

# ASSIGNMENT 5

## TWO-WAY ANOVA

In this assignment you will use the general linear model (GLM) in SPSS to assess the impact of different combinations of the levels of temperature and pressure on thickness of film coatings applied to semiconductor wafers. In particular, you will explore the interaction effect of temperature and pressure on thickness. You will also test the model assumptions and apply diagnostic tools in SPSS.

### Film Coatings Applied to Semiconductor Wafers

Chemical vapor deposition is a process used in the semiconductor industry to deposit thin films of silicon dioxide and photoresist on substrates of wafers as they are manufactured. The films must be as thin as possible and have a uniform thickness, which is measured by a process called infrared interference. A process engineer wants to evaluate a low-pressure chemical vapor deposition (LPCVD) process that reduces costs and increases productivity. The engineer has set up an experiment to study the effect of chamber temperature and pressure on film thickness. Three temperatures and three pressures are selected to represent the low, middle, and high levels of operating conditions for both factors. An experiment is conducted various levels of operating conditions for both factors. An experiment is conducted by randomly selecting one of the temperature-pressure combinations and determining the thickness of the film coating after processing is completed. This experiment is repeated three times with each temperature-pressure combination. The engineer wants to determine the joint effects of temperature and pressure on the mean film thickness.

The data are available in the SPSS file *lab5.sav* that can be downloaded to your workstation by clicking on the link *Data* in *Lab 5*. The data are not to be printed in your submission.

The following is a description of the variables in the data file:

<u>Column</u>	<u>Name of Variable</u>	<u>Description of Variable</u>
1	Temperature	Temperature (1=low, 2=middle, 3=high)
2	Pressure	Pressure (1=low, 2=middle, 3=high)
3	Thickness	Thickness (in angstroms) of film coatings

Use the data to answer the following questions:

1. First you will describe the experiment in the two-way ANOVA setting and examine the experiment design.
  - (a) What are the experimental units in the study? What is the response variable? How will it be measured and in what units? What are the two factors in the experiment? What are the levels of each factor?
  - (b) Comment on the experiment design. What kind of inferences can be made given the design? What assumptions should be made about the wafers used in the experiment to make the inferences valid?

2. Before doing any actual hypothesis testing, you should examine your data visually to get a picture of the effects.
  - (a) Use the *Line Chart* feature in the *Graphs* menu to obtain the plot of mean thickness versus pressure by temperature. What do you conclude about the effects of temperature and pressure on thickness? Can you conclude that one of the two factors affects thickness more than the other? What combinations of the factor-levels produce the thinnest and the thickest coatings?
  - (b) Use the *Means* procedure in the *Compare Means* submenu in the *Statistics* menu to obtain the table of the marginal means of thickness for all combinations of temperature and pressure. Temperature and pressure should be entered as two layers in the procedure. What do you conclude about the effects of the two factors on thickness?
3. In this part you will use the GLM (General Linear Model) in SPSS to carry out the statistical analysis of the effects of temperature and pressure on film thickness.
  - (a) Use the *Univariate Procedure* in the *General Linear Model* menu to examine the main and interaction effects on the mean thickness of film coatings. State the null hypotheses for main effects and for interaction to be tested, report the observed significance levels of the appropriate F-tests, and state the conclusions about the significance of the effects.
  - (b) If the hypothesis for main effects for at least one of the factors is rejected, multiple comparisons might be considered for the means of the levels of the factor. Use the Tukey HSD procedure in SPSS to determine which levels of the factor differ. State your conclusions briefly.
4. The results of the analysis in Question 3 are valid only if the appropriate assumptions are valid. The assumptions are that the data come from a normal population and in the population, all cell variances are the same.
  - (a) Is there any evidence that the assumption of equal error variance might be violated? Obtain side-by-side boxplots displaying the two factors together (select *Clustered* from the *Boxplot* menu) to verify the assumption. Moreover, refer to the Levene test to confirm your findings.
  - (b) Is the normality assumption reasonable? Comment referring to the appropriate plots.

## LAB 5 ASSIGNMENT: MARKING SCHEMA

Proper Header: 10 points

### Question 1

- (a) Experimental units: 1 point  
Response variable and measurement units: 2 points  
Two factors: 2 points  
Levels of each factor: 1 point
- (b) Experiment Design: 3 points  
Type of inferences: 2 points  
Assumption: 2 points

### Question 2

- (a) Plot of mean thickness: 5 points  
Effect of temperature and pressure on thickness: 2 points  
Stronger factor: 2 point  
The combination to produce the thinnest coatings: 2 point  
The combination to produce the thickest coatings: 2 point
- (b) Table of marginal means: 5 points  
Effect of temperature and pressure based on the table: 2 points

### Question 3

- (a) GLM output: 3 points  
Null hypotheses: 2 points each (6 points total)  
P-values: 1 point each (3 points total)  
Conclusions: 4 points
- (b) Tukey HSD output for temperature: 2 points  
Conclusions for temperature: 2 points  
Tukey HSD procedure for pressure: 2 points  
Conclusions for pressure: 2 points

### Question 4

- (a) Side-by-side boxplots: 3 points  
Comments about the plot: 3 points  
Levene test: 3 points
- (b) Normality assumption (either conclusions based on the boxplots or Q-Q plot): 3 points

**TOTAL= 79**