

ECEn 452 – Semiconductor Devices Lab  
Week 5: “Contact Resistance”  
Background Reading

**Contact Resistance**

When a metal pad is deposited on a semiconductor there is a small amount of resistance across the junction. This is called **R<sub>pad</sub>**. A larger pad has a greater surface area between the metal and the semiconductor. This can be compared to placing a number of resistors in parallel, reducing the overall resistance. Thus, a larger pad will have less pad resistance than a smaller pad. R<sub>pad</sub>, as defined, is inversely proportional to the area of the pad:

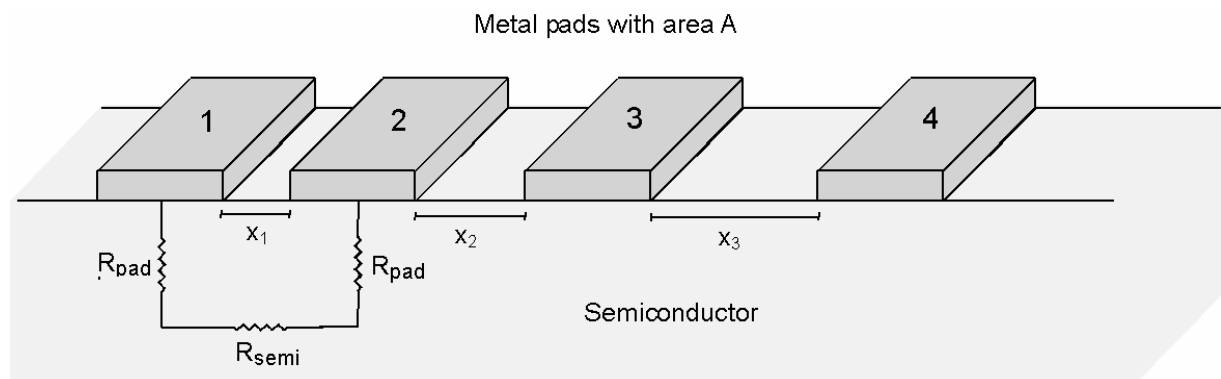
$$R_{\text{pad}} \propto \frac{1}{\text{Area}}$$

**R<sub>c</sub>**, by contrast, is the specific contact resistance and is constant for a given metal and semiconductor junction. Its units are in  $\Omega\text{-cm}^2$ . This results from the R<sub>pad</sub> being inversely proportional to the area of the pad. As the area of the pad increases, R<sub>pad</sub> decreases. Thus R<sub>c</sub> will remain constant.

$$R_c = R_{\text{pad}} \times \text{Area}$$

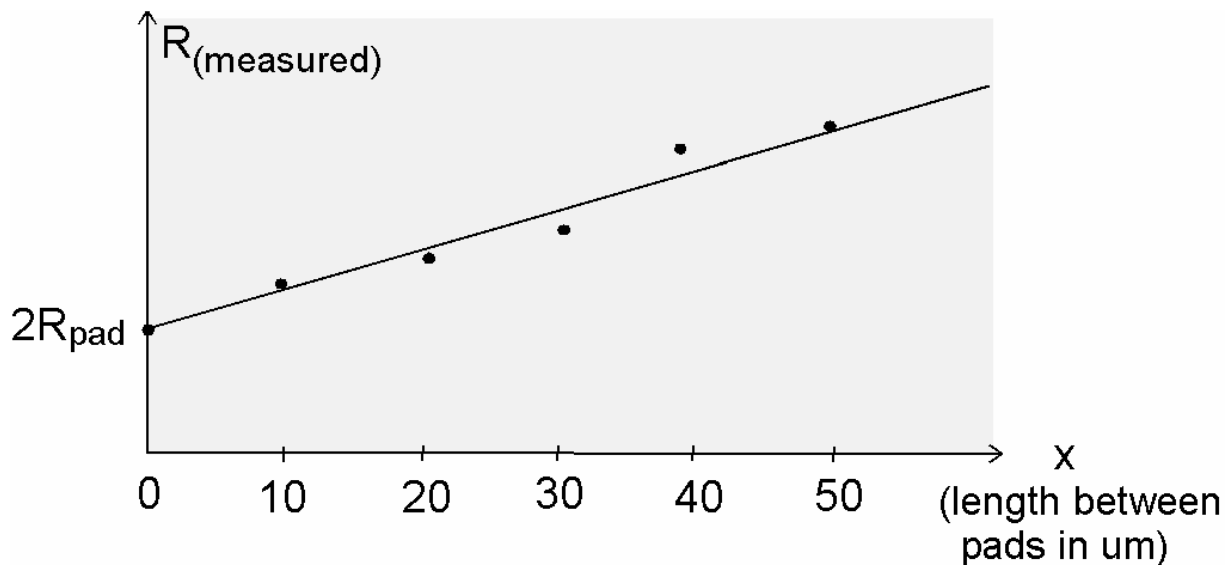
**Measuring R<sub>c</sub>**

For this lab, you will be measuring R for different pad sizes and separation distances. This will enable you to calculate R<sub>c</sub> and determine if R<sub>c</sub> is independent of pad area. In the previous lab a pattern of metal pads was placed on a doped silicon wafer. There are several columns in the pattern and each column contains 11 pads of equal area. Pad areas vary from column to column; separation distances vary from pad to pad within each column. You will use the probe station and the HP4145 Parametric Analyzer to collect some resistance data that will allow you to calculate R<sub>c</sub>. The figure below represents some metal pads on a semiconductor.



