STAT 496, Spring 2009

Homework Assignment #5, Due by Friday, March 13

1. A factorial experiment is performed as part of the development of a nitride etching process on a single wafer plasma etcher. The process uses C_2F_6 as the reactant gas. For factors are manipulated in the experiment. The factors and levels are given below.

Factor	Low (–1)	High (+1)
A: Anode-Cathode Gap (cm)	0.8	1.2
B: Pressure (mTorr)	450	550
C: C_2F_6 gas flow (SCCM)	125	200
D: Power applied to cathode (W)	275	325

The response is the etch rate for silicon nitride in Angstroms per minute. The data are given below. Note that coded levels of the factors are given in the data table.

Trmt. Comb.	XA	XB	XC	XD	Etch Rate	Run
1	–1	–1	–1	–1	550	13
a	+1	–1	–1	–1	669	8
b	–1	+1	–1	–1	604	12
ab	+1	+1	–1	–1	650	9
c	–1	–1	+1	–1	633	4
ac	+1	–1	+1	–1	642	15
bc	–1	+1	+1	–1	601	16
abc	+1	+1	+1	–1	635	3
d	–1	–1	–1	+1	1037	1
ad	+1	–1	–1	+1	749	14
bd	–1	+1	–1	+1	1052	5
abd	+1	+1	–1	+1	868	10
cd	–1	–1	+1	+1	1075	11
acd	+1	–1	+1	+1	860	2
bcd	–1	+1	+1	+1	1063	7
abcd	+1	+1	+1	+1	729	6

a) For each factor, calculate the mean etch rate when that factor is at the high level and at the low level. Display these means in four main effects plots, one for each factor. Comment on the apparent size of each main effect.

b) Construct interaction plots for the four factors. Pay particular attention to the combinations of A - Anode-Cathode Gap with B - Pressure, A - Anode-Cathode Gap with C - C_2F_6 gas flow, and A - Anode-Cathode Gap with D - Power applied to the cathode. Comment on the apparent presence or absence of interaction for these three combinations.

c) Compute the overall grand sample mean and the 15 estimated effects. Be sure to indicate whether you are computing estimated full effects of half effects.

d) Construct a normal probability plot for the 15 estimated full effects. Label on your plot effects that appear to be significant.
e) You should be able to pick up some pseudo replication by eliminating a factor and all its interactions with the other three factors. This should give you a 23 experiment with 2 replicates. With this reduced model, compute MSrepError and the standard error of an estimate.
f) Which of the remaining estimated effects are statistically significant? Statistically non-significant? Be sure to support your answer.
g) Give the most parsimonious (include only significant terms) prediction equation. Be sure to explicitly define each variable in the equation.
h) In order to maximize the etch rate of this process, what settings of the four factors would you recommend?
i) Give a predicted value, and prediction interval, for the etch rate at the choice of factor levels you give in (h). Be sure to indicate what you are using for the estimate of error variation and why.
j) If one wanted an etch rate of 900 Angstroms per minute but wanted to use the least amount of power to the cathode, what settings would you recommend?
k) Using the prediction equation in (g) construct plots of residuals versus predicted values and residuals versus run order. Are there any discernible patterns in these plots?

Note: You may use JMP, or another computer program, to assist you with any of the graphing or calculations needed to answer the questions above.