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Characterization of Sputtering Platinum Using the Denton Explorer-14 System

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Characterization of Sputtering Platinum Using the Denton Explorer-14 System

Disciplines
Nanoscience and Nanotechnology

Comments
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Goal:

To characterize the deposition rates of platinum within the Explorer 14 as a function of supplied power and gas pressure, and the resulting film stress.

Materials:

- Platinum target
- Diamond Scribe/Cleaver
- Acetone
- 3 inch Patterned Silicon Wafers
- 4 inch Silicon Wafers

Equipment:

- Explorer 14 Magnetron Sputterer
- KLA Stress Profilometer

Units:

- Pressure: milliTorr (mT)
- Cathode Power: Watts
- Time: Seconds (s)
- Stress: MegaPascals (MPa)
- Thickness: nanometers (nm)

Protocol:

<u>Pre Measurement</u>

Pre Measurement steps are noted in the *Measurement of residual stress in deposited films* document in the *Pre-Deposition wafer bow measurement* section.

<u>Deposition</u>

1. Cleave 3 samples from the 3 inch patterned silicon wafer
2. Orient the wafer and sample pieces on opposite ends of the plate, as seen in Fig.1
3. Deposit platinum onto the 4 inch wafer and three sample pieces

<u>Post Measurement</u>

Post Measurement steps are noted in the *Measurement of residual stress in deposited films* document in the *Post-Deposition film thickness measurement* & the *Post-Deposition Wafer bow measurement and stress calculation* sections.

