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**$AlN_x$-Sputtering Film on 4” Si wafer**
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Process Sequence:
1) Clean 4” Si wafer: solvent clean [acetone (2’) + methanol (1’) in ultrasonic clean bath and DI rinse)] and BOE dip (1’), DI rinse, and $N_2$ blow dry.

2) Sputter $AlN_x$ film using Sputter#2 with PM1 (make sure the Al target is inside of PM1).

Sputtering Recipe:

Ning_20_20_3kW (power=3000 W, $Ar/N_2$ flow-rate=20/20 sccm, time=4932 sec for ~2.1 µm thick $AlN_x$ film).

Ning_clean_2 (power=3000 W, Ar flow-rate=20 sccm, time=600 sec).

heat_350_1800 (PM1 chamber is heated to 350 $^0$C and is remained at the temperature for 999 sec).

Ning_clean_3 (power=3000 W, Ar flow=20 sccm, time=300 sec).

Ning_condi_1 (power=3000 W, $Ar/N_2$ flow=40/20 sccm, time=600 sec).

Sputtering Flow:

| Flow | Step | Chamber | Action | Parameter |
|---|---|---|---|---|
| ning_aln_9: | 1 | PM1 | Wait | 30 seconds |
| | 2 | PM1 | Sputter | Ning_20_20_3kW |
| | 3 | PM1 | Wait | 30 seconds |
| ning_cl_co_1: | 1 | PM1 | Wait | 30 seconds |
| | 2 | PM1 | Sputter | Ning_clean_2 |
| | 3 | PM1 | Wait | 30 seconds |
| | 4 | PM1 | Heat | heat_350_1800 |
| | 5 | PM1 | Wait | 30 seconds |
| | 6 | PM1 | Sputter | Ning_clean_3 |
| | 7 | PM1 | Wait | 30 seconds |
| | 8 | PM1 | Sputter | Ning_condi_1 |

| 9 | PM1 | Wait | 30 seconds |
|---|---|---|---|

Sputtering Sequence: ning_aln_7 (#5 A ning_cl_co_1; #10 A ning_aln_9).

3) Vent CM (cassette module) and, after reaching to atmosphere, load the wafer with the sputtering film side down into the cassette, Slot#10, counted from the bottom, and a dummy Si wafer into slot#5.

4) Pump down CM.

5) Run automatically Sputtering Sequence of ning_aln_7.

6) Wait until the sequence is finished, then, vent CM and take both the $AlN_x$-sputtered wafer and dummy wafers out.

7) Pump down CM.

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Table 1 DOE of $AlN_x$ film using Sputter#2.

| $AlN_x$ Sputtering Film using Sputter#2 (all wafers except #3 using the same pre-film-sputtering clean & condition with flow name: ning_cl_co_1*; wafer#3 using Ar clean only with flow name: Ning_clean**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wafer # | $Ar/N_2$ Flow Rate (sccm) | Power (kW) | PM1 Pressure from CVG (mT) | Bipolar | Sputtering Temperature (°C) | Sputtering Time (min.) | Film Thickness at Center (µm) | Film Refractive Index | Sputtering Rate (Å/min.) | Thickness variation (%) | Defects density (/cm2) |
| 3 | 40/20 | 2 | n/a | 3 | R.T. | 110 | 2.0708 | 2.1316 | 188 | n/a | n/a |
| 5 | 40/20 | 3 | 11 | 10 | R.T. | 5 | n/a | n/a | n/a | n/a | 1 |
| 6 | 40/20 | 3 | 11 | 10 | R.T. | 30 | 0.7873 | 2.1669 | 262 | n/a | n/a |
| 7 | 20/15 | 0.5 | 6 | 10 | R.T. | 10 | 0.88731 | 2.1183 | 100 | n/a | 16 |
| | 40/20 | 3 | 11 | 10 | R.T. | 30 | | | 262 | | |
| 8 | 40/20 | 3 | 11 | 10 | R.T. | 10 | n/a | n/a | n/a | n/a | 6 |
| 9 | 40/20 | 3 | 11 | 10 | R.T. | 60 | n/a | n/a | n/a | n/a | 147 |
| 10 | 40/20 | 3 | 11 | 10 | 300 | 10 | n/a | n/a | n/a | n/a | 41 |
| 11*** | 40/20 | 3 | 11 | 10 | R.T | 4x5 | 0.5861 | 2.1188 | 293 | 18.3 | 21 |
| 12 | 20/20 | 3 | 6.8 | 10 | R.T | 30 | 0.76651 | 2.1189 | 256 | 12.1 | 9 |
| 13 | 20/20 | 3 | 6.8 | 1 | R.T | 30 | 0.81065 | 2.0333 | 270 | 14.5 | 9 |

*Ning_clean: 30-min. Ar clean (30 sccm, 3 kW).
**ning_cl_co_1: 10-min. Ar clean (20 sccm, 3 kW); heating to 350 °C for 999 s; 5-min. Ar clean (20 sccm, 3 kW) during temperature dropping; 10-min. condition ($Ar/N_2$=40/20 sccm, 3 kW).
***: four 5-minute sputtering runs with 5-minute off between each two runs.

**Conclusion of $AlN_x$ DOE**: Sputtering recipe of Wafer#12 gives the best $AlN_x$ film.