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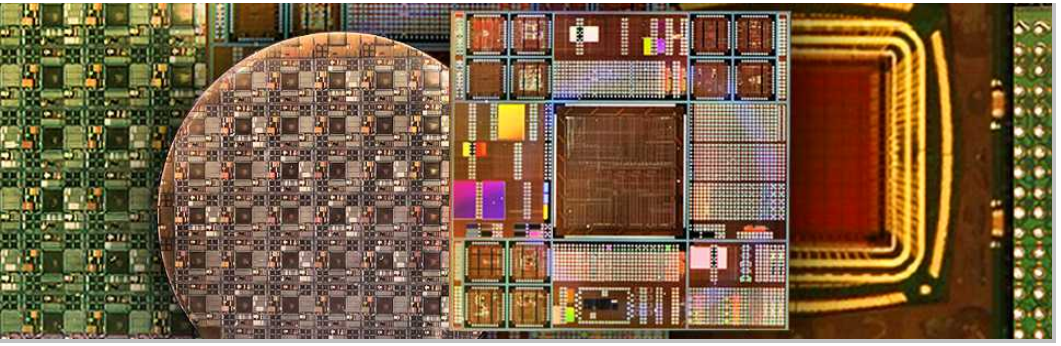

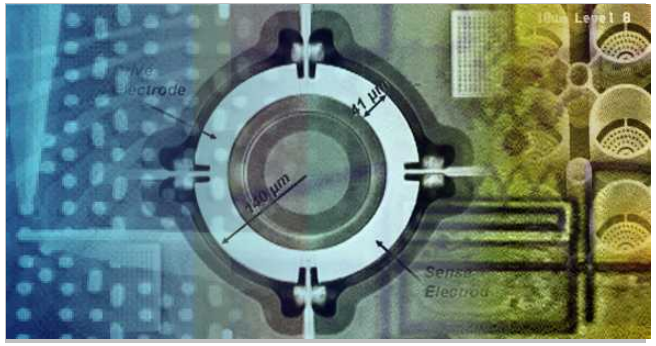

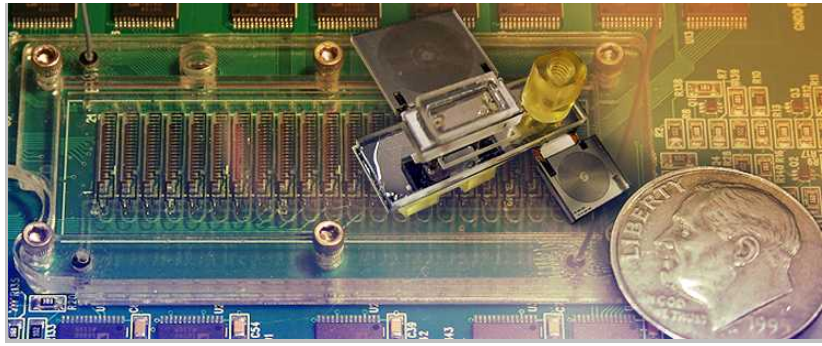

