LAB 1 ASSIGNMENT

DISPLAYING AND DESCRIBING DISTRIBUTIONS

In this lab assignment, you will use Excel to display and describe observations on a single variable such as thickness of film coatings applied to wafers at several pre-determined levels of pressure and temperature. In particular, you will use histograms to display the data and calculate summary statistics for the data like the mean, standard deviation, median, and interquartile range. Moreover, you will use scatterplots to explore the relationship between thickness and pressure or temperature. Before you start working on the assignment questions, you should get familiar with the instructions provided in *Lab 1 Instructions*.

Thickness of Film Coatings

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 levels of temperature (400ºC, 600ºC, and 800ºC) and twenty levels of pressure are selected to represent 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. The engineer wants to determine the joint effects of temperature and pressure on the mean film thickness. The preliminary experiments proved that the pressure required for the LPCVD process to be successful should be between 0.25 and 1.20 Torr.

The data file *lab1.xls* can be downloaded at http://www.stat.ualberta.ca/statslabs/index.htm (click *Stat 235* link, and *Data* for *Lab 1*). Note that the data in the worksheet are provided in two alternative formats as one of those formats may be more suitable for some analyses. The data are not to be printed in your submission.

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

Column	Name of Variable	Description of Variable
1	Temperature	temperature (degrees in Celsius, at three levels: 400, 600, 800ºC),
2	Pressure	pressure (spaced evenly between 0.25 and 1.20 of Torr),
3	Thickness	thickness (in angstroms) of film coatings.

Use the data to answer the following questions:

1. First obtain the histograms of thickness of film coatings for the three temperature levels.

   (a) Obtain a histogram of thickness for each of the three temperature levels: 400ºC, 600ºC, and 800ºC. The format of each histogram should be the same as the format of the sample histogram in *Lab 1 Instructions* (title, names of axes, no gaps between bars). Use the same bins for all three histograms.

   (b) Compare the shapes of the three histograms obtained in part (a). Are they symmetric or skewed? Are they single-peaked or double-peaked? Are there any outliers?

   (c) Use the histograms to compare the centers and spreads of the three thickness distributions. What is the relationship between the mean and the median for each distribution?

   (d) Based on the histograms, what can be stated about the effect of temperature on thickness of film coatings?

2. Now obtain some summary statistics for thickness of film coatings for each of the three levels of temperature: 400ºC, 600ºC, and 800ºC and for each of twenty values of pressure. More precisely:

   (a) Use the *Descriptive Statistics* tool (*Lab 1 Instructions*) to calculate the mean, standard deviation, and variance of thickness for each temperature level. Comment about the effect of temperature on the mean and standard deviation of thickness of film coatings.

   (b) Use the *Insert Function* feature (*Quartile.Inc*) to compute the first (lower) quartile, the second quartile (median), third (upper) quartile, and the interquartile range of thickness for each temperature level.
   Do the positions of the quartiles for each temperature level show consistency with your conclusions about the shape of the corresponding distribution in Question 1? Explain briefly.

   (c) Use the *Descriptive Statistics* tool to calculate the mean and standard deviation of thickness at each of the twenty pressure values. How does the mean thickness change as pressure increases? On average, by how much does thickness change as pressure increases by 0.05 Torr?

3. Now display the relationship between thickness, temperature and pressure.

   (a) Use the *Insert* tool to obtain a scatterplot of thickness versus temperature (pressure ignored).
   The format of the scatterplot should be consistent with the format used in *Lab 1 Instructions* (names of the axes, no lines or grids, axes rescaled to display only the observed values). Paste the plot into your report. Comment about the effect of temperature on thickness. Are your conclusions consistent with the summaries in Question 2? Comment briefly.

   (b) Use the *Scatter* feature to obtain a scatterplot of thickness versus pressure by temperature. Use different plotting symbols to mark observations for the three temperature levels. The format of the scatterplot should be consistent with the format used in *Lab 1 Instructions* (names of the axes, no lines or grids, axes rescaled to display only the observed values). Paste the plot into your report. The alternative format for the data may be useful in this part.

   (b) Comment about the relationship between thickness and pressure for each level of temperature.

4. How should the temperature and pressure be selected to produce the thinnest possible film for the LPCVD process? Answer the question by referring to the summary statistics and plots obtained in Questions 1-3.

MARKING SCHEMA

Proper Header and appearance: 10 points

Question 1 (33)

(a) Correctly formatted histogram: 4 points each (12 points total)
(b) Analysis of the shape of each histogram: 3 points each (9 points total)
(c) Comparing the centers and spreads: 2 points each (6 points total)
The relationship between the mean and the median: 2 points
(d) Effect of higher temperature on thickness: 4 points

Question 2 (41)

(a) Summaries (mean, standard deviation, variance) for each of three temperatures: 1 point each (9 total)
Effect of temperature on mean and standard deviation: 2 points
(b) Summaries (quartiles and IQR) for each of the three temperatures: 1 point each (12 total)
Positions of quartiles relating to shapes: 2 points
(c) Table of means and standard deviations: 8 points
Effect of higher pressure on mean thickness: 4 points
Reduction in mean thickness as pressure increases by 0.05: 4 points

Question 3 (22)

(a) Correctly formatted scatterplot of thickness versus temperature: 4 points
Effect of temperature on thickness: 4 points
Consistency with conclusions in Question 2: 2 points
(b) Scatterplot of thickness vs. pressure by temperature: 8 points
(c) Relationship between thickness and temperature: 4 points

Question 4 (6)

Final conclusions: 6 points

TOTAL = 112