**PSET 9 – Design of Experiments – due 4.10.19 at Midnight**

**Problem 1[[1]](#footnote-1) -**  Consider a semiconductor wafer processing experiment where the goal is to fit response surface models to the two responses, *deposition layer uniformity* and *deposition layer stress*, as a function of two particular controllable factors of the chemical vapor deposition (CVD) reactor process. These factors were Pressure (measured in torr) and the ratio of the gaseous reactants H2 and WF6 (called H2/WF6).

The minimum and maximum values chosen for Pressure were 4 torr and 80 torr. The minimum and maximum H2/WF6 ratios were chosen to be 2 and 10. Since response curvature, especially for Uniformity, was a distinct possibility, an experimental design that allowed estimating a second order (quadratic) model is needed.

**Part 1)** Use Matlab to generate a randomized list of experiments for Uniformity and a randomized list of experiments for Stress, both using a CCI design. Show run variables in real, uncoded units (torr and ratio values).

The experimenters decided to use a central composite inscribed (CCI) design. Perhaps to conserve a limited supply of wafer resources, they chose to include only 3 centerpoint runs. The table below shows the CCI design and experimental responses, in the order in which they were run:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Run** | **Pressure** | **H2/WF6** | **Uniformity** | **Stress** |
| 1 | 80 | 6 | 4.6 | 8.04 |
| 2 | 42 | 6 | 6.2 | 7.78 |
| 3 | 68.87 | 3.17 | 3.4 | 7.58 |
| 4 | 15.13 | 8.83 | 6.9 | 7.27 |
| 5 | 4 | 6 | 7.3 | 6.49 |
| 6 | 42 | 6 | 6.4 | 7.69 |
| 7 | 15.13 | 3.17 | 8.6 | 6.66 |
| 8 | 42 | 2 | 6.3 | 7.16 |
| 9 | 68.87 | 8.83 | 5.1 | 8.33 |
| 10 | 42 | 10 | 5.4 | 8.19 |
| 11 | 42 | 6 | 5 | 7.9 |

**Part 2)** Analyze the experimental data:

1. Fit both responses (uniformity and stress) to quadratic models
2. Display p-values for each of the fit coefficients. Determine which can be neglected if your threshold for significance is p<0.075 (note that *normally* a p value of 0.05 might be more appropriate, but for this problem we’ll use 0.075).
   1. NOTE: if a cross term (e.g. x1\*x2) is significant, then the main effects (x1 and x2 linear terms) must BOTH be included even if they have a higher p-value
3. Once you have decided which terms are significant, re-fit both responses to the corresponding reduced models (removing all parameters with HIGH p-values). Check the new corresponding p-values.
4. Using the reduced fit models, determine best pressure and H2/WF6 ratio settings if a Uniformity of 5.7 and Stress of 7.7 are desired. (fsolve may be useful here)
5. Overlay line contour plots of the two reduced models. Indicate the operating point found in question 4 on the plot.

1. Adapted from Chapter 15 of Czitrom, V., and Spagon, P. D., (1997), Statistical Case Studies for Industrial process Improvement, Philadelphia, PA, ASA-SIAM Series on Statistics and Applied Probability. [↑](#footnote-ref-1)