AJA Sputter 1 & 2 Materials Characterization

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Abstract:

The application of sputtering for thin-film deposition has been a staple technique for decades, and its importance is growing with the expansion of nanotechnology. As new materials are developed to address unique challenges, their characterization within sputtering tools becomes increasingly essential. This study investigates the effects of various sputtering conditions on key film properties. The primary objective was to understand the relationship between sputtering parameters and both film Deposition Rate and Film Stress, while also measuring secondary characteristics such as Sheet Resistance and Index of Refraction. Depositions were performed using AJA 1 and AJA 2 Sputtering machines. The primary variable was chamber pressure, tested at three levels: 3 mTorr, 7 mTorr, and 20 mTorr. Deposition times were controlled to achieve a target film thickness between 100-300 nm for all samples. For a range of previously uncharacterized materials (Zr, Nb, Ru, Si3O4, Hf, NiO), trends for deposition rate and film stress were consistent with existing data. Specifically, increased chamber pressure generally resulted in a lower deposition rate. Film stress, as plotted and recorded against pressure, also matched general trends found with similar elements on other sputtering tools under different conditions. The key finding of this research was the consistency of these trends. The results suggest that the trends in film stress are element-specific and predictable. This research provides a foundation for future studies, allowing researchers to more accurately predict and plan for the effects of deposition parameters when working with novel materials.

Summary of Research:

Sputtering is a common deposition technique used to create the thin films necessary for building devices. Materials are selected based on their desired electrical, physical, or chemical properties. To ensure these desired effects are achieved, a standard table of characterization data is crucial, especially since sputtering tools can differ from each other even under "identical" conditions. Additionally, secondary effects like film stress are key considerations, as they can lead to device or film failure.

This research focused on collecting comprehensive data for a set of new materials on the AJA 1 and AJA 2 sputtering machines. The experimental process involved the following steps:

1. Wafer Preparation: Wafers underwent a MOS clean to remove organic contaminants and unwanted metals.
2. Native Oxide Removal: Prior to deposition, wafers were submerged in a two-minute buffered oxide etch to remove the native oxide layer.
3. Deposition: Experimental conditions were varied, with deposition times estimated to achieve a target thin-film thickness of 100-300 nm.
4. Data Collection: A patterned chip, or "witness sample," was attached to the carrier during deposition. After liftoff, a profilometer was used to measure the film height, assuming uniform deposition. This data was then used to measure film stress using a Flexus tool. Additional measurements were taken using a four-point probe for sheet resistance and an ellipsometer for refractive index.

Conclusions and Future Steps:

Analysis of the data reveals consistent trends between sputtering pressure and the resulting film properties, particularly for deposition rate and film stress. For most materials, an increase in chamber pressure correlated with a decrease in deposition rate, a widely observed phenomenon in sputtering processes. Similarly, film stress exhibited predictable, element-specific responses to pressure changes, with a clear shift from tensile to compressive stress in several cases (e.g., Zr, Nb) and a general trend of becoming less compressive with increasing pressure (e.g., Si3N4, Hf, Ti). These consistent, predictable trends suggest that film properties can be reliably tuned by controlling chamber