Effect of Oxygen Contamination on PVD AlN Growth

K. Knisely, B. Griffin, R. Timon, T. Young, M. Monochie, H. Dallo, and M. Olewine

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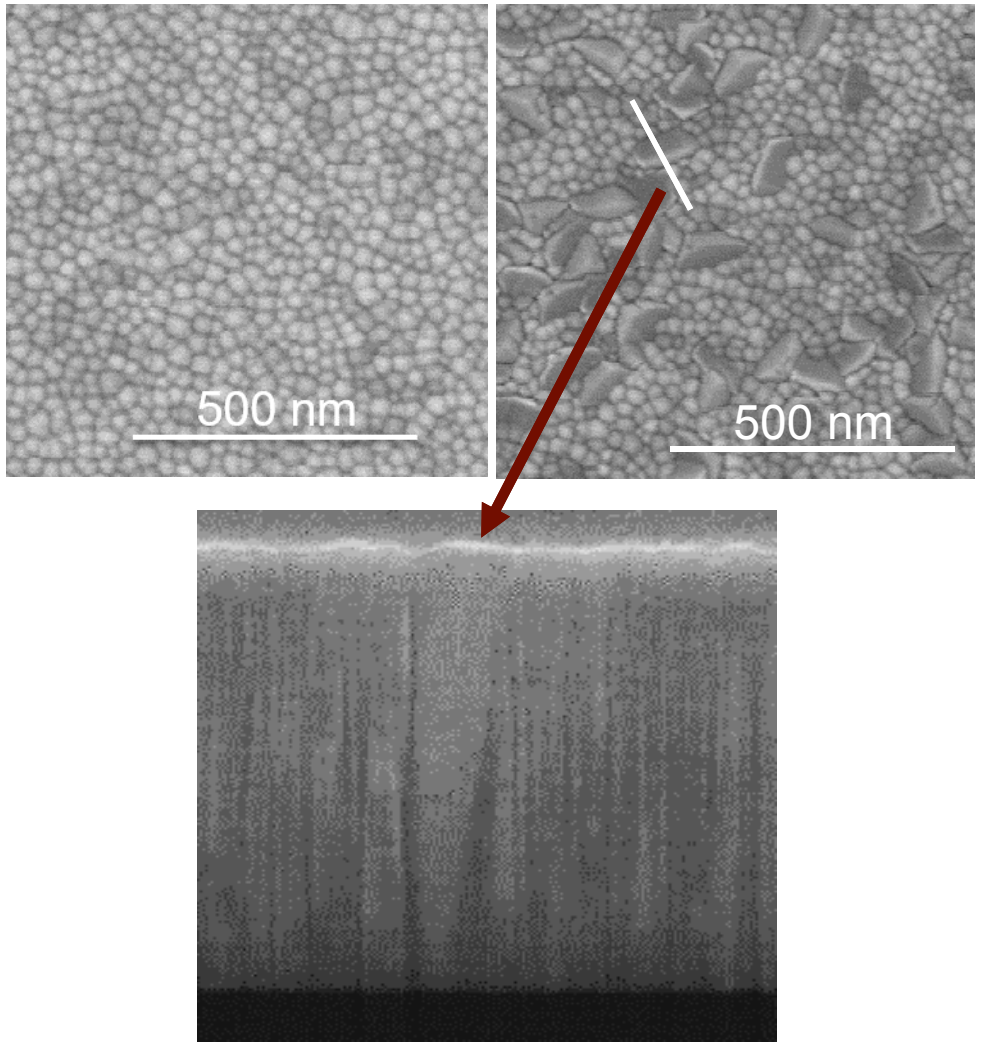
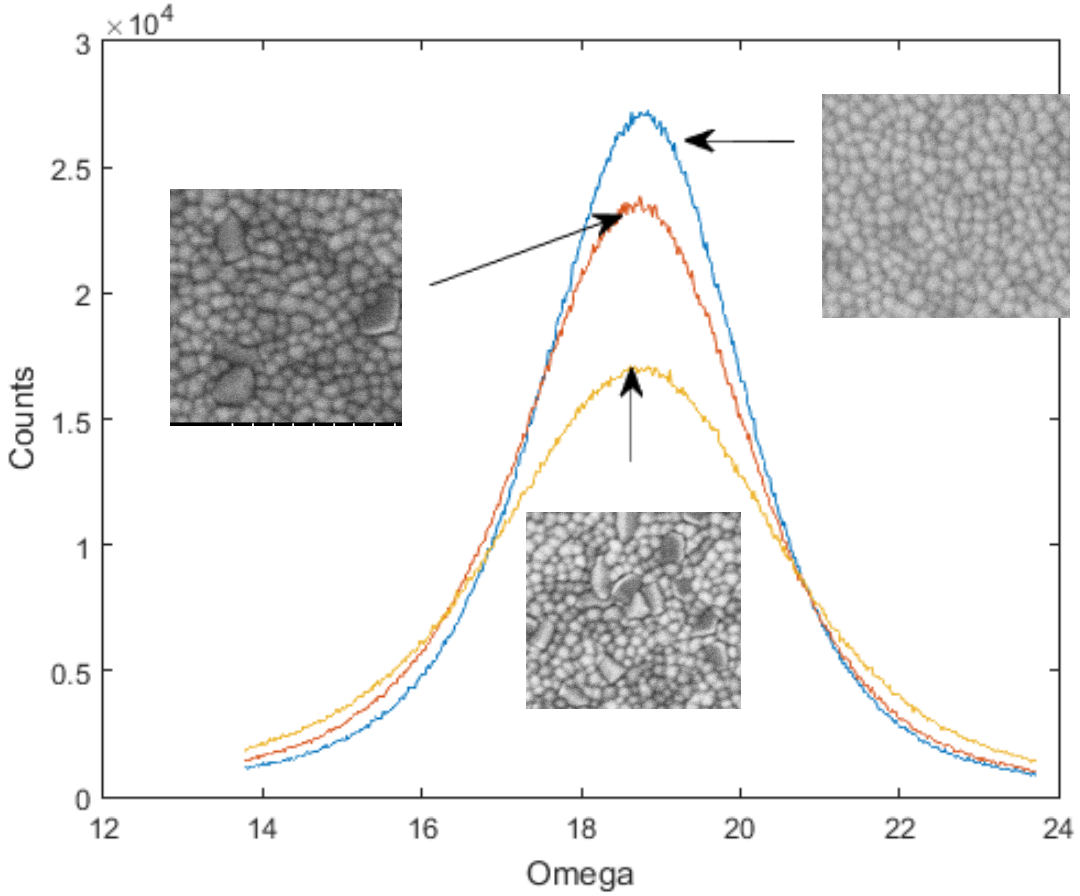
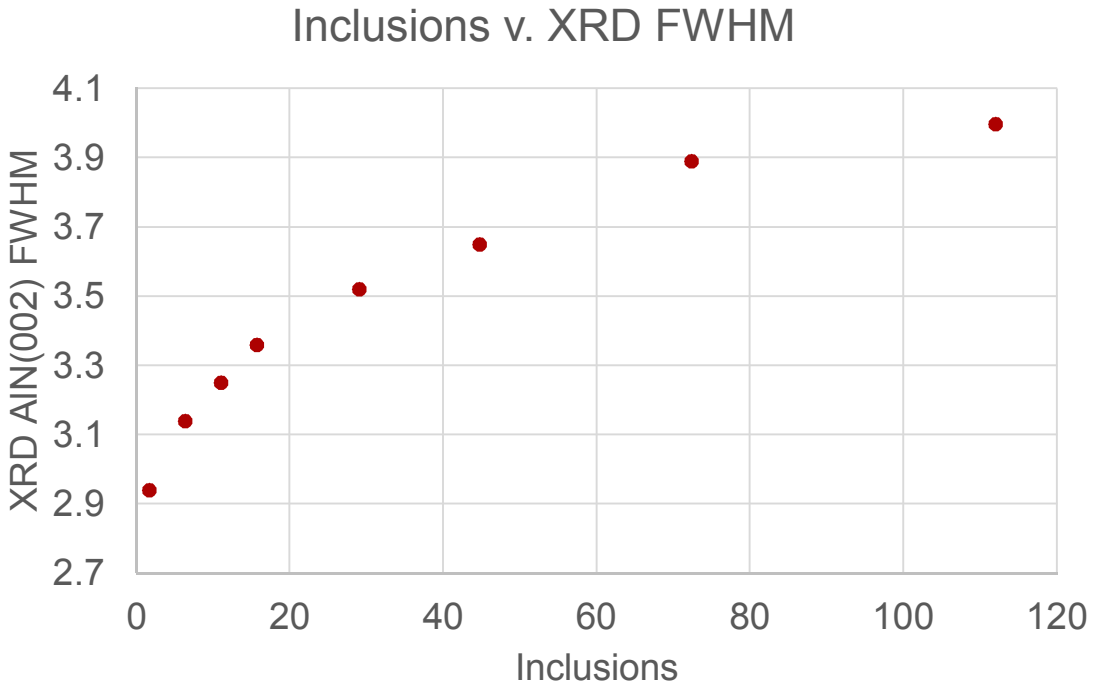
Motivation

