CNF NORDTECH Internship: Characterization of Oxynitride Films

CNF Project Number: CNF Summer Internship
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Primary CNF Tools Used: MRL Industries E4 Furnace

Abstract:

As part of the CNF NORDTECH internship program, various projects were worked upon this summer. One of the projects was the characterization of an oxynitride process using the MRL Industries LPCVD furnaces. The oxynitride film is heavily used in photonics, and specifically done to gather information for a remote request for the film. The characterization of the thin film involved varying the gas ratios in order to determine the effect of adding oxygen to the recipe. Other factors such as pressure, and temperature were kept constant. The time variable was flexible since the sample needed to be thick enough to gather the data. The main objective of the characterization was to determine the deposition rate, the index of refraction and the stress of the film. From the data gathered, a few conclusions were drawn. As the concentration of oxygen in the film increased, the index of refraction, the deposition rate, and the stress all decreased.

Experimental Procedure:

The oxynitride film was deposited using the Low-Pressure Chemical Vapor Deposition (LPCVD). In order to properly determine the effects of different gas ratios, many of the determining variables were kept constant throughout the experiment. These included the chamber pressure, and the dichlorosilane set percentage. For the gas flow settings, the mass flow controller (MFC) has a set amount of gas flow it can allow measured in standard cubic centimeters per minute (sccm). The gas ratios are a percentage of that flow. For the oxynitride run, there are 3 different gasses used to deposit the film. The gasses given are Ammonia (NH_3), Nitrous Oxide (N_2O) and Dichlorosilane (DCS). Using the gasses we can determine the constant parameters for the experiment. These gasses can be viewed in Table 1 and the constant parameters in Table 2.

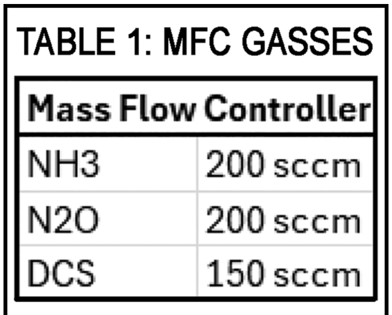

TABLE 1: MFC GASSES

Mass Flow Controller	
NH3	200 sccm
N2O	200 sccm
DCS	150 sccm

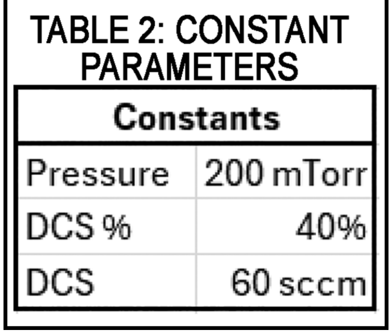

TABLE 2: CONSTANT PARAMETERS

Constants	
Pressure	200 mTorr
DCS %	40%
DCS	60 sccm

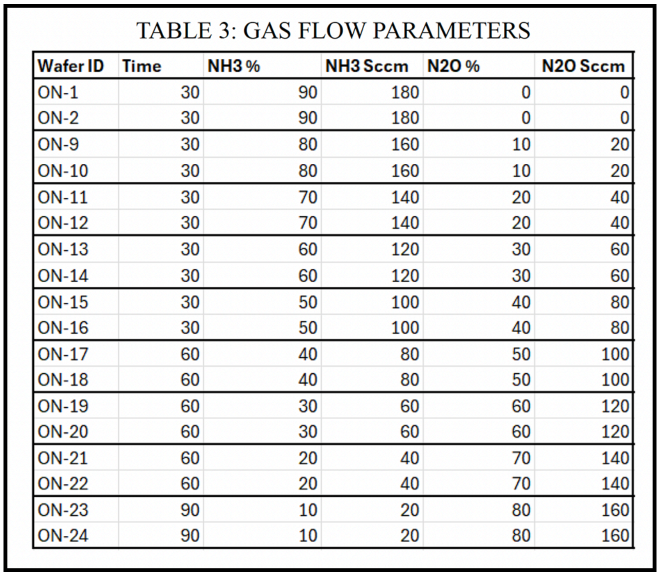

TABLE 3: GAS FLOW PARAMETERS

Wafer ID	Time	NH3 %	NH3 Sccm	N2O %	N2O Sccm
ON-1	30	90	180	0	0
ON-2	30	90	180	0	0
ON-9	30	80	160	10	20
ON-10	30	80	160	10	20
ON-11	30	70	140	20	40
ON-12	30	70	140	20	40
ON-13	30	60	120	30	60
ON-14	30	60	120	30	60
ON-15	30	50	100	40	80
ON-16	30	50	100	40	80
ON-17	60	40	80	50	100
ON-18	60	40	80	50	100
ON-19	60	30	60	60	120
ON-20	60	30	60	60	120
ON-21	60	20	40	70	140
ON-22	60	20	40	70	140
ON-23	90	10	20	80	160
ON-24	90	10	20	80	160

From these initial parameters, a formulated experiment can be developed. Starting out by scribing our wafers, the gas ratios can be compiled. Silicon Nitride is formed using NH_3 and DCS. So that will become the start point. After the initial run the NH_3 percentage will decrease while the N_2O percentage will increase. This pattern will be repeated until there is no NH_3 flow left, and the only gasses in the chamber are N_2O and DCS. The specific gas flows used can be viewed in Table 3.

