In our research lab, the magnetron sputtering is used to deposit thin films of materials on various substrates. For our next project, we want to deposit thin films of FeCo alloy on Silicon dioxide (SiO_2) substrate. The quality of the film is extremely important to explore the desired characteristics. Hence, we are interested in designing an experiment to optimize the input factors to produce the best quality films.

We are mainly interested in two response variables: thickness and crystalline quality of the films. The thickness is a continuous variable whereas crystalline quality is a categorical variable. The categorical variable has three levels: excellent, good, and bad. An X-ray diffractometer with Cu source will be used to measure the thickness and to determine the quality. This instrument is accurately calibrated, however there could some variation in our measurement due to sample position alignment. We assume that this variation is relatively small as compared to other possible variation. While the measurement of thickness is straight forward, to determine the crystal quality we will refer to the intensity of the peaks and the smoothness of the surface.

During the film deposition there are several factors that might impact the growth mechanism. Based on our previous experience the most important factors are deposition temperature, Argon (Ar) pressure, and the deposition time. These factors will be chosen as design factors for this experiment. Each of the factors will have two levels as follows;

Temperature : 500°C, and 700°C

Ar Pressure : 3 mTorr, and 10mTorr

Time : 5 min, and 15 min

The power to the sputtering gun will be held at constant. The substrate will be used from different batches and the batch will be assigned as a blocking factor. In addition, there are natural uncontrollable factors such as initial base pressure inside the chamber, the material ejection rate off the target, and exposure to the atmosphere while transferring the film to X-ray diffractometer. However, we assume that variation due to these factors are relatively small.

Experimental Design

We anticipate that there is an interaction between all the three factors, hence we choose to design a factorial design. The maximum trails that we can perform is 24. Since there is substrate batch as a blocking factor, we will run all the possible treatments in a single batch. This way we will have three blocks and inside each blocks the treatments will be randomized. For this design, by setting the square root of mean square error (Anticipated RMSE) to 1 and setting the size of each anticipated model coefficient to 1, we see that power can be as high as 99.4%. The JMP output for power analysis is shown below. The design matrix with the levels and the order of runs are also shown below. In the design matrix, A = Temperature, B = Ar Pressure, and C = Time.

Power Analysis

Significance Level 0.05

Anticipated RMSE 1

Term	Anticipated Coefficient	Power
Intercept	1	0.166
A	1	0.994
B	1	0.996
C	1	0.994
A*B	1	0.994
A*C	1	0.994
B*C	1	0.994
A*B*C	1	0.994

	Random Block	A	B	C	Treatment Combinations	Thickness	Quality
1	1	-1	-1	-1	(1)	•	•
2	1	-1	-1	1	c	•	•
3	1	1	1	1	abc	•	•
4	1	-1	1	-1	b	•	•
5	1	1	-1	-1	a	•	•
6	1	1	1	-1	ab	•	•
7	1	1	-1	1	ac	•	•
8	1	-1	1	1	bc	•	•
9	2	-1	-1	1	c	•	•
10	2	1	-1	-1	a	•	•
11	2	-1	1	-1	b	•	•
12	2	-1	1	1	bc	•	•
13	2	1	1	1	abc	•	•
14	2	-1	-1	-1	(1)	•	•
15	2	1	-1	1	ac	•	•
16	2	1	1	-1	ab	•	•
17	3	1	1	1	abc	•	•
18	3	1	1	-1	ab	•	•
19	3	1	-1	1	ac	•	•
20	3	-1	1	-1	b	•	•
21	3	-1	-1	1	c	•	•
22	3	-1	-1	-1	(1)	•	•
23	3	-1	1	1	bc	•	•
24	3	1	-1	-1	a	•	•