



Effect of thermal cycling on aluminum metallization of power diodes

Mads Brincker

Department of Physics and Nanotechnology

Aalborg University, Denmark

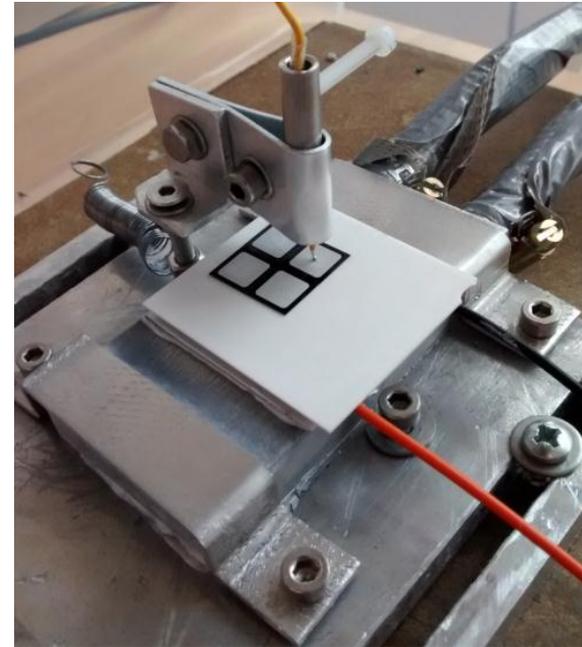
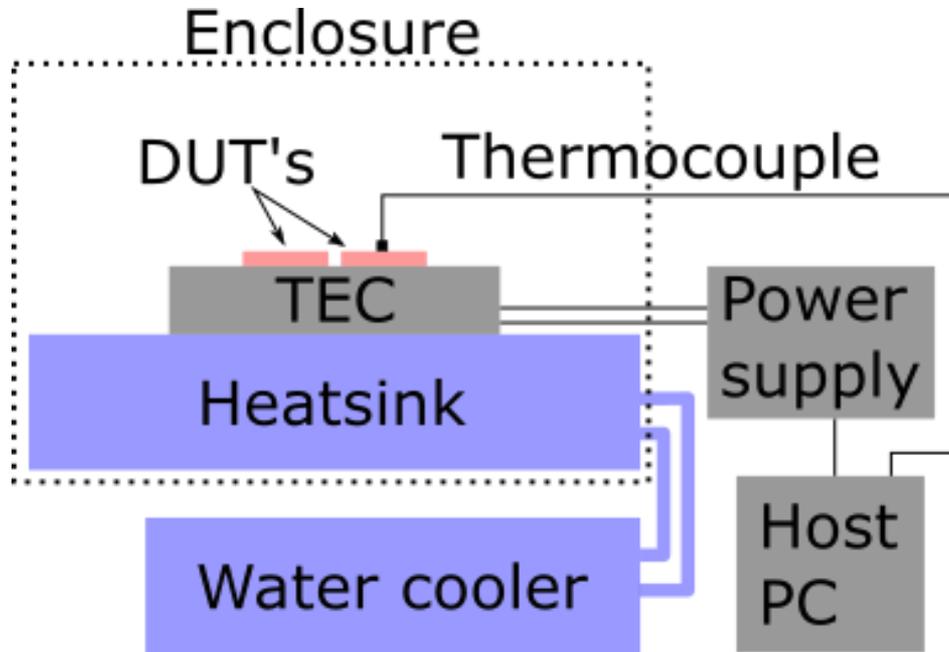
Objectives

- Perform passive thermal cycling of power diodes
 - No current through component
- Compare cycling in pure nitrogen environment to cycling in atmospheric air
- Correlate metallization reconstruction with sheet resistance
- Examine the change in grain texture during cycling
- Get insights into physical mechanisms governing the metallization reconstruction

Outline

- Passive thermal cycling setup
 - Schematic
 - Thermal profile
- Metallization degradation
 - Sheet resistance
 - Microstructural evolution
 - Grain texture evolution
- Conclusion and outlook