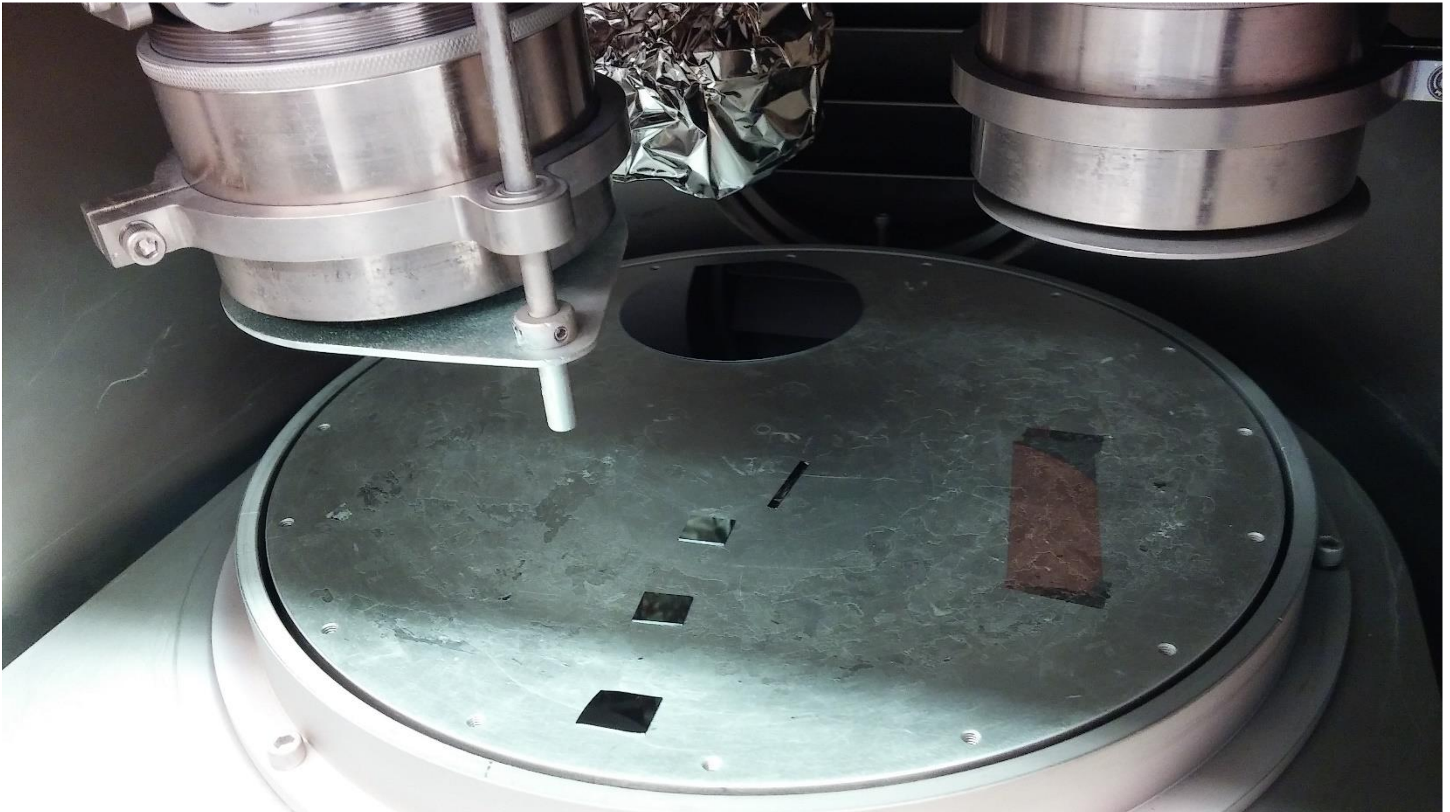

Fig.1. The general orientation of the 4 inch wafer and the samples from the 3 inch wafer. Note the positioning, which, due to the rotation of the plate, allow the samples to map to the different positions of the wafer (Major flat, Center, and Far from Major Flat)

Results:

The goal of this study was to obtain an understanding of the stress and thickness properties of a deposited platinum film at varying powers and pressures. Towards this end, depositions were done by varying the cathode power and gas pressure while depositing for 180 seconds. From this data, predictions can be made about how the deposition rates and stresses of the film vary with gas pressure and cathode power.

The following results were obtained using cathode powers of 400W, 450W, and 500W, as well as having gas pressures of 3 mTorr, 5mTorr, 7 mTorr, 8 mTorr, and 10 mTorr for each power setting. Fig.2 denotes the deposition rates as a function of supplied power and gas pressure with relevant data being in Table 1. Fig.3 denotes the stress trend that was obtained from the deposited films.

