Stat 235

Lab 1

WOOSAREE, Arun

Lab EL12

TA: Jessa Marley

September 27, 2018

1 Histograms

1.a Histograms of Thickness: 400°C, 600°C, and 800°C

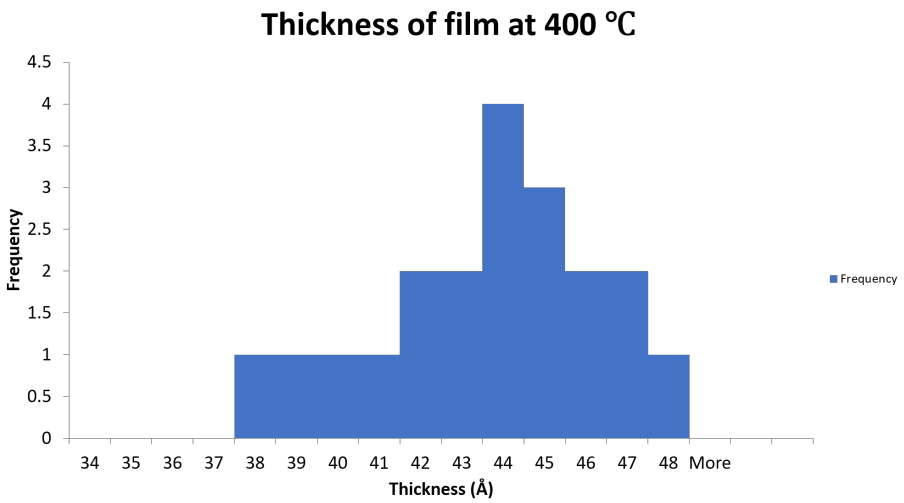

Figure 1: Distribution of film thickness for the LPCVD process at 400 °C

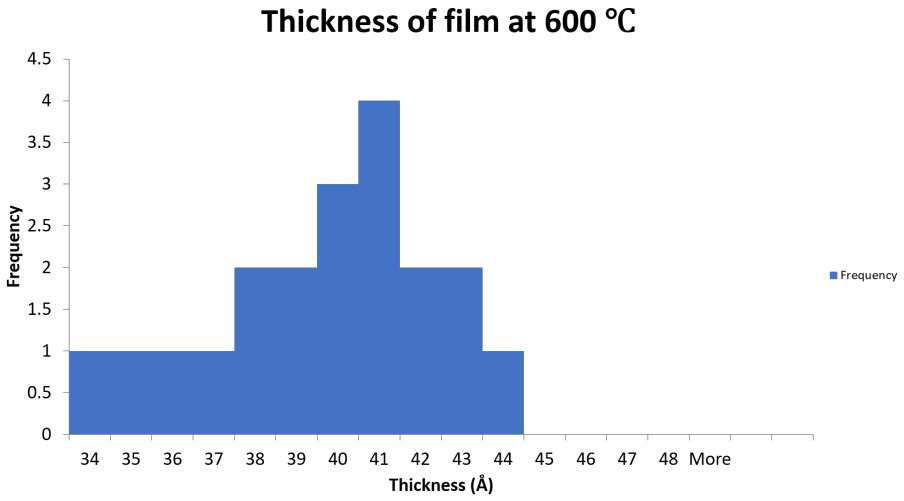

Figure 2: Distribution of film thickness for the LPCVD process at 600 °C

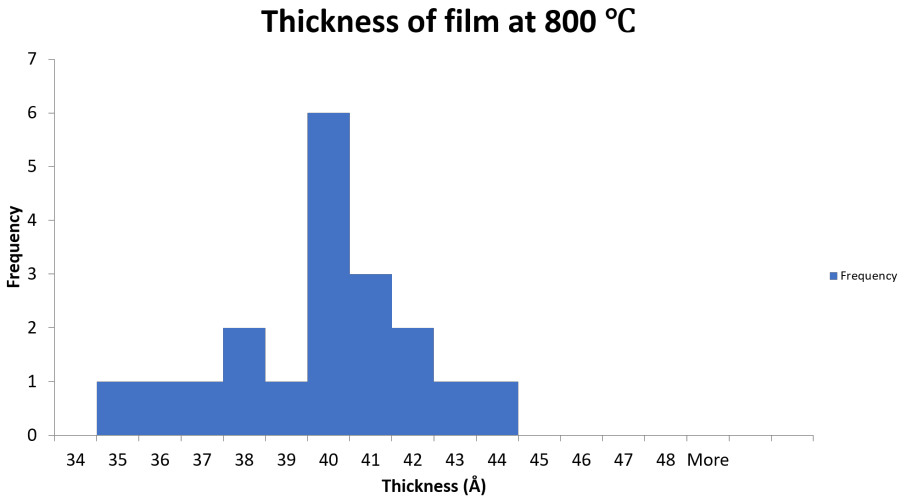

Figure 3: Distribution of film thickness for the LPCVD process at 800 °C

1.b Shapes

All the histograms above appear to be slightly left-skewed. Figure 1 appears to be very slightly left-skewed, while Figure 2 appears to be a little more left-skewed. Figure 3 also visually looks left-skewed as well. All histograms have one obvious peak, but at first glance, Figure 3 might seem to have a second smaller peak in bin 38, but upon further inspection, the frequency count only has a difference of 1 compared to its surroundings, which does not seem significant enough to count as a second peak. So, each histogram above is single-peaked. There don't seem to be any obvious outliers judging from the 3 histograms above. When taking a step back and squinting, nothing seems to be visually away from the bulk of the data.

1.c Centers and Spreads

The first histogram (Figure 1) has a center at bin 44, and a spread (range) of 10. The second histogram (Figure 2) has a center at bin 41 and a spread of 10 as well. The third histogram (Figure 3) has a center around 40, and has a spread of 9. For all 3 histograms, the means are slightly less than their respective medians, or visually, the means are slightly to the left of the medians, which seems to partially confirm the left skewness of the histograms. (Although the difference betweem the medians and their respective means is not huge.) The mean and median for each distribution can be found in Tables 1 and 2 on page 3.

1.d Effect of Temperature on Thickness

It would appear that increased temperature tends to result in overall lower thickness of the films deposited. It can be noted that increasing the temperature from 400 °C to 600 °C seems to result in a more significant decrease in thickness overall, compared to the difference between the process happening at 600 °C and 800 °C.

