ASSESSING THE UNIFORMITY OF THE OXIDE THICKNESS

How can you tell if the thickness varies across the wafer?

You've had a chance to determine the precision of the measurement system. While you were taking the measurements, you may have noticed that the color of the oxide was not the same across the wafer. As you know, the color is a result of destructive interference of the reflected white at the surface and the refracted white light

\[ 2 \cdot x_{ox} = \frac{k \cdot \lambda}{n_f} \]

where \( x_{ox} \) is the thickness of the oxide, \( n_f \) is the refractive index of the oxide and \( ? \) is the wavelength of light associated with the color that you observe.

So, as you can imagine, the variation in the color across the wafer could be coming from a variation in the oxide thickness across the wafer, a variation in the index of refraction or some of both. If the refractive index varies across the wafer, the quality of the oxide varies across the wafer. This is possible. You are going to assume that the variation is due to thickness variations from differences in gas flow around the wafer.

How thick is the oxide film and how does the thickness change over the surface of the wafer?

In the last exercise, you determined how thick the oxide film is on one spot. Now the challenge is to determine how that thickness varies across the surface of the wafer. This value is called uniformity — how uniform is the film thickness across the wafer? In statistical terms, you are going to assess the variation within the sample (versus variation between samples).

Before you get started, you must first assess the measurement variation. Luckily you've already done this. When you figure out the variation on the wafer, you will need to compare these two numbers. Obviously if the variation in the measurement system is about the same size as the variation across the wafer, you will have a bit of a problem.
The quantity that you are going to assess is called the \textit{coefficient of variance (CV)} by statisticians and the \textit{uniformity} by process engineers:

$$CV \text{ or uniformity} = \frac{s}{\bar{x}} \cdot 100\%$$

\textbf{A WORD ABOUT YOUR WAFERS}

You will be using the wafers from the FAT team. One piece of critical information is the position of the wafer in the boat. Please make sure you record this information for the wafer that you are analyzing. You will need this information to analyze the data on the next exercise.

1. First you will determine if the thickness and standard deviation are stable relative to the radial position on the wafer. To do this, you'll need to make a bull's eye pattern on your wafer so that you have five zones. The center zone should have a radius of 1 cm. The next zone should have a radius of 2 cm and so on.

2. Before you take your measurements, carefully observe the wafer and make any notes of an unusual pattern of color on the surface. Note the color and look at the color chart to approximate the thickness of your wafer. You may have to discuss with the FAT team what thicknesses are possible. Take two measurements per zone for a total of 10 measurements. Remember to take these measurements in a random order and follow the SOPs. You might want to organize your data like this:

<table>
<thead>
<tr>
<th>Zone:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x_2$</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R =</td>
<td>x_1 - x_2</td>
<td>$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. From the data set, construct a control chart for the range, using 0 for the lower control limit, $D_4 \bar{R}$ for the upper control limit (for a sample size of 2, $D_4$ equals 3.267), $\bar{R}$ as the central value, and “zone” as the x-axis of the control chart.

4. Compute the standard deviation for the measurements using the control chart constant, $d_2$, $s = \frac{\bar{R}}{d_2}$ . For a sample size of 2, $d_2$ equals 1.128.

5. Also construct a control chart for the thickness, using $\bar{x} + A_2 \bar{R}$ for the upper control limit, $\bar{x} - A_2 \bar{R}$ for the lower control limit (for a sample size of 2, $A_2$ equals 1.880), $\bar{R}$ as the central value, and “zone” as the x-axis of the control chart.
NOTE: The upper control limit is $\bar{x} + 3 \frac{s}{\sqrt{n}}$, and you can use the approximation that you used in the control chart for $\bar{R}$, that $s = \frac{\bar{R}}{d_2}$. Notice that this time, the limits of the control chart for the mean are reduced by a factor of $\frac{1}{\sqrt{n}}$, where $n$ is the number of measurements (in this case 2).

So, you see that an increased number of measurements enables you to more precisely determine the mean value.

6. Now, take a look at your control chart. Are there any outages, that is, data points that lie outside the boundaries of the control limits? If so, what does this mean? In theory, if you did have data points that were outside the limits, the calculation of the uniformity would not really be meaningful. Why?

7. Assuming that you have no outages, calculate the CV (uniformity) of your film thickness.

**What did you just do?**

The exercise that you just completed took you through the process of determining if the measured thickness values within a wafer were “stable” with respect to the zone. If you found that there was no variation due to special causes, you are in good shape. In other words, the variation that exists in the thickness is part of the process. If you found that there were variations due to special causes, you would want to think about what those special causes might be. Again, determining that the thickness is "stable" across the wafer is a VERY important step, because it tells you something about the process of growing the oxide…is it "stable" with respect to the surface of the wafer?

So this exercise enabled you to assess the variation within the sample. The next level of complexity is determining whether there is variation from sample to sample. That is, is there variation between samples?