ALD Film Characterization

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Objective

The following set of tests was performed to determine the characteristics of films created by the Atomic Layer Deposition system and how they varied with the operation temperature. The films tested were aluminum oxide, hafnium oxide, and zinc oxide. The use of different recipes was also tested to determine the temperature ranges best suited to a recipe.

Procedure

Each wafer was run for 800 cycles at its respective temperature and recipe. Four measurements were made on each sample: deposition rate, index of refraction, stress, and roughness

Deposition Rate measurements: The Gaertner Ellipsometer was used to take measurements of the wafer film thickness before and after ALD processing by measuring five points on each wafer to determine the film thickness.

Index of Refraction measurements: The Gaertner Ellipsometer was used to take five measurements on the surface of each wafer giving an average index of refraction value.

Stress measurements: Each wafer was scanned three times in the Stress Test-1 before and after ALD processing to measure the stress induced by the film.

It was found that the extra film deposited on the outer edge of the backside of each wafer can significantly affect stress measurements. To eliminate the effects of this factor, we removed the extra film on each wafer before taking stress measurements. This was accomplished using two different methods:

For aluminum and zinc films: After taking the deposition rate and index of refraction measurements, the front side of the wafer was coated with S13 photoresist. Wafers were soft-baked and then immersed in a BOE bath for about 3 minutes or until the backside film was removed. Once the photoresist was removed with solvents, the second stress measurement was taken.

For hafnium films: The BOE solution is ineffective in removing this film. Instead, the Oxford Etcher recipe “N etch al” was used for about 10 minutes with the same coating of photoresist as described above and the wafer placed face down in the machine. Then the photoresist was removed and the stress measurement was taken.

Roughness measurements: Roughness measurements were taken by the Atomic Force Microscope. A 10 µm and a 1 µm image were taken of each sample. The Rms and Ra of each image were taken by the AFM roughness analysis. In the graphs displayed in this report, a measurement labeled 1 refers to the 10 µm image and a measurement labeled 2 refers to the 1 µm image of each sample.

Results

Summary of Results

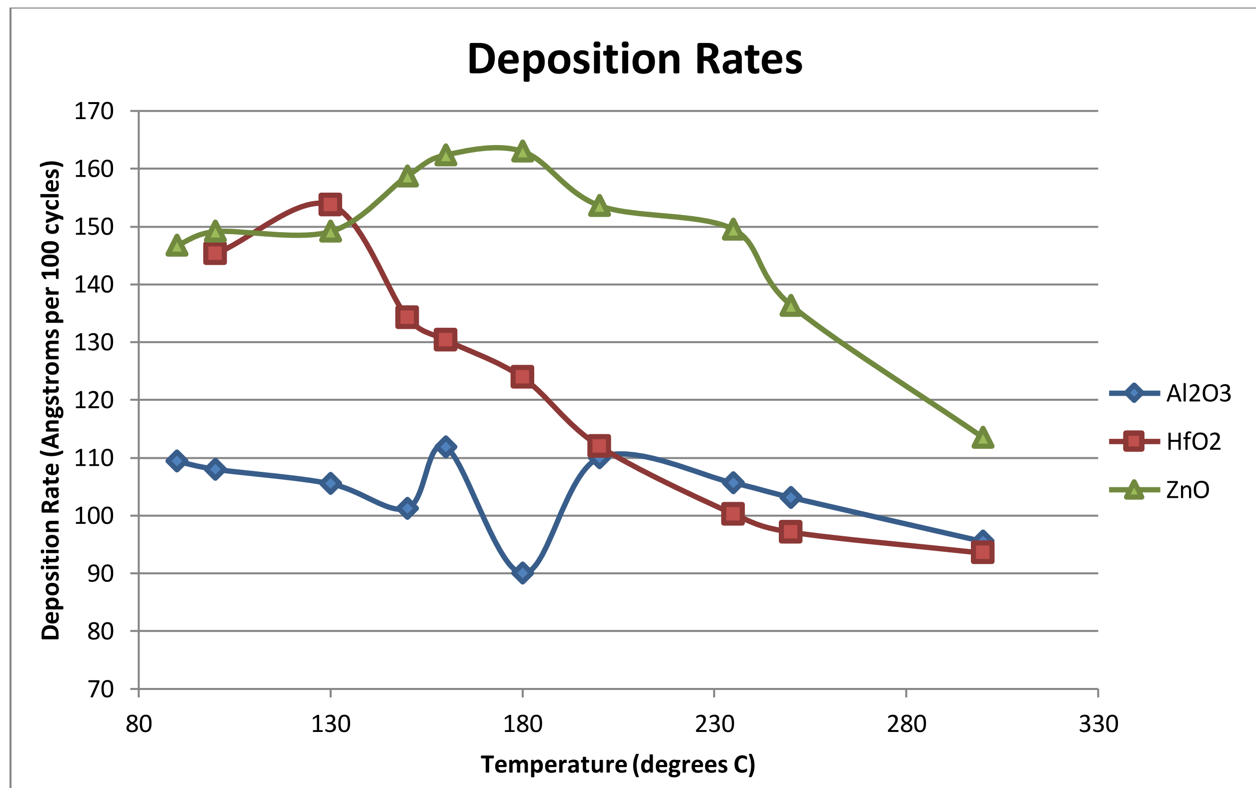
Temp	Al2O3				Hf2O3			
	Deposition Rate (angstroms per 100 cycles)	Index of Refraction	Average Stress (MPa)	Roughness	Deposition Rate (angstroms per 100 cycles)	Index of Refraction	Average Stress (MPa)	Roughness
90	109	1.646	334	1.36				
100	108	1.644	435		145	2.508	942	1.21
130	106	1.641	442	0.76	154	2.165	713	
150	101	1.635	510		134	2.105	781	5.31
160	112	1.641	463		130	2.108	655	
180	90	1.604	565	1.10	124	2.105	671	2.87
200	110	1.648	388	0.51	112	2.091	1054	3.70
235	106	1.653	350		100	2.092	930	
250	103	1.652	302	0.66	97	2.084	1032	2.08
300	96	1.655	274	0.91	94	2.082	379	1.83

