

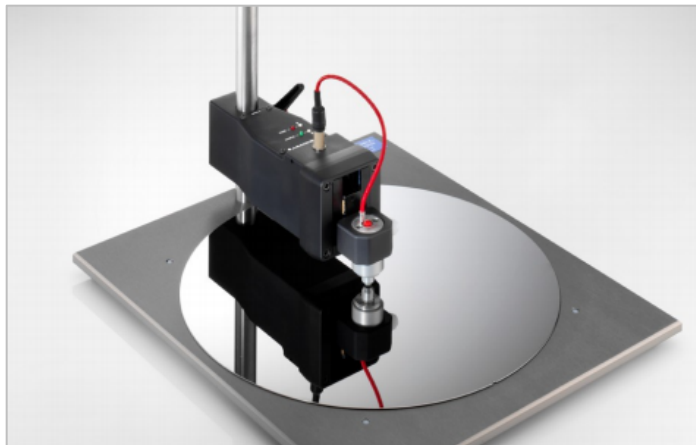
## SEMICONDUCTOR SHEET RESISTANCE GAUGE STUDY

### RELEVANT JMP PLATFORMS AND STATISTICAL TECHNIQUES

Graph Builder :     Dotplots with Connect Lines

### PROBLEM STATEMENT

Electrical resistance is a critical performance metric that is used to evaluate the quality of semiconductor wafers used in chip manufacturing. A common device used to measure this characteristic is a 4-point probe. To measure sheet resistance, four electrodes are placed onto the surface of the film. Electric potential is applied to two of the electrodes, and the electric current flowing through to the other two are measured.



Engineers in one of the labs that uses this measurement device are concerned that there may be factors that could result in inaccurate and imprecise measurements. The main concern they have is that residual material may build up on the probes resulting in an inaccurate reading on subsequent film that is measured. This is of particular concern when the films are of different materials. A step that can be taken is to condition (i.e., clean) the probes prior to each use. This does add time to the measurement process and thus is only done periodically in practice.

Another consideration they have is that perhaps different operators of the device may not be following the exact same measurement protocol and thus producing different results, specifically an experienced user vs. a new user.

The engineers design an experiment to test these concerns. The experimental design is as follows:

	Probe Conditioning				
	No		Yes		
	Operator		Operator		
Wafer	Experienced	New	Experienced	New	
1	2	2	2	2	
2	2	2	2	2	
3	2	2	2	2	
4	2	2	2	2	
5	2	2	2	2	
6	2	2	2	2	

There are 6 wafers. Each of these wafers is measured under 4 different scenarios – Probes conditioned or not before making the measurements, and the measurement being made by the experienced or new operator. This results in 24 unique treatment combinations of Wafer, Operator and Conditioning. 2 separate measurements are made for each treatment combination resulting in a total of 48 total experimental runs.

The experimental procedures followed:

1. 6 Titanium Nitride film wafers are selected for the study.
2. 1 Tungsten film wafer will be used as the alternate film to test for residual material remaining on the probes.
3. Before each experimental run, the 4-point probe is used to make 10 readings on various parts of the Tungsten film. Electric resistance is not recorded for this step as it's merely done as the means to generate the potential residual material on the probes.
4. One of Titanium Nitride wafers, operators, and conditioning (Yes/No) is randomly selected.
5. A single sheet resistance measurement is made.
6. This random assignment continues for all 48 experimental runs.

## DATA SET


Semiconductor\_Sheet\_Resistant\_Gauge\_Study.jmp

Test Order	The random order in which all measurements were made (1,2,...,48)
Wafer	ID of wafer (1,2,...,6)
Operator	The operators' experience level (Experienced, New)
Probe Conditioning	Probe conditioning step before measurement (Yes, No)
Resistance	The sheet resistance produced by the gauge (Ohms)

## EXERCISES

The exercises consist of creating a variety of different visualizations of the data. All the graphs you'll create are dotplots with connected lines. The different graphs are alternative ways to display the data. As you'll see, certain ones will be better suited at illustrating specific features than others.

1. Create a dotplot with lines connected displaying 'Resistance' on the Y axis, probe condition and operator on the X axis, and the 6 wafers as separate panels.

*Instructions: Use Graph Builder. Place the variable 'Resistance' on the Y axis. Place 'Probe Conditioning' on the X axis. Place 'Operator' also on the X axis, but on the outside of 'Probe Conditioning' (Drag the 'Operator' variable to the blue trapezoid region below where the 'Probe Conditioning' tile is). Place 'Wafer' on the top (Group X) region. Choose the Line graph from the graph palette at the top.  Save this graph to the data table by selecting Save Script > to Data Table under the top red triangle.*

2. Change the graph created above so that the 'Operator' variable is on the inside level of the X axis and 'Probe Conditioning' on the outside.

*Instructions: Grab one of the variable names on the X axis and drag it to the other position. Save this graph to the data table using a different name.*

3. Create a dotplot with lines connected displaying the 'Resistance' on the Y axis, 'Wafer' on the X axis, 'Probe Conditioning' as separate panels, and 'Operator' in the Overlay role.

*Instructions: Use Graph Builder. Drag each variable into their respective roles. Save this graph via. Save Script to the data table.*

4. Change the graph created above so that the 'Operator' variable is on the inside level of the X axis and 'Probe Conditioning' on the outside.

*Instructions: Easiest way to do this is to right click on 'Operator' or 'Probe Conditioning' in their respective role on the graph, and choose Swap and select the other variable from the list. Save this graph to the data table using a different name.*

5. Change the graph created above so that the 'Operator' is on the X axis inside 'Operator'.

*Instructions: Drag 'Operator' from the X Group role and place it on the X axis below Wafer.*

*Save this graph to the data table using a different name.*

6. Create a graph that displays the Range between the 2 measurements made by each 'Operator' on each 'Wafer' for each 'Probe Conditioning'.

*Instructions: Use Graph Builder. Place the variable 'Resistance' on the Y axis. Place 'Operator' on the X axis. Place 'Wafer' on the top (Group X) region. Place 'Probe Conditioning' in the Overlay role. Choose the Line graph from the graph palette at the top.*

*In the Control Panel on the left, select Range under Summary Statistics for both the Points and the Line.*

*Save this graph to the data table.*

*Create alternative versions of this graph by choosing different roles for the variables. Right click on a variable and choose Swap and select another variable from the list.*

*Save each graph you make using a different name.*

7. Examine all the graphs created in Exercises 1-6. Describe features uncovered in these data with regard to the potential effects that 'Probe Conditioning' and 'Operator' has on producing consistent Electric Resistance values. Recall that all the graphs are essentially plotting the same information in different arrangements. Choose the graphs that best illustrate the features observed.
8. Do these data indicate that the measurement device is able to produce accurate Sheet Resistance values? That is, are the measured Sheet Resistance obtained from the device, on average, equal to the true Sheet Resistance of the wafers?