- Reduced AlN device performance
- Planar SEM of AlN films showed faceting, with large (100-150nm) wide inclusions in the film structure
- X-section FIB SEM showed v-shaped grains nucleating at the substrate surface



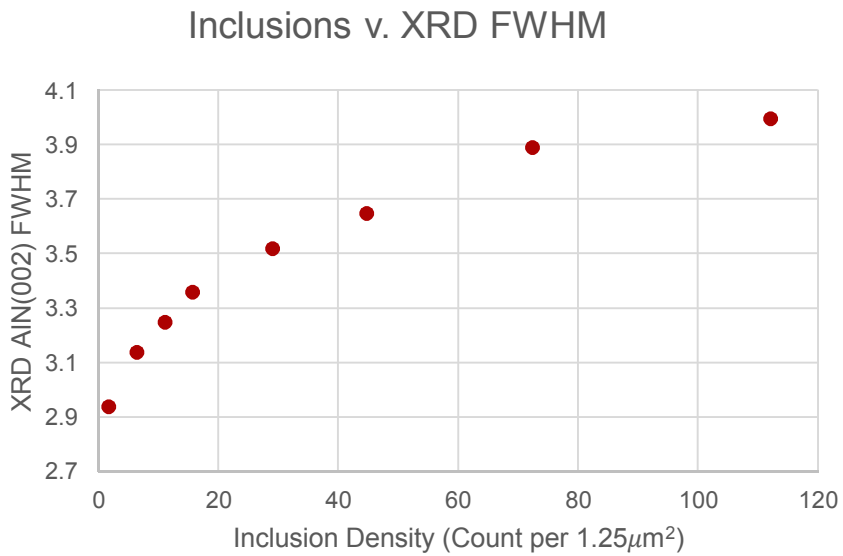
X-Ray Diffraction Results

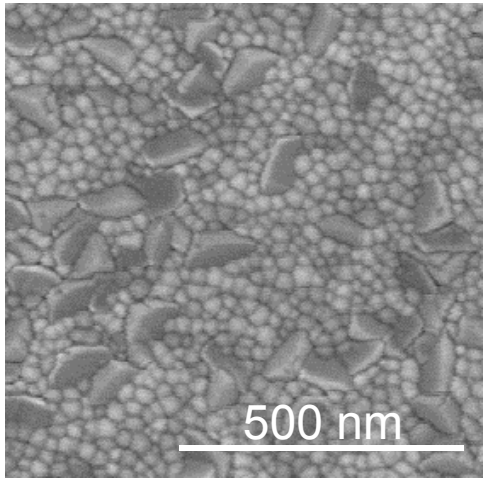


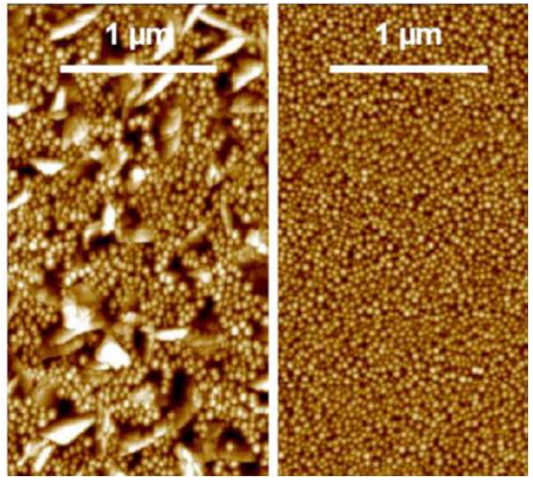


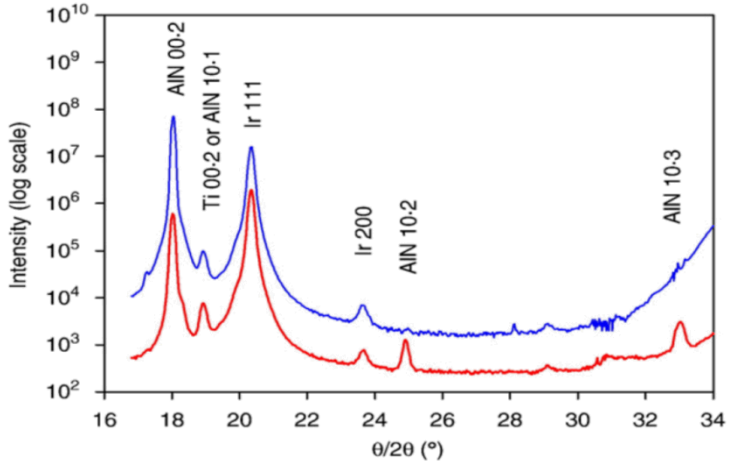
Why Are Inclusions a Problem?

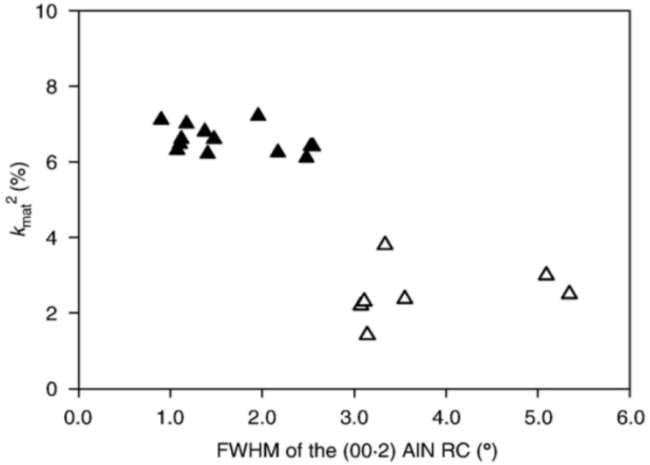
- XRD Ω-2θ of films with inclusions have AlN 10·1, 10·2, and 10·3 peaks in addition to c-axis orientation
- Higher inclusion densities result in larger XRD AlN(002) FWHM values
- Films with high inclusion densities/FWHMs have reduced piezoelectric coupling performance











Clement, et al. *Thin Solid Films,* **517** (2009)

Potential Causes

- Defective test wafers
- Defective or deteriorated Al target
- Malfunctioning cryo
- Temperature drift of pedestal
- RF or pulsed DC power delivery
- Chamber leak
- Gas line contamination
- Process kit contamination
- Water contamination