2 Summary Statistics

2.a Mean, Std. Deviation, Variance for each Temperature Level

Statistics	Temperature Levels (°C)		
	400	600	800
Mean	43.65	39.7	39.5
Std. Deviation	2.700389	2.716421	2.704771
Variance	7.292105	7.378947	7.315789

Table 1: Mean, standard deviation, and variance of the resulting film's thickness at 400 °C, 600 °C, and 800 °C

When observing Table 1, we can see that the mean thickness of the film goes down as the temperature is increased, (the change from 400 °C to 600 °C is more significant than the change in thickness from 600 °C to 800 °C) while the standard deviation seems to mostly remain the same, fluctuating from about 2.70-2.72.

2.b Quartiles

Statistics	Temperature Levels (°C)		
	400	600	800
Lower Quartile	42	38	38
Median	44	40	40
Upper Quartile	45.25	41.25	41
IQR	3.25	3.25	3

Table 2: Quartile positions and the inner quartile range for the resulting film's thickness of the LPCVD process at 400 °C, 600 °C, and 800 °C

Looking at Table 2, each lower quartile is further from the median than their respective upper quartiles. This supports the conclusion that each histogram is left-skewed which was reached in Section 1.b by visual inspection of the histograms.

2.c Mean & Std. Deviation of Thickness at Each Pressure Value

Pressure	Mean	Std. Deviation	Mean Change
0.25	45.33333	2.309401	
0.3	44	1.732051	-1.33333
0.35	43.33333	1.527525	-0.66667
0.4	43.66667	2.886751	0.33334
0.45	42.66667	2.886751	-1
0.5	43.33333	3.21455	0.66666
0.55	42	1.732051	-1.33333
0.6	42	2.645751	0
0.65	41.33333	2.309401	-0.66667
0.7	42	2.645751	0.66667
0.75	41.33333	2.309401	-0.66667
0.8	40.66667	1.154701	-0.66666
0.85	40.66667	2.081666	0
0.9	40.66667	2.886751	0
0.95	39.66667	2.886751	-1
1	38.66667	1.154701	-1
1.05	38.33333	2.309401	-0.33334
1.1	38	3.464102	-0.33333
1.15	36	1.732051	-2
1.2	35.33333	3.214550	-0.66667
Average			-0.526315

Table 3: Mean thicknesses of the films produced through the LPCVD process at varying pressures. It should be noted that this is the same data, just represented differently