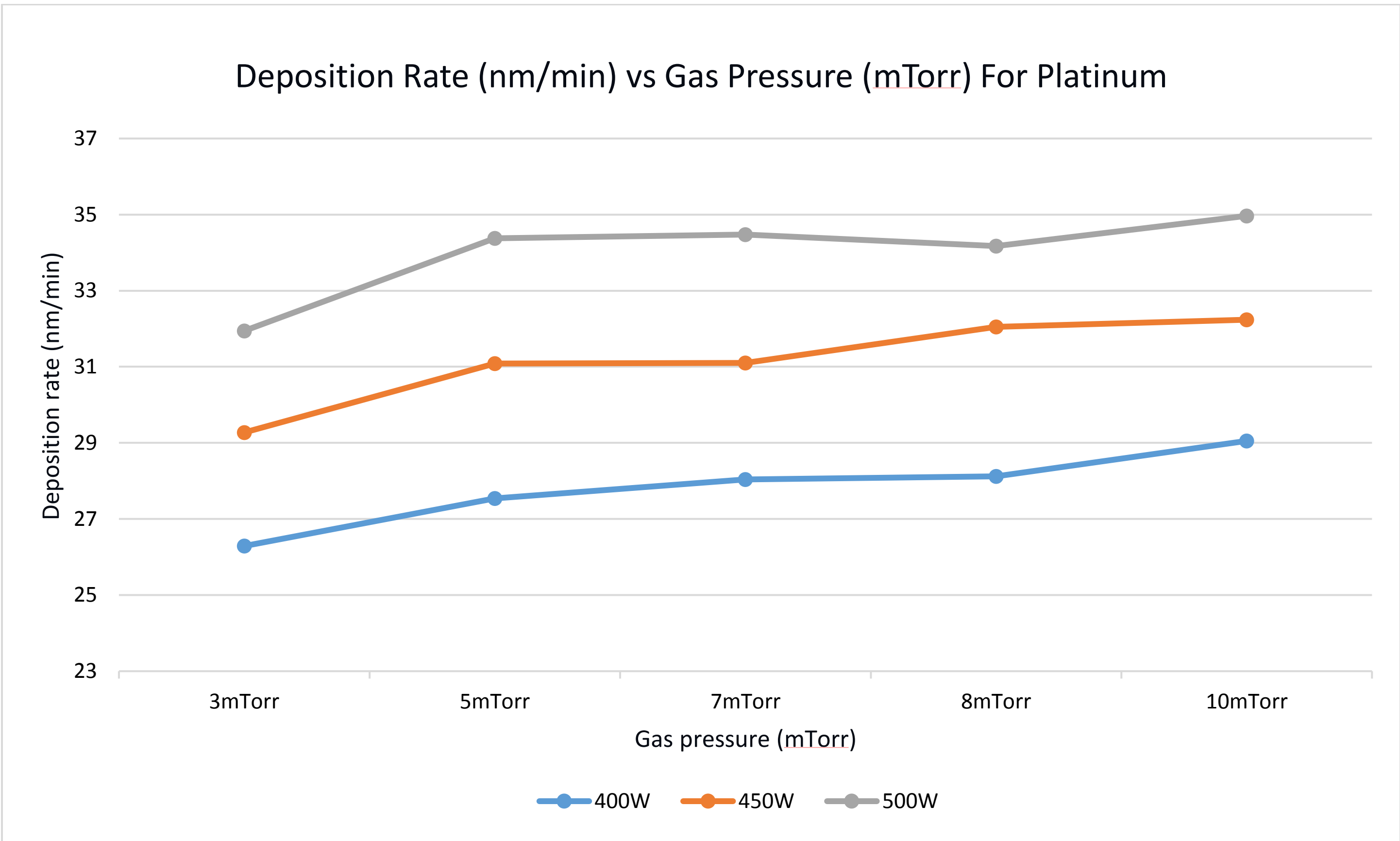

Fig. 2. The deposition rate of platinum (nm/min) as a function of gas pressure and cathode power. Each point is an average of measurements taken from representative samples of the major flat, center, and far end of the substrate.

	3mTorr	5mTorr	7mTorr	8mTorr	10mTorr
400W	26.28889	27.54444	28.03704	28.12222	29.05185
450W	29.27407	31.08519	31.1037	32.04815	32.23704
500W	31.94444	34.37778	34.47407	34.17037	34.96667

Table.1. The (averaged) values of the platinum deposition rates (nm/min) for different cathode power values and different pressure