Material	Sputtering Machine	Pressure (mTorr)	Avg Height (A)	Time (s)	Deposition Rate (A/s)	Stress (MPa)	Stress Type	Avg Sheet Resistance(Ohm/sq)	Resistivity (µOhm * m)	Refractive Index	Box #	Wafer #
Zr	1	3Uncleaned	1490	1000	1.49	147.0	Tensile	9.39	1.3989312	N/A	1	1
Zr	1	3	1391	1000	1.39	-34.5	Compressive	7.74	1.07627234	N/A	1	2
Zr	1	7	1502	1000	1.50	-500.9	Compressive	46.93	7.0482852	N/A	1	3
Zr	1	20	1124	1000	1.12	-257.6	Compressive	427.57	48.058868	N/A	1	4
Al2O3	1	3	472	2000	0.24	-273.4	Compressive	Invalid	Invalid	1.60	1	5
Al2O3	1	7	1295	4000	0.32	-286.1	Compressive	Invalid	Invalid	1.63	1	6
Al2O3	1	20	668	4000	0.17	8.2	Tensile	Invalid	Invalid	1.63	1	7
Al2O3	1	3	1395	4000	0.35	-304.1	Compressive	Invalid	Invalid	1.66	1	8
Nb	1	3	1571	1800	0.87	619.7	Tensile	1.40	0.21957867	N/A	2	6
Nb	1	7	2020	1800	1.12	-248.3	Compressive	12.95	2.615092	N/A	2	7
Nb	1	20	1964	1800	1.09	-89.3	Compressive	92.81	18.2276876	N/A	2	8
Si3N4	1	3	1528	2500	0.61	-490.5	Compressive	Invalid	Invalid	1.93	2	13
Si3N4	1	7	1575	2500	0.63	-51.0	Compressive	Invalid	Invalid	1.62	2	14
Si3N4	1	20	931	2500	0.37	-6.4	Compressive	Invalid	Invalid	1.57	2	15
Ti	1	3	1808	1500	1.21	151.5	Tensile			N/A	2	22
Ti	1	7	2284	1750	1.31	63.4	Tensile	20.88	4.7683068	N/A	2	17
Ti	1	20	2695	3600	0.75	38.7	Tensile	30.38	8.186871	N/A	2	18
Al	2	3	1887	1000	1.89	-35.9	Compressive	0.21	0.038781624	N/A	2	19
Al	2	7	1617	1200	1.35	-19.9	Compressive	0.32	0.051009882	N/A	2	20
Al	2	20	1613	2500	0.65	-44.7	Compressive	0.45	0.072481768	N/A	2	21
Hf	1	3	2134	1200	1.78	-2669.2	Compressive	4.60	0.98221618	N/A	3	1
Hf	1	7	1114	600	1.86	-808.3	Compressive	8.68	0.96665122	N/A	3	6
Hf	1	20	2915	1200	2.43	-71.0	Compressive	43.35	12.636525	N/A	3	7
NiO	1	3	1546	4000	0.39	-436.7	Compressive		0		3	10
NiO	1	7	1576	4000	0.39	-25.1	Compressive		0		3	11
NiO	1	20	799	4000	0.20	-122.1	Compressive		0		3	12
Ti	2	3	1471	1500	0.98	159.6	Tensile	6.68	0.98289278	N/A	3	13
Ti	2	7	1645	1750	0.94	30.0	Tensile	17.58	2.8917455	N/A	3	14
Ti	2	20	1686	3600	0.47	38.9	Tensile	28.47	4.7998734	N/A	3	15
Ru	2	3	2345	1000	2.35	-509.3	Compressive	0.54	0.125938225	N/A	2	2
Ru	2	7		1000	0.00				0	N/A	2	
Ru	2	20	3499	1000	3.50	-3.6	Compressive	19.87	6.9528629	N/A	2	5

Figure 1.

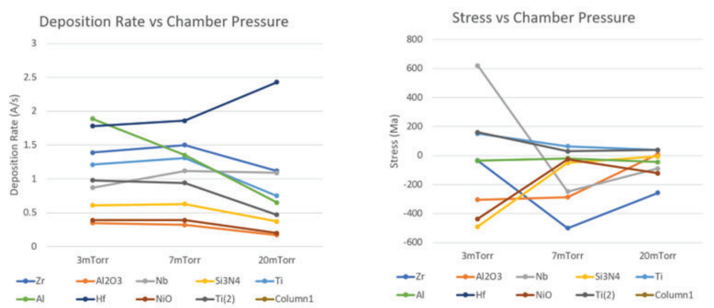

Figure 2.

pressure. The findings not only validate established sputtering principles but also provide a critical starting point for future researchers to optimize deposition conditions for a wide range of materials. In the future, this research hopes to expand its characterization by looking at film uniformity and roughness.

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