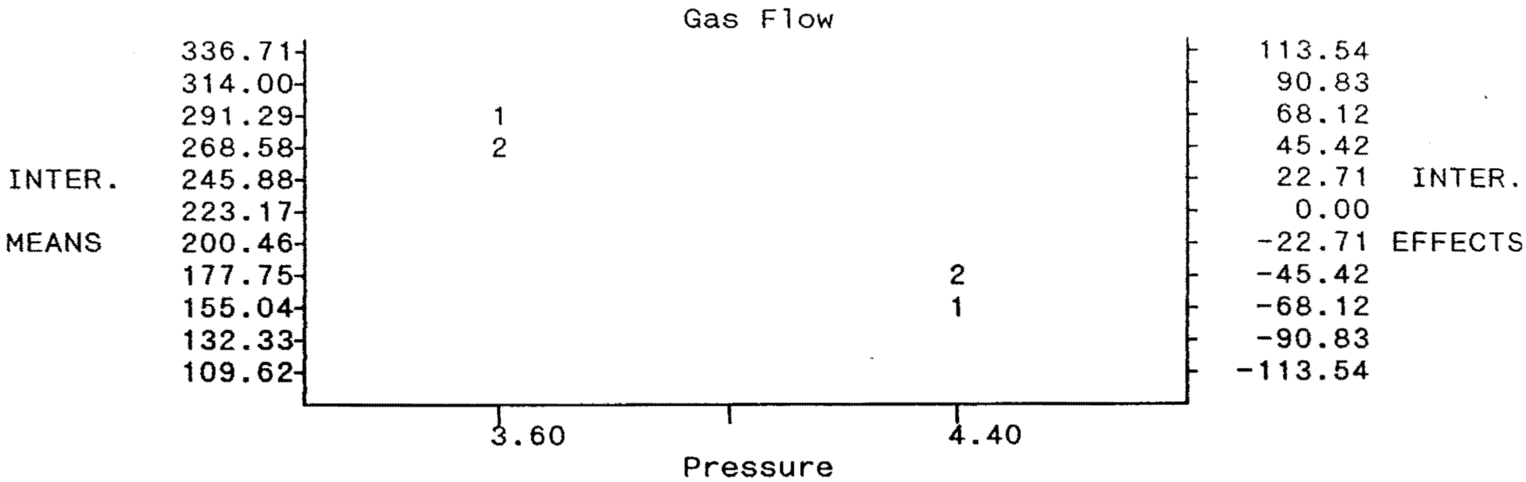
FACTOR	NAME	LEVEL	LEVEL MEANS	LEVEL EFFECTS	TOTAL EFFECTS
1 P	Pressure	1 3.60	277.00	53.83	-107.67 **
		2 4.40	169.33	-53.83	
2 GF	Gas Flow	1 30	223.83	.67	-1.33
		2 45	222.50	-.67	
3 PxGF	PxGF	1	227.83	4.67	-9.33 *
		2	218.50	-4.67	
4 W	Power	1 450	193.83	-29.33	58.67 **
		2 500	252.50	29.33	
5 PxW	PxW	1	233.67	10.50	-21.00 **
		2	212.67	-10.50	
6 GFxW	GFxW	1	220.17	-3.00	6.00
		2	226.17	3.00	
7 e		1	223.33	.17	-.33
		2	223.00	-.17	

ATD - MATRIX PHOTO RESIST STRIPPER EVALUATION
Etch Rate (45 sec)



