Process Summary

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Process Performed: Uniformity Testing of Sputtered Aluminum on Si
Equipment Used: DC Sputterer
Process Technician: Lage Matzke
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Process Overview:

6" silicon wafers had a "line" of masking material drawn on them, extending from one side of the wafer to the other. The wafers were put into a DC magnetron sputterer, with the masked line on the wafer extending from the inner to outer region of the sputtering track. This accomplished two things: it provided an easy method for metal lift-off for measurement purposes, and also provided a profile of the track in terms of sputtering rate and uniformity versus position on the track (inner or outer region). Several parameters were varied including: power, pressure, substrate-target distance, and use of an aperture; to see the effect on both the sputtering rate, and most importantly, the uniformity of the deposition across the wafer. Once each deposition was performed, the wafer(s) were sonicated in methanol to remove the masking material, providing metal lift-off, and a feasible step height to measure. All measurements were performed with a KLA-Tencor P16 Profilometer. From these measurements, uniformity could be calculated. It was found upon using "apertures" in conjunction with the sputtering target assembly, that the uniformity could be controlled around 3%.

Process Steps:

Masking of wafer-

- Each 6" silicon wafer (single side polished) was obtained and blown off with Nitrogen gas
- A "line" of masking material was drawn on the polished side of the wafer extending from one side of the wafer to the other, effectively tracing the diameter of the substrate
- Substrate was blown off with Nitrogen gas to ensure masking material was completely dried, and to reduce particles on the wafer prior to loading

Sputtering of Aluminum-

- Substrate was placed into a Perkin-Elmer DC Magnetron Sputterer
- Wafer was centered on the sputtering track, effectively covering the majority of the track (less ~ 2 cm)

- Wafer was oriented so the masked line ran across the track from the outer to inner edge
- System was evacuated to vacuum with a base pressure of 2 x 10E-6 Torr
- Once base pressure was reached, Argon was introduced into the system as the sputtering gas (~ 5.2 sccm gas flow rate of Argon)
- The system's variable orifice was adjusted to set the desired process pressure
- The substrate rotation was turned on, and set to ~ 3 RPM
- The power supply was set to ramp up at 2.5 kW/min
- The power was held at the desired set point for 2 minutes to allow sufficient pre-sputtering of the target prior to depositing onto the substrate
- The target's shutter was opened after the 2 minute pre-sputter time was completed
- The process had a total sputtering time of 6.8 minutes, then the DC power supply was turned off
- The target's shutter was closed
- Substrate rotation was turned off
- The system was vented, and the substrate removed from the vacuum chamber

Sputtering Variables Tested-

- Runs were performed at several process pressures (7.2 mTorr, 10 mTorr, and 15 mTorr)
- Runs were performed with the table height (substrate-target distance) set to either the highest position (minimal substrate-target distance) or lowest position (maximum substrate-target distance) with this variable change in distance equal to about 1 inch
- Runs were performed either with or without an aperture mounted onto the target assembly (two different apertures were used; Aperture # 1 & Aperture # 2)

Metal Lift Off-

- Substrate(s) were placed into a beaker and submerged in Methanol
- Beaker was placed into a sonicator for a few minutes to assist with metal lift-off
- Once metal lift off was completed, the exposed silicon was lightly cleaned in methanol with a cotton swab applicator (if necessary) to ensure any residual masking material was removed
- Sample was dried off with nitrogen gas

Profile Measurement-

- Substrate(s) was loaded into a KLA-Tencor P16 Profilometer
- Each substrate was measured every centimeter along the masked line to extrapolate a profile of the wafer deposition relative to it's position on the track
- Measurements were recorded and a standard deviation, as well as uniformity value was determined for each sputtering run

Conclusion:

The wafer uniformity was tested for each run. Here were the results:

RUN #	1	2	3	4	5	6	7
Base Pressure (Torr)	2 x 10E-6	"	"	"	"	"	"
Process Pressure (mTorr)	7.2	7.2	**10**	**15**	7.2	7.2	7.2
Argon Flow Rate (sccm)	5.1	"	"	"	"	"	"
Rotation Speed (RPM)	3	"	"	"	"	"	"
Power (kW)	5	5	5	5	**2. 5**	5	5
Pre-Sputter Time (min.)	2	"	"	"	"	"	"
Table Height (High or Low)	H	**L**	H	**L**	H	H	H
Aperture Used?	No	No	No	No	No	**#1**	**#2**
AVG. Sputtering Rate (Å/min)	904.7	876.7	883.7	668.9	414.9	436.9	526.3
Uniformity**	*31.5%*	*30.8%*	*29.6%*	*31.6%*	*28.2%*	*17.6%*	**13. 9%**
Std. Deviation (Å)	1050	1005	1025	798	432	346	**235**
Std. Dev. Uniformity**	*17.1%*	*16.9%*	*17.1%*	*17.6%*	*15.3%*	*11.6%*	**6. 6%**
Comments	If points 0, 1, and 2 are removed from Run # 7 data then: Run 7 Uniformity = **3. 3%** Std. Deviation (Å) = **80** Std. Dev. Uniformity = **2. 2%**						

Ultimately, varying the pressure, power, and substrate-target distance had little impact on the uniformity data. The largest improvement was seen after the apertures were mounted onto the target assembly. Using these apertures, uneven sputtering from the target and peripheral edge differences of sputtering on the sample was corrected. This in turn led to a remarkable improvement in the uniformity. As seen in the table above, the uniformity was cut in half from an initial ~ 30% to ~14% when using Aperture # 2. If you remove the first three data points (measurements 0 cm, 1 cm, and 2 cm), the uniformity improves dramatically from 13.9% to 3.3%. As well, the standard deviation uniformity reduces from 6.6% to 2.2%. This is due to these first 3 points being outliers in the series of measurements, as a result of the aperture being non-optimized for that particular region. With this in mind, wafers can be placed anywhere on the track, excluding these 3 to 4 cm,

and obtain a uniformity between 2-5%. The only drawback of using these apertures was a decrease in the deposition rate, as the rate dropped from ~900Å/min (no aperture) to ~526Å/min (Aperture #2).

****For the purposes of this experiment, the equations used for uniformity data were:**

Uniformity = (Max - Min) / (Max + Min)
Std. Dev. Uniformity = Std. Dev. / Average