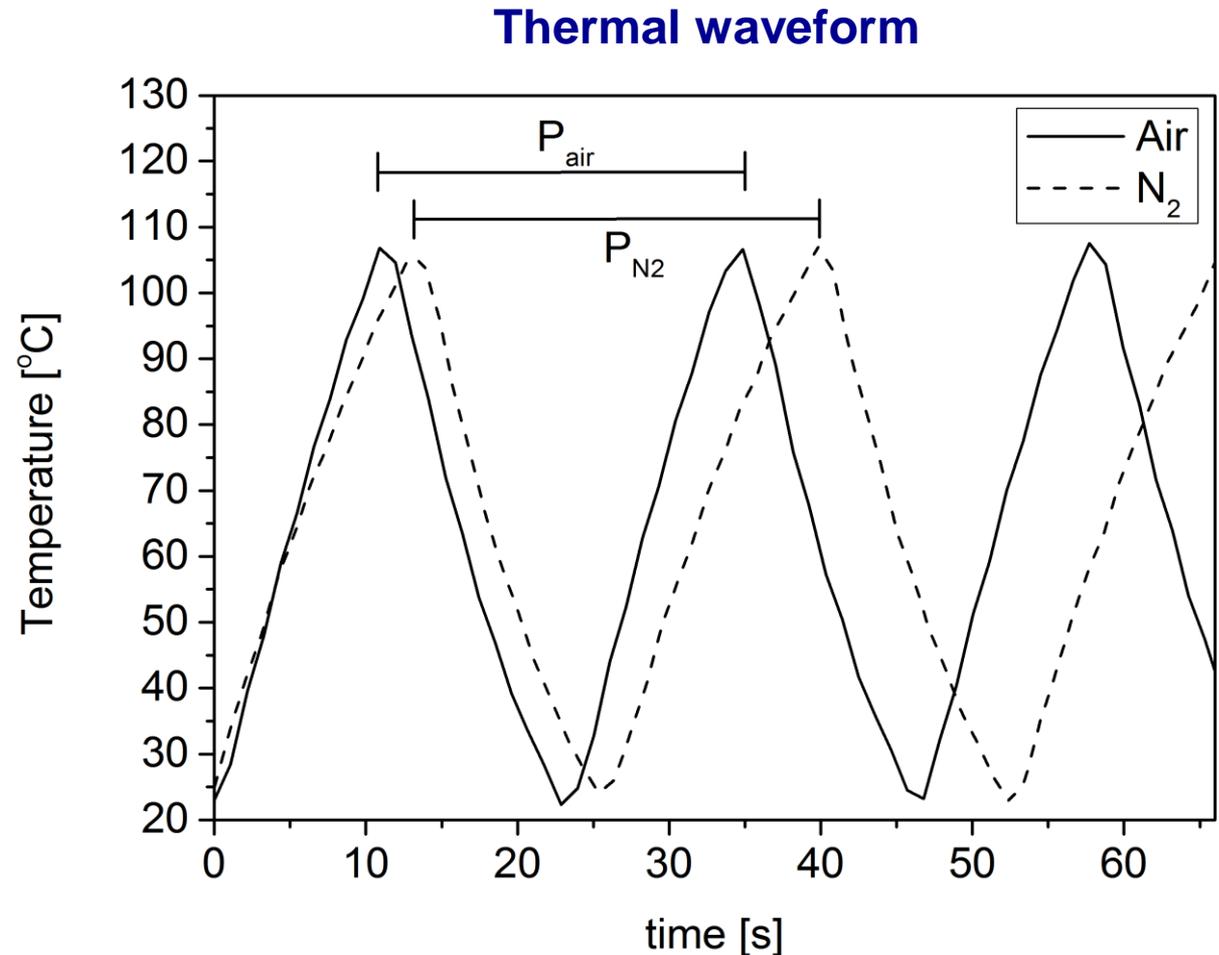
Passive thermal cycling setup



- Unpackaged chips can be thermally cycled using a thermoelectric cooler (TEC)
- DUT are high power diode chips (100 A/1200 V)
- Different atmospheric conditions can be introduced
- DUT's are characterized *ex situ*