Temp	ZnO			
	Deposition Rate (angstroms per 100 cycles)	Index of Refraction	Average Stress (MPa)	Roughness
90	147	2.074	168	3.18375
100	149	2.133	173	
130	149	2.378	-131	4.279
150	159	2.272	26	
160	162	2.128	-36	
180	163	2.061	-23	1.398
200	154	2.012	-29	1.4505
235	150	1.996	-4	
250	136	1.995	225	2.08775
300	114	1.972	1261	4.13575

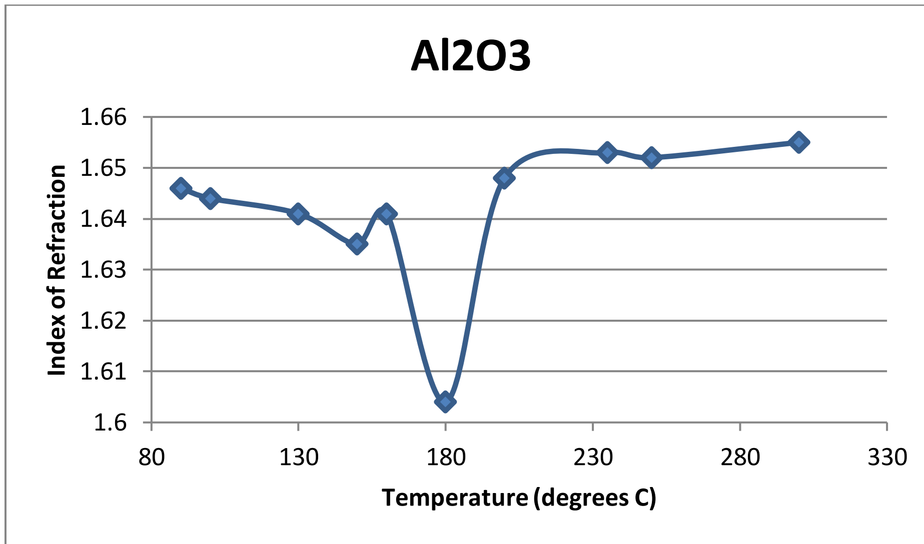
Low Temperature Recipes

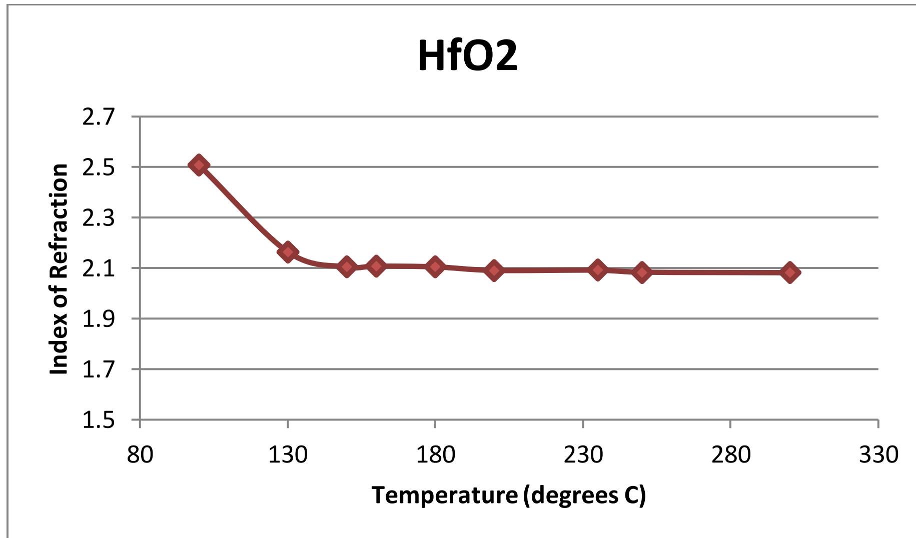
Temp	Deposition Rate (angstroms per 100 cycles)	Index of Refraction	Average Stress (MPa)	Deposition Rate (angstroms per 100 cycles)	Index of Refraction	Average Stress (MPa)
80	126	1.525	489	225	2.056	654
100				151	2.986	794
130	116.75	1.698		132.375	2.1	1182
150	115.5	1.682	538	126.75	2.042	832
180	116	1.676	536	116.375	2.1	673

