

STAT 496, Spring 2009
Homework Assignment #4, Due by Friday, March 6

1. An experiment is performed on a process that manufactures integrated circuits. A basic step in the process is to deposit a thin film (epitaxial layer) on a polished silicon wafer. The wafers are placed in a chemical vapor deposition (CVD) reactor. Chemical vapors are introduced and the reaction takes place until the epitaxial layer is the desired thickness. An experiment is run with two factors: vapor flow rate and time in the reactor. For the purpose of the experiment, one reactor is used and one wafer is placed in the reactor at a time. Each wafer's thickness is measured before and after being placed in the reactor and the thickness (μm) of the epitaxial layer is determined. The same operator processes and measures all wafers for the experiment. Four wafers are run for each combination of flow rate and time. The order of the 16 runs is completely randomized. Below are the resulting epitaxial layer thicknesses (μm).

Flow Rate	Time	Epitaxial Layer Thickness (μm)				Mean	Variance
55	15	14.01	14.13	13.94	13.88	13.99	0.0115
59	15	13.88	13.79	14.06	13.91	13.91	0.0126
55	30	14.81	14.76	14.64	14.87	14.77	0.0095
59	30	14.98	14.92	14.73	14.93	14.89	0.0121

- a) Is this a well designed experiment? Comment briefly on control of outside variables, randomization and replication within the experiment.
- b) Calculate means for each level of flow rate and each level of time.
- c) Display the means for flow rate and time and comment on the apparent effects of each factor.
- d) Construct two interaction plots, one with flow rate on the horizontal axis, one with time. Does there appear to be an interaction between the two factors? Explain briefly.
- e) Compute the MS_{repError} by pooling the individual sample variances for each treatment combination.
- f) Calculate the estimated full effect for each factor and the interaction effects.
- g) Give the standard error of an estimated full effect and use it to determine what estimated effects are statistically significant. Use $t=3$ for the critical value.
- h) Eliminate any non-significant effects and give the reduced model prediction equation. Be sure to define the coded predictors explicitly.
- i) Predict the values for the four treatment combinations. Construct prediction intervals for each of these values.
- j) What recommendation would you make if you wanted an epitaxial thickness of $14.2 \mu\text{m}$?
- k) We could also look at this experiment as a “one-factor” experiment, where the “treatments” for the “one-factor” are combinations of flow rate and time. Calculate the LSD (use $t=3$) for such an experiment.
- l) Based on the LSD, which “treatments” are significantly different? Which “treatments” are not significantly different? Does this analysis agree or disagree with the one done previously? Explain briefly.

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. However, since exams will contain some hand calculations it may be worthwhile to do the calculations by hand and verify the hand calculations with the computer.