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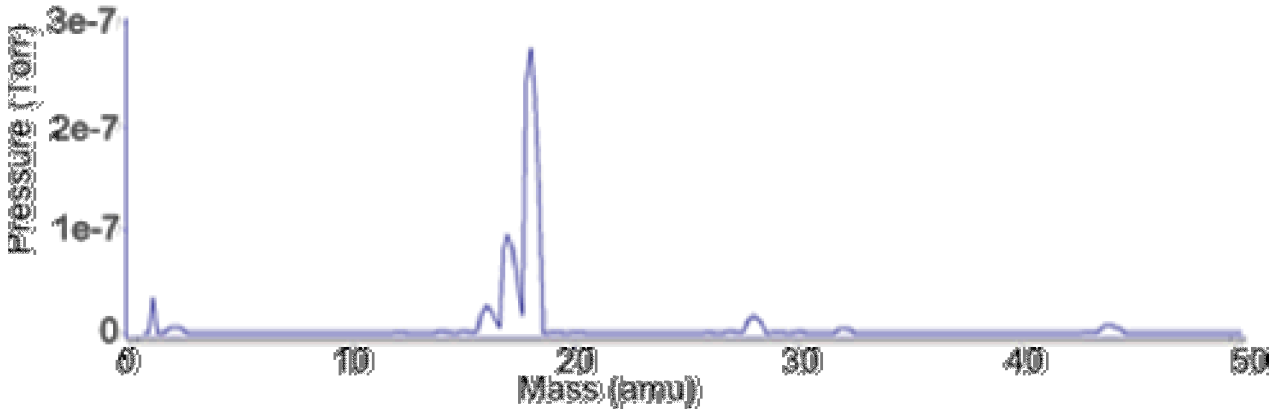
- ~~Process kit contamination~~
- Water contamination

Why?

- Repeated venting of process and dealer chambers due to wafer retrievals and software upgrades
- Insufficient chamber conditioning after being opened

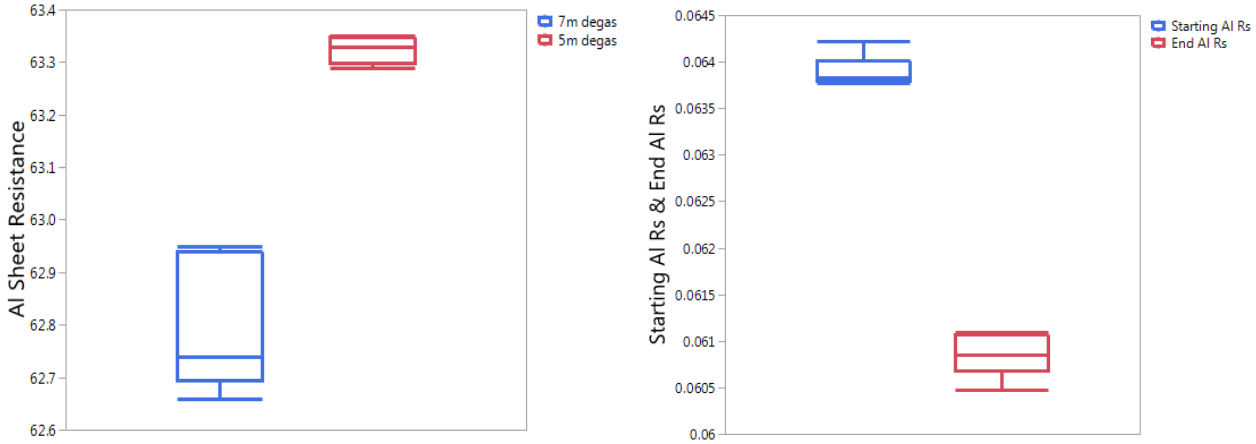


Chamber Conditioning

Steps taken:

- Al and AlN film burn in wafers
- 400C chamber wall bakeouts for extended time
- Load lock pumps to a lower pressure before slit valve to dealer can open
- Dealer pumps down to lower pressure before slit valve to process chamber is opened
- Water pressure reduced from 3e-7 to 3e-8 Torr

Note: For fast turnaround in production environment, sheet resistance changes for 100-400nm thick Al films were found to be sensitive to the chamber water content