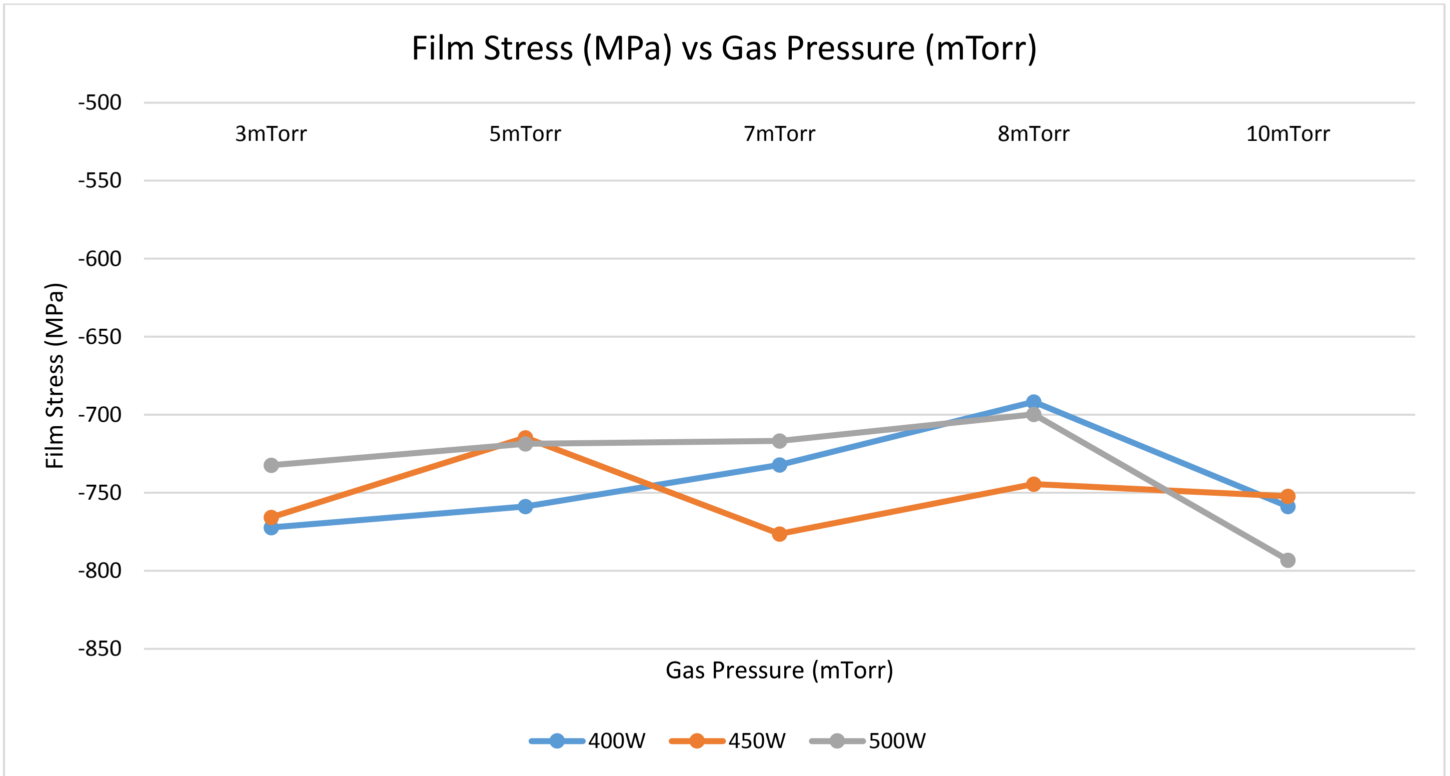

Fig. 3. The film stress (MPa) as a function of gas pressure (mTorr).

Power	3mTorr	5mTorr	7mTorr	8mTorr	10mTorr
400W	-772.2	-758.7	-732.2	-691.7	-758.7
450W	-765.8	-714.6	-776.3	-744.4	-752.2
500W	-732.3	-718.6	-716.7	-699.7	-793.1

Table 2. The (Average) values of the film stress (MPa) for differing values of cathode power and gas pressure.

Discussion:

In Fig.2, note that the deposition rate increases both as a function of cathode power and gas pressure. Also, the amount of uncertainty that is attached to these values are in the range of 1.5-2.5 nm/min. The general trend of platinum's behavior here has also been observed in a paper by NASA (see: https://www.grc.nasa.gov/WWW/sensors/PhySen/docs/TM-2005-213433.pdf)

In Table.1, the values are averaged from three data points taken from each of the three samples.

In Fig.3, note that the film stress values are negative, because platinum is a compressive film, which contracts and bends upwards. Also note that the stress of the film lies essentially within the bounds of -690 to -795 MPa, or essentially -742.5±52.5. From the analysis which is discussed in *Error propagation for Substrate Thickness post-deposition (Stoney Equation Analysis),* it can be verified that the uncertainties that are associated with each stress point would indeed overlap, giving a general view of what the stress of the film upon the substrate would be.