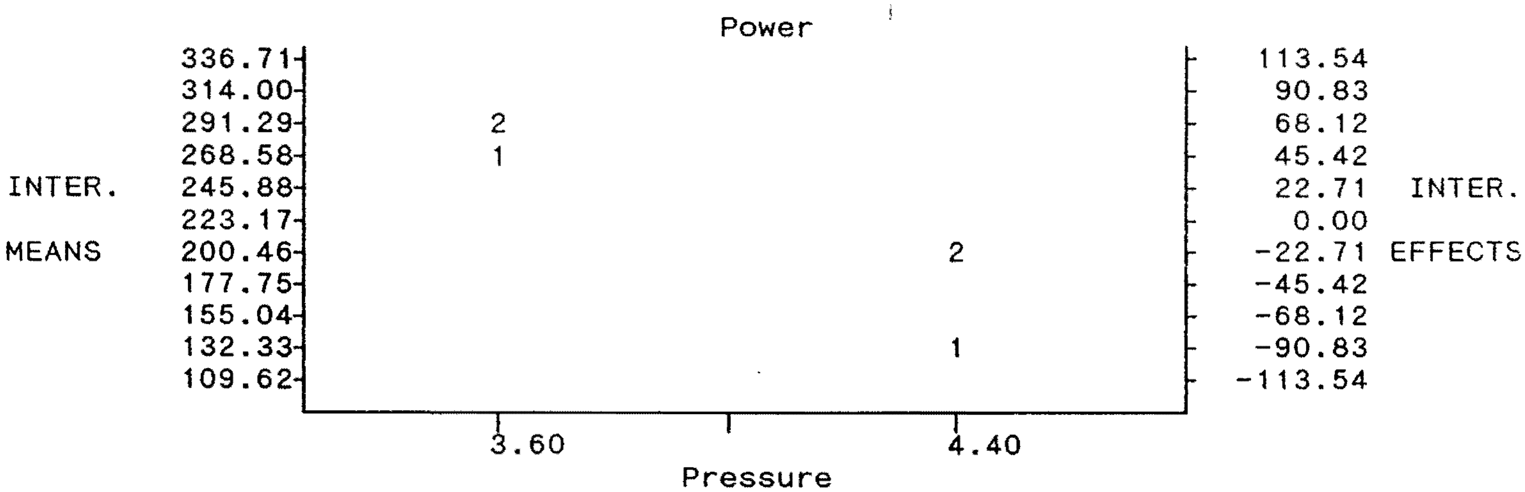
DESIGN CUBE
INTERACTION PLOTS

Pressure x Gas Flow



	Pressure	Gas Flow	MEANS
LEVEL 1x1	3.60	30	282.33
LEVEL 1x2	3.60	45	271.67
LEVEL 2x1	4.40	30	165.33
LEVEL 2x2	4.40	45	173.33