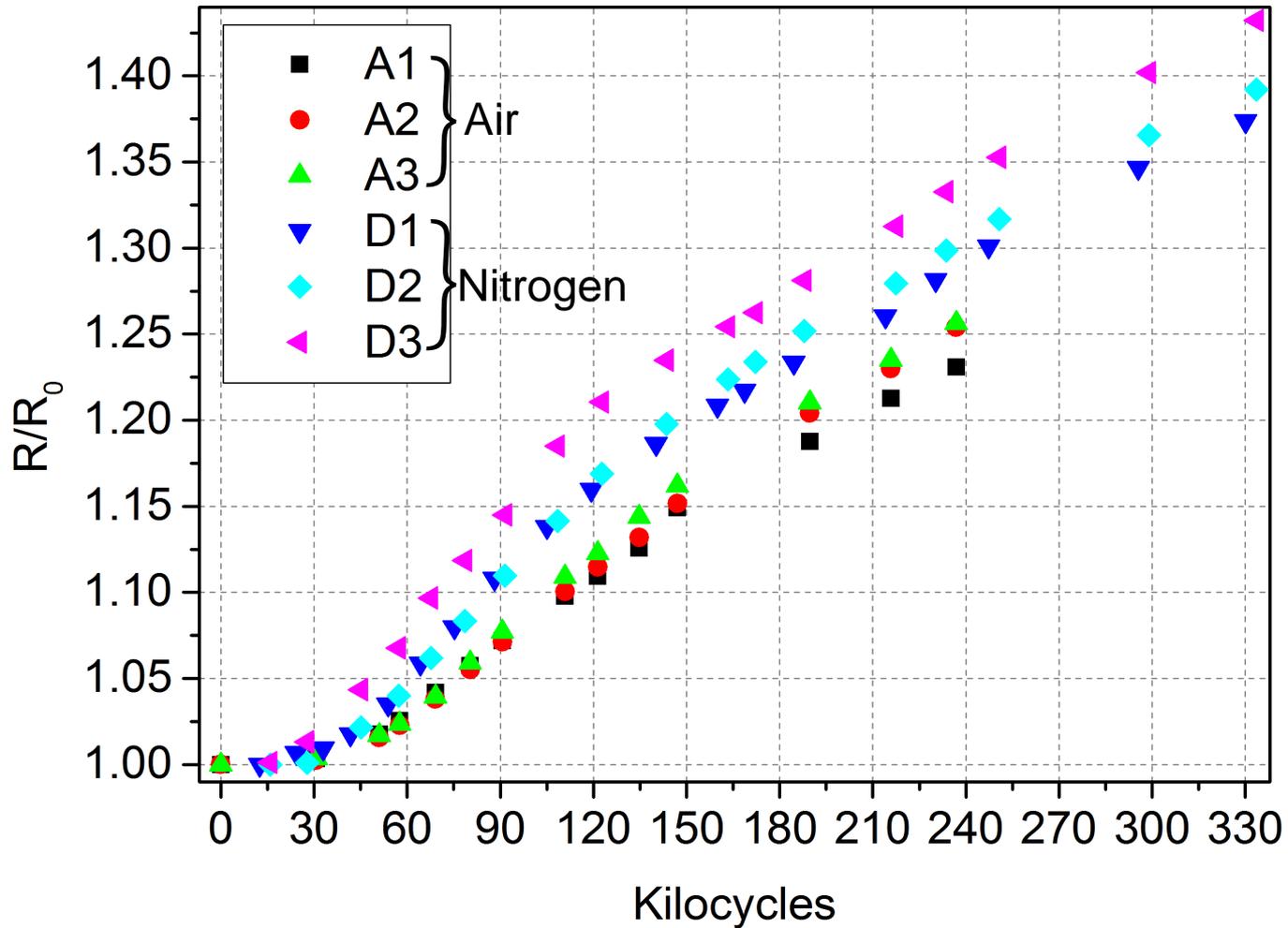
Passive thermal cycling setup

- The temperature is controlled by switching the direction of the TEC current
- Period is ~ 26 s.
- Mean temperature is 65°C
- ΔT is 80°C