Additional Data:

Sample #	Major Flat Measures (nm)			Center Measures (nm)			Furthest from MF (nm)			MEAN	STD	ERROR
21	60	59.7	59	83.1	83.2	83	93	94.5	94.3	78.86667	14.35316	4.784388
22	64.6	64.6	63.1	87.1	91.5	82.8	101.5	100.1	101.7	84.11111	15.40371	5.13457
23	72.3	67.8	65.8	94	91.6	87.2	100.7	102.5	102.5	87.15556	14.03307	4.677688
24	65.7	63.5	60.3	84	87.4	86.3	99.5	98.6	98.4	82.63333	14.82355	4.941185
25	62	65.4	62.3	85.3	87.2	88.9	103.1	99.1	106	84.36667	16.37206	5.457354
26	65.9	49.8	66.7	95.5	93.4	96.5	107.8	107.2	107.6	87.82222	20.28561	6.761872
27	66.6	65.7	70.8	100	98.2	103.6	110	112.1	112.3	93.25556	18.70592	6.235306
28	69.1	66.7	71	97.2	98.7	99.7	111.5	112.8	113.1	93.31111	18.19447	6.064824
29	67.2	71.3	75.2	103	102.4	99.4	116	114.4	116.4	96.14444	18.6435	6.214501
30	74.2	72.9	71.4	102.8	101.1	98.1	116.2	116.6	117.1	96.71111	18.14671	6.048904
31	68.3	69.6	72.9	99.3	98	102.8	118.5	115.6	117.5	95.83333	19.46906	6.489688
32	81.5	78.6	76.8	107.1	109.7	111.6	121.5	121	120.4	103.1333	17.79063	5.930211
33	78.9	78.8	76.2	110.7	107.7	107.4	124	122.8	124.3	103.4222	19.06292	6.354308
34	71.4	74.8	76.8	105.1	107.1	109.1	125.8	124.2	128.3	102.5111	21.46286	7.154286
35	83.5	77.6	74.8	109.6	109.6	108.6	128	125.4	127	104.9	20.02609	6.675365

Table.2. The raw data for the film thicknesses for the platinum depositions. Each column under the major flat, center, and furthest from major flat represent one of the three measurements taken from that area of interest.

Power (W)/ Pressure (mTorr)	MFD Average (MPA)	MFD Max (MPa)	MFD Center (MPa)	MFR Average (MPa)	MFR Max (MPa)	MFR Center (MPa)
400 W/3 mTorr	-772.2	-1100	-655.9	-815.9	-1278	-752.5
400 W/7 mTorr	-732.2	-897.8	-706.1	-777.3	-810.9	-805.7
400 W/10 mTorr	-775.3	-815.5	-808	-786.5	-861.6	-849.6
400 W/5 mTorr	-758.7	-794.1	-766.9	-750.5	-1060	-744.2
400 W/8 mTorr	-691.7	-1203	-986.5	-911.1	-1578	-1130
450 W/3 mTorr	-765.8	-942.4	-753.4	-757.3	-864.2	-770.4
450 W/5 mTorr	-714.6	-726.4	-717	-748.8	-835.5	-751.2
450 W/7 mTorr	-776.3	-796.3	-767.8	-803.7	-898.6	-813.7
450 W/8 mTorr	-744.4	-753	-749.1	-776	-918.2	-782.2
450 W/10 mTorr	-752.2	-762.3	-748.9	-793.6	-885.2	-800.6
500 W/3 mTorr	-732.3	-826.4	-725.6	-757.6	-868.4	-756
500 W/5 mTorr	-718.6	-839	-699.6	-724.9	-787.4	-752.3
500 W/7 mTorr	-716.7	-742.2	-720.5	-740.7	-811.2	-751.4
500 W/8 mTorr	-699.7	-738.8	-691.8	-800.1	-843.7	-807.1
500 W/10 mTorr	-793.1	-853.4	-793.3	-789.2	-844.3	-811.1

Table.3. The raw data of the stress measurements across the wafers, where MFD refers to major flat facing down, and MFR refers to major flat facing towards the right inside the profilometer. For the stress measurements and graphs, the average values were utilized.