From this table, one of the most noticeable columns is the time column. Initially time was supposed to be held as a constant. But as the N_2O percentage increased, the deposition rate decreased dramatically which will be showcased later in the results section. If the time was not increased, the thickness of the film would have been way too thin to gather any usable data.

Results:

After each run was performed, the films were tested using the J. A. Woollam RC2 Ellipsometer. This was used to determine the thickness of the film, which would allow the deposition rate to be calculated. The ellipsometer also provided the index of refraction of the film. After the initial film properties were gathered, the film on the back side of the wafer was etched, to make a stress measurement using the FleXus. This allowed for the film to generate stress on only the top side of the wafer, so the stress of the film can be measured. Before the furnace process, each wafer was tested to determine an initial stress value. This can then be used to determine the stress of the film by taking the difference. The overall results can be viewed in Table 4.

TABLE 4: RESULTS

Wafer ID	Time	NH3 %	NH3 Sccm	N2O %	N2O Sccm	Thickness	Dep Rate	Index	Stress
ON-1	30	90	180	0	0	100.37	3.345667	2.0174	
ON-2	30	90	180	0	0	101.89	3.396333	2.0176	
ON-9	30	80	160	10	20	90.73	3.024333	1.994	
ON-10	30	80	160	10	20	91.35	3.045	1.994	
ON-11	30	70	140	20	40	80.2	2.673333	1.965	
ON-12	30	70	140	20	40	79.04	2.634667	1.965	
ON-13	30	60	120	30	60	70.19	2.339667	1.936	856.915
ON-14	30	60	120	30	60	69.65	2.321667	1.935	
ON-15	30	50	100	40	80	59.06	1.968667	1.90369	848.105
ON-16	30	50	100	40	80	59.58	1.986	1.90474	
ON-17	60	40	80	50	100	95.66	1.594333	1.87467	
ON-18	60	40	80	50	100	96.59	1.609833	1.87606	677.133
ON-19	60	30	60	60	120	92.59	1.543167	1.8689	732.999
ON-20	60	30	60	60	120	90.93	1.5155	1.87191	
ON-21	60	20	40	70	140	44.28	0.738	1.75273	619.534
ON-22	60	20	40	70	140	45.33	0.7555	1.75518	
ON-23	90	10	20	80	160	31.59	0.351	1.65041	321.178
ON-24	90	10	20	80	160	32.2	0.357778	1.65213	

From the results we can observe the decrease in deposition rate, index of refraction and stress as a factor of the gas ratio. For the stress data, only one wafer was etched, to leave a complete wafer still intact for more possible further exploration such as etch tests etc. The first few wafers there were no stress data for, due to some errors with the furnace, that led to the tool needing maintenance. With the other data, a better visualization is provided in Figures 1 and 2.

The figures tend to show a very linear trend for the deposition rate, with one outlier at the 60 percent mark. A similar trend appears with the index. At this range the film possibly has a larger concentration of oxygen than nitrogen. The same point also shows an inverse exponential regression of the index of refraction. As the original few points are very linear, at 60 percent N_2O, the index decreases rapidly. Overall the characterization will allow users to better produce certain films to their specifications. Consistent characterization of tools allows for more accurate results based on the tool information sheets. With tools going down, and requiring maintenance, the results of a process may change over time. This experiment should allow users to produce an accurate oxynitride film to their specifications.

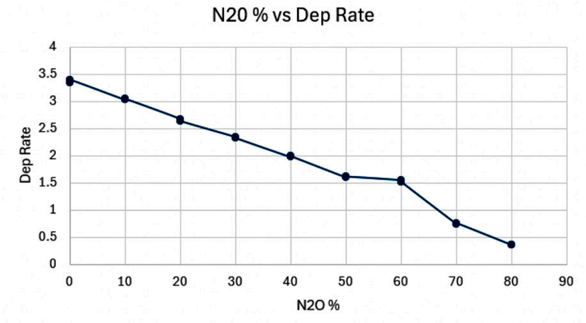

Fig. [1]: N2O% Vs Dep Rate

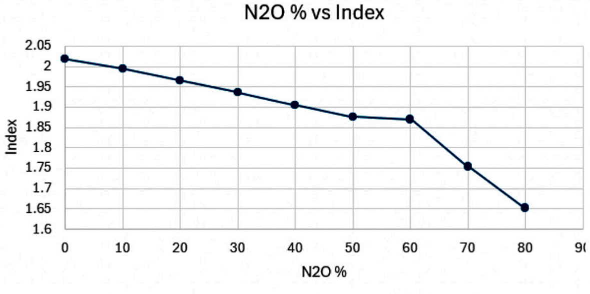

Fig. [2]: N2O Vs Index