The 4145 applies a voltage between two probes and then measures the current flow. If, for example, you placed the probes on pads 1 and 2, the display on the 4145 would show a specific V-I curve. The measured resistance ( $R_{\text{pad1}}+R_{\text{semi}}+R_{\text{pad2}}$ ) between the two pads can then be calculated.

By repeating this process for all the pads in a column, you can make a chart of the measured R vs. separation distance. Extrapolating the graph to the y-intercept allows you to approximate R measured at 0 separation distance. This is the point where  $R_{\text{semi}}$  is 0, thus leaving you with  $2R_{\text{pad}}$ . From this we can calculate  $R_c$ .  $R_c = R_{\text{pad}} \times A$ . An example chart is shown below.

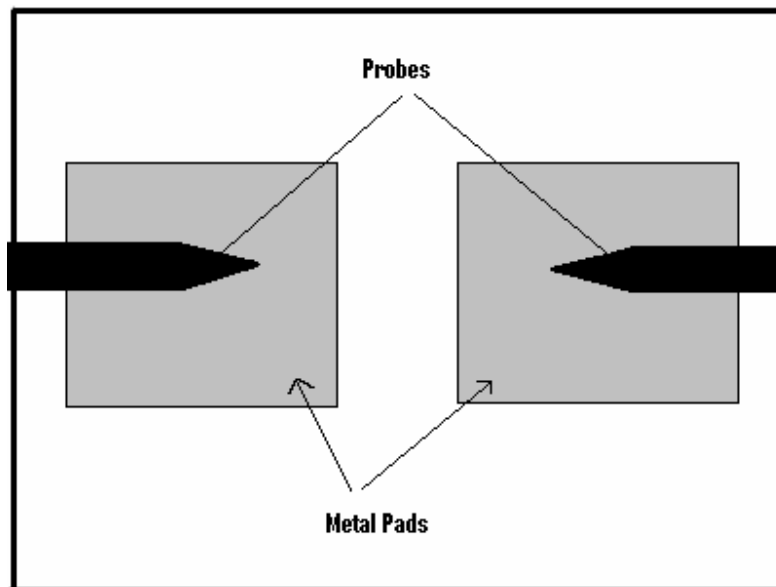


In the lab you will not want to measure the resistance between every pad. This will take way too long. Choose 3 or 4 different pad lengths that will give a reasonable line on the graph to extrapolate. Also, since the probes are bulky, there are only two or three pad columns large enough to fit the probes. Use these columns to collect your data. You should measure the resistance on at least two different columns to see if  $R_c$  is independent of pad area.

### Measurement Tools

In order to measure pad contact resistance, you will need to know a little about the probe station and the HP4145 parameter analyzer. The probe station is used to apply a voltage across the metal pads while the parameter analyzer is used to collect and display the resistance data. Place the wafer onto the adjustable table of the microscope station and position the probes so they can be seen in the microscope. Making sure the probes are well above the table surface, adjust the turntable so the wafer slides under the probes and position the wafer so that the two pads to be touched are visible. While looking into the microscope, use the probe dials to bring each probe into position on a different pad. It is important to do this while looking into the microscope because the distances we are working with are in the microns, too small to see with the human eye. If the probes are placed too tightly they can be damaged along with the wafer surface. The probes should be out of focus and then come into focus as they approach the wafer surface. The

probes are touching the surface when they are relatively in focus and you have seen the probes move slightly towards one another on the metal pads. A diagram of what this should look like is show below.



After the two probes are placed, the parameter analyzer can be used to display the voltage – current curve between the two probes. This will be displayed as a graph on the screen of the HP4145. The resistance will be calculated from the slope (rise over run) of the curve. The TA will show you how to set up the appropriate screen information. After the recorded value is taken, the probes can be lifted from the metal pad surface, and the procedure can be executed again. **DO NOT MOVE THE MICROSCOPE TABLE WHILE THE PROBES ARE TOUCHING THE PADS!** The probes are very fragile and can break easily, being very costly to replace.

### **Effect of Annealing on Contact Resistance**

In the previous lab, samples of silicon with either nickel or aluminum patterns were annealed for various times, temperatures, and atmospheres. We will study the results of these experiments in this lab. We shall attempt to measure the contact resistance between the metal and the silicon of each sample, and thereby determine the best anneal time and temperature.

### **4145 Parameter Analyzer**

Read about the operation of this piece of equipment on the cleanroom website:  
[www.ee.byu.edu/cleanroom](http://www.ee.byu.edu/cleanroom).