3 Relationships

3.a Thickness vs. Temperature

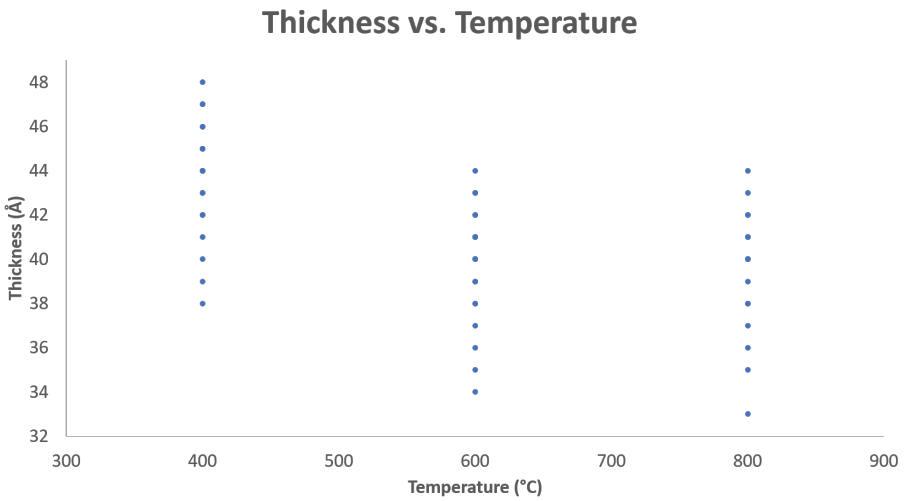

Figure 4: Scatterplot of the film's resulting thickness at 400 °C, 600 °C, and 800 °C

From Figure 4, we can see that higher temperatures result in overall lower thickness of the films deposited. This is consistent with the summaries obtained in Section 2

3.b Thickness vs. Pressure by Temperature

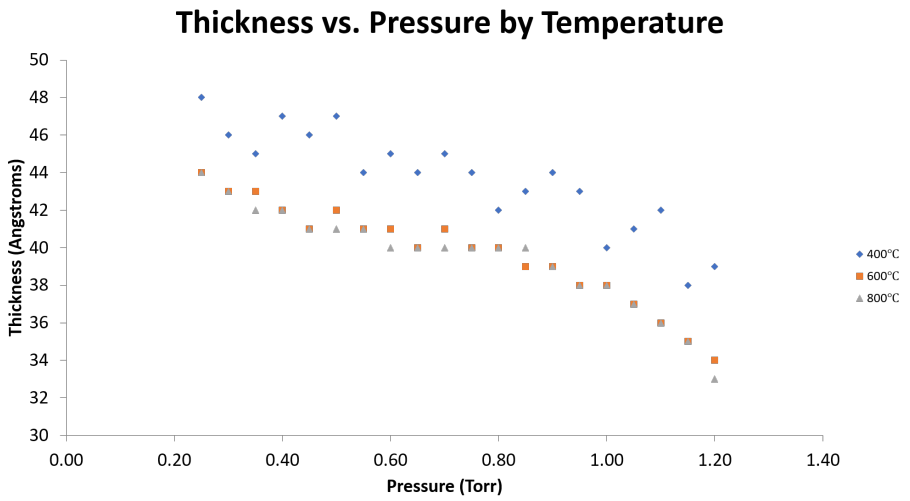

Figure 5: Thickness as a result of pressure and temperature scatterplot

3.c Relationship Between Thickness and Pressure for each Temperature Level

From Figure 5, we can see very clearly that as pressure is increased, the thickness of the film deposited decreases. At 400 °C, we can see that the resulting thickness of the film varies a bit more as the pressure varies, compared to 600 °C and 800 °C. When the temperature is increased to 600 °C and 800 °C, the resulting thicknesses were more consistent and lower. At pressures over about 0.9 Torr, the thickness of the films still go down as the pressure increases, but increasing the temperature from 600 °C to 800 °C does not seem to decrease the thickness by much.

4 How should the temperature and pressure be selected to produce the thinnest possible film for the LPCVD process?

From Figures 1, 2, and 3 we can see that as the temperature is increased, the thickness of the film decreases, evidenced by the bulk of the data shifting left in the histograms as the temperature increases. By observing Tables 1 and 2, we can see that the mean and median averages for thickness also decrease as the temperature is increased. We can also see this effect in Figure 5, where the effect is evidenced by the higher temperature lines (600 °C & 800 °C) being

lower than the 400 °C line. Next, when looking at the effect of pressure on the thickness of the film deposited, we can see that in Table 3, the mean thickness decreases when the pressure is increased. This effect is also seen in Figure 5, indicated by the negative slope of each line. Therefore, in order to produce the thinnest possible film for the LPCVD process, high pressure and temperature is desireable. It can be noted however, that there may be diminishing returns as higher temperature and pressure is used. For example, In Figures 1, 2, and 3, there is a more significant decrease in thickness by increasing the temperature from 400 °C to 600 °C compared to the decrease in thickness by increasing the temperature from 600 °C and 800 °C.