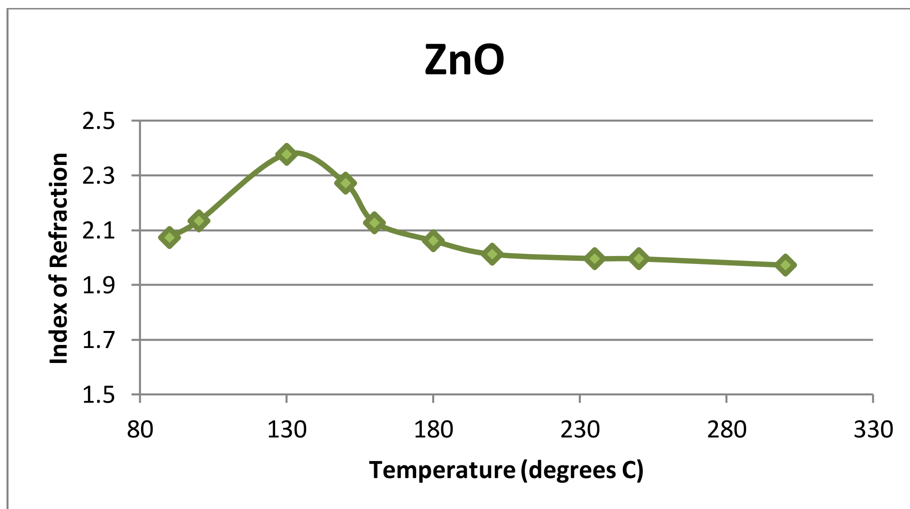
Deposition Rate



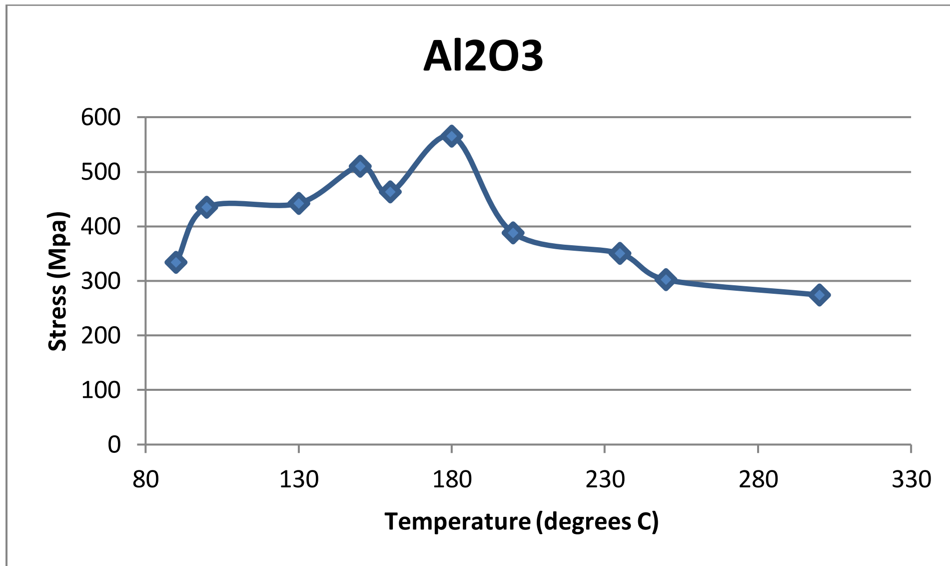