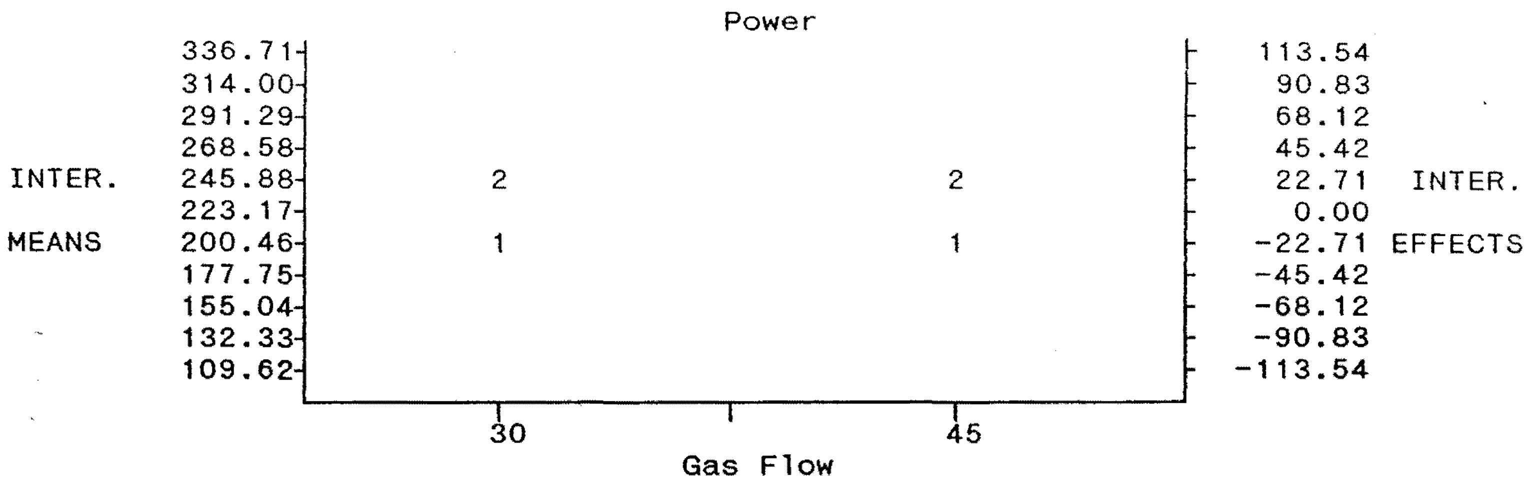
Pressure x Power



	Pressure	Power	MEANS
LEVEL 1x1	3.60	450	258.17
LEVEL 1x2	3.60	500	295.83
LEVEL 2x1	4.40	450	129.50
LEVEL 2x2	4.40	500	209.17

DESIGN CUBE
INTERACTION PLOTS

Gas Flow x Power



	Gas Flow	Power	MEANS
LEVEL 1x1	30	450	191.50
LEVEL 1x2	30	500	256.17
LEVEL 2x1	45	450	196.17
LEVEL 2x2	45	500	248.83

Data Calculation Results

Wafer #	1	2	3	4	5	6	7	8	9	10	11	12
Minimum	6,431	10,521	11,377	12,393	5,704	7,923	10,187	7,599	4,984	11,227	12,175	13,008
Mean	7,047	11,073	12,205	13,290	6,145	8,459	10,902	8,174	5,330	11,856	13,150	14,033
Maximum	8,342	11,504	13,410	14,420	6,732	9,185	11,901	8,865	5,836	12,589	13,931	15,101
One Sigma	560	355	662	646	372	409	583	467	282	481	507	683
Position #1	6,519	10,609	11,377	12,393	5,704	7,969	10,289	7,666	5,021	11,227	12,175	13,008
Position #2	7,020	11,124	12,034	13,037	6,111	8,316	10,611	7,956	5,232	11,747	13,178	13,854
Position #3	6,431	10,732	11,499	12,550	5,744	7,923	10,187	7,599	4,984	11,330	12,802	13,204
Position #4	6,555	11,060	11,929	12,818	5,842	8,089	10,800	7,913	4,988	11,396	12,970	13,491
Position #5	7,095	11,504	12,917	13,599	6,720	8,856	11,687	8,865	5,615	12,155	13,520	14,476
Position #6	8,342	11,477	12,893	14,134	6,732	9,185	11,424	8,668	5,836	12,583	13,697	15,101
Position #7	6,815	10,521	12,014	13,448	6,325	8,449	10,711	8,130	5,368	11,722	13,303	14,297
Position #8	7,465	11,193	13,410	14,420	6,257	8,821	11,901	8,857	5,480	12,589	13,931	14,885
Position #9	7,180	11,433	11,773	13,214	5,869	8,519	10,508	7,911	5,445	11,955	12,774	13,978

Wafer #	1	2	3	4	5	6	7	8	9	10	11	12
Design #	01	01	04	02	07	06	03	08	05	01	04	02
Wafer Unif	0.136	0.044	0.083	0.076	0.084	0.075	0.079	0.077	0.080	0.057	0.067	0.075
Etch Rate	157	246	271	295	137	188	242	182	118	263	292	312

(Etch rate based on 45 second time)

Lot Min	4,984	Lot Uniformity	0.510
Lot Mean	9,922	Lot Etch Rate	220
Lot Max	15,101		
One Sigma	2,920		

FILE: 6517-ALL.WR1