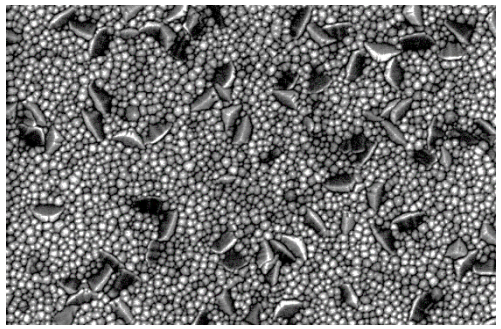


Chamber Improvement

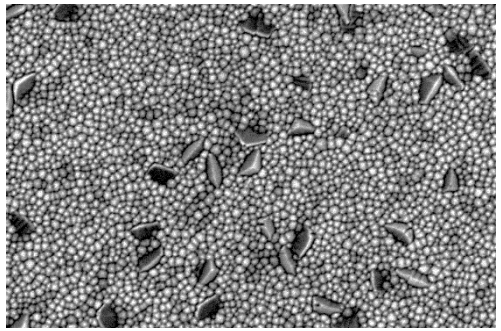
Sandia National Laboratories

Water peak 3e-7 Torr:

Wafer 1

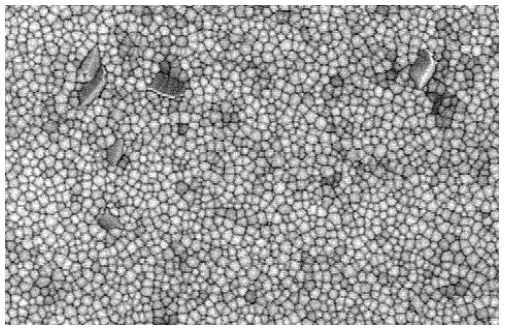


Wafer 2

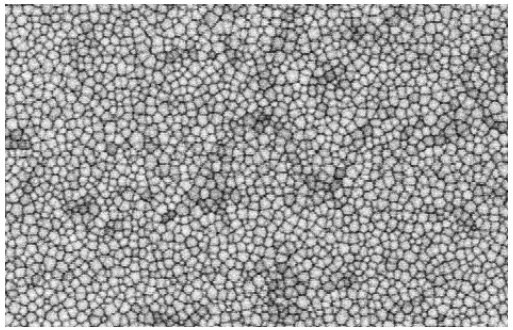


Water peak 3e-8 Torr:

Wafer 1

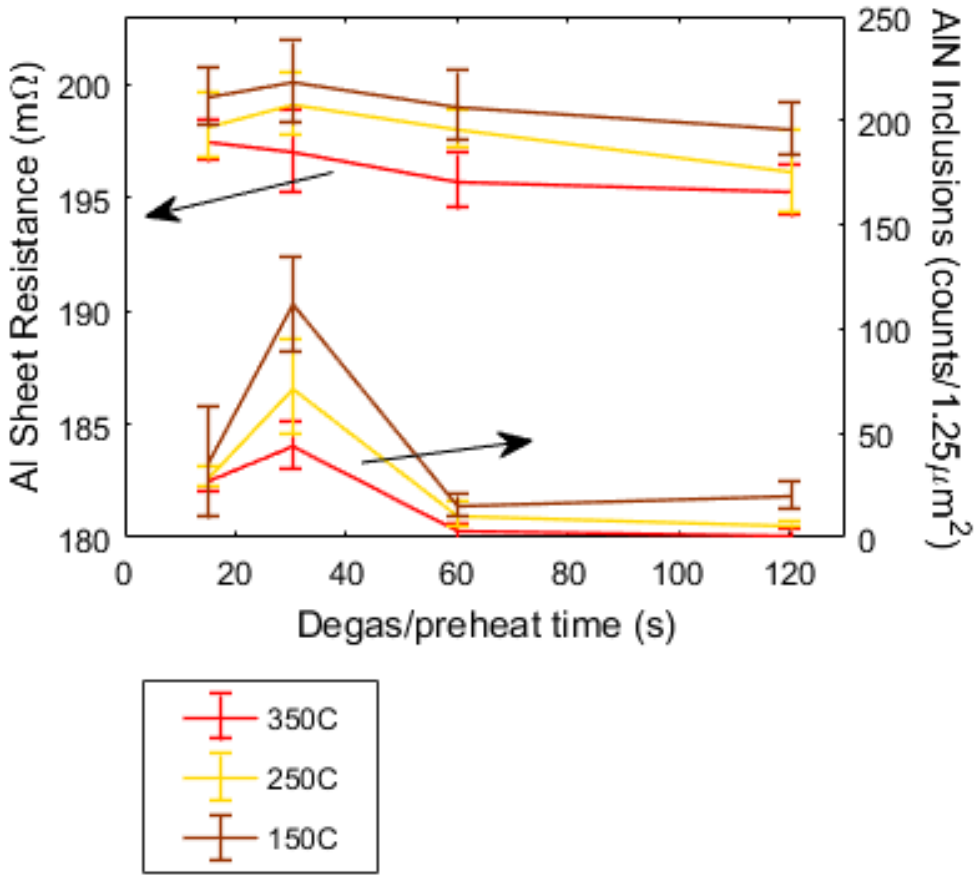


Wafer 2



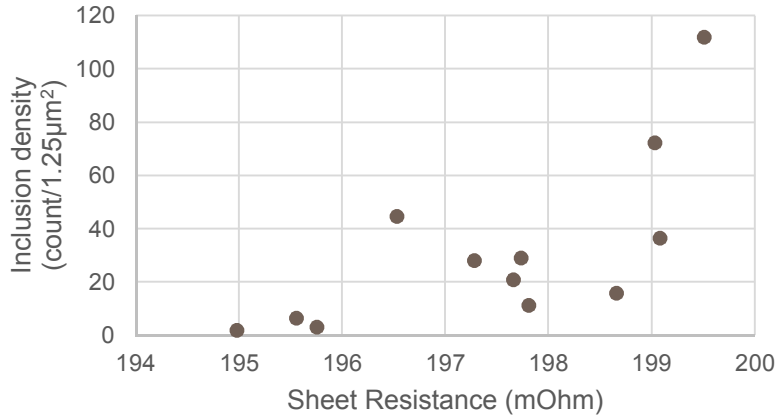
A larger first wafer effect for inclusion density was observed when the chamber had higher water content, likely due to higher amounts of water condensation that subsequently get redistributed when the plasma is first turned on, as well as higher amounts of target oxidation during chamber idle times.

Al Sheet Resistance and AlN Inclusion Density Correlation



Al sheet resistance and AlN inclusion density correlation:

- Varied the chamber temperature to reduce Al desorption (150C, 250C, 350C)
- Measured sheet resistance for 20s Al deposition as the in situ degas/preheat step time was varied
  - Degas step in vacuum
  - Wafer is on pedestal
  - Runs prior to turning on plasma
- Deposited 300nm AlN films using same degas preheat step and measured inclusion density
- Rough correlation, data inconclusive, especially for short (15s) degas times



Summary

- Water levels in the range of 3e-7 Torr were sufficient to promote the nucleation and growth of non-c-axis oriented inclusions in sputtered AlN films
- The presence of these inclusions is correlated with higher AlN(002) rocking curve FWHM values, which in turn correlates with reduced film piezoelectric performance
- Burning in and baking out the chamber reduced the water content, as did reducing the threshold pressures for the load lock/dealer and dealer/process chamber slit valves
- A larger first wafer effect for inclusion density was observed when the chamber had higher water content, likely due to higher amounts of water condensation that subsequently get redistributed when the plasma is first turned on, as well as higher amounts of target oxidation during chamber idle times
- Measuring the resistance of thin Al films is a quick and dirty metric to use for testing chamber water levels when fast data turnaround is desired, but SEM and/or XRD of AlN films directly is a better indictor of AlN quality
- Reducing process temperature produced Al films with higher sheet resistances and AlN films with higher inclusion densities. Longer in situ degas/preheat times likely allowed for better desorption of water, reducing both Al film sheet resistance and AlN inclusion density

Acknowledgements

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