Index of Refraction:

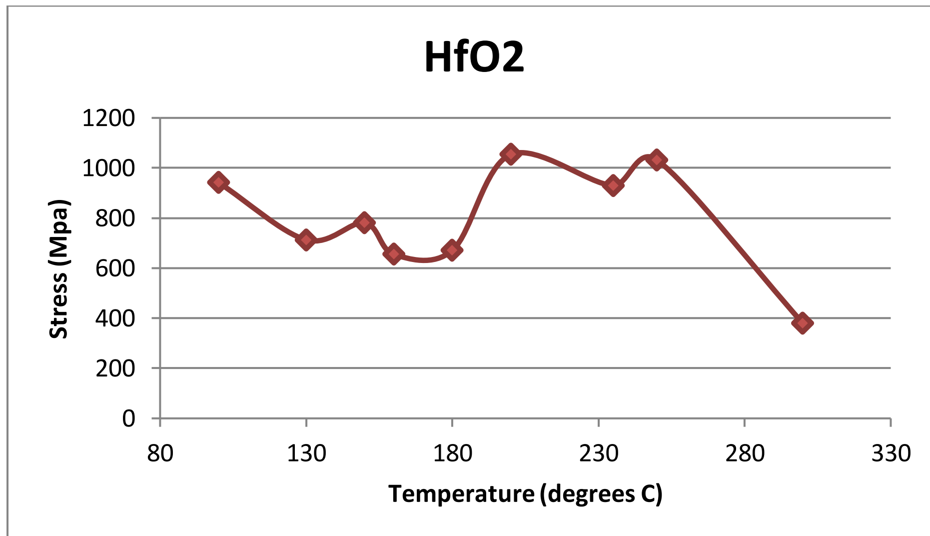


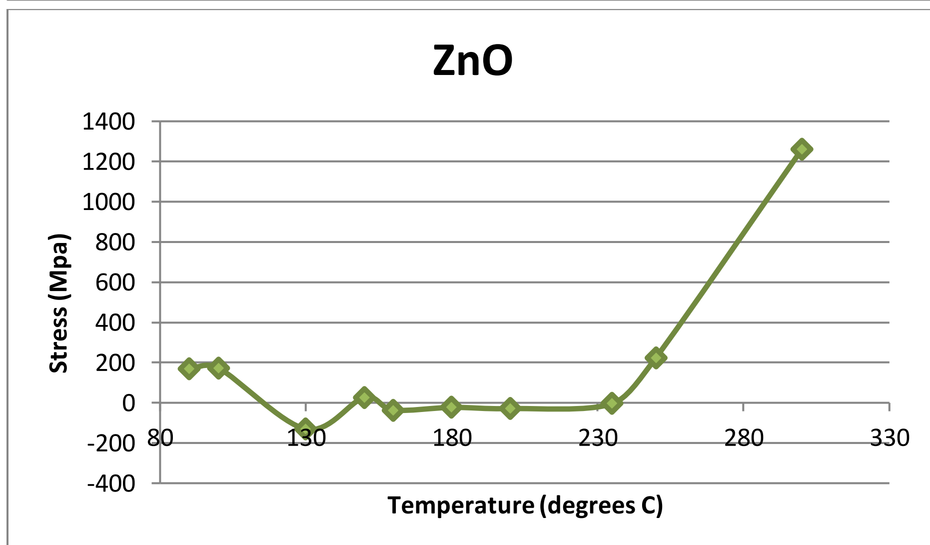




Stress:

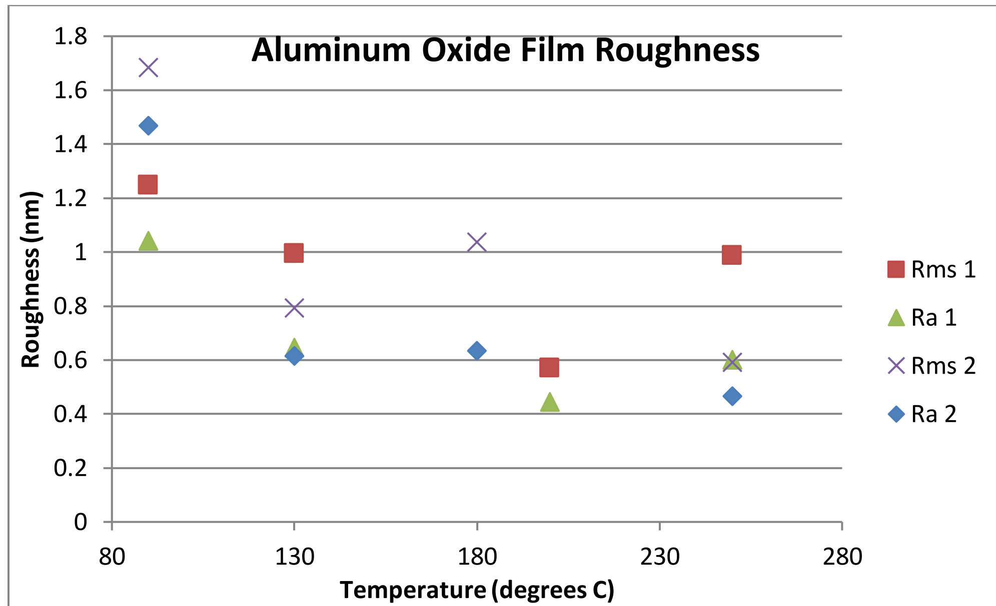






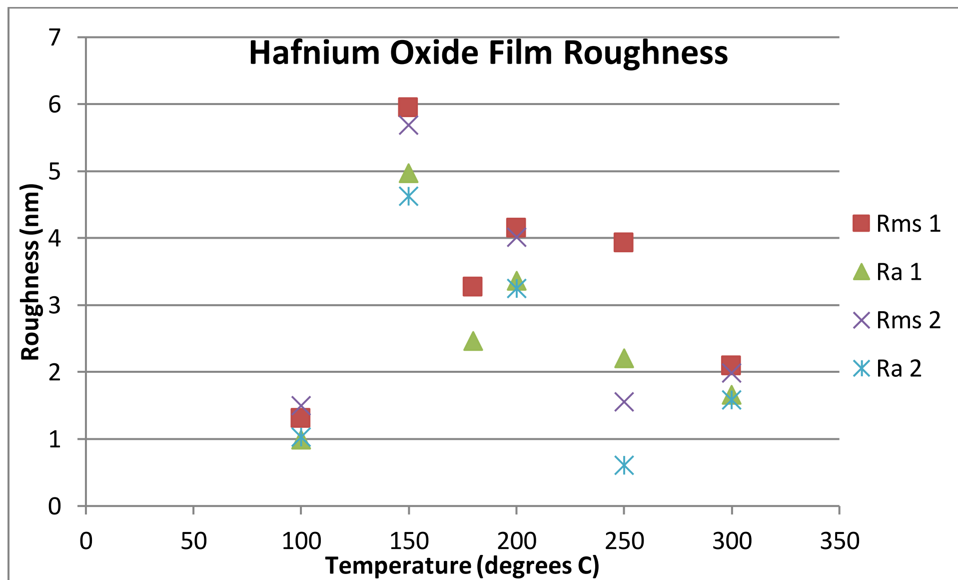
Roughness:

<u>Aluminum Oxide:</u>



(A measurement labeled 1 refers to the 10 µm image and a measurement labeled 2 refers to the 1 µm image of each sample.)

<u>Hafnium Oxide:</u>



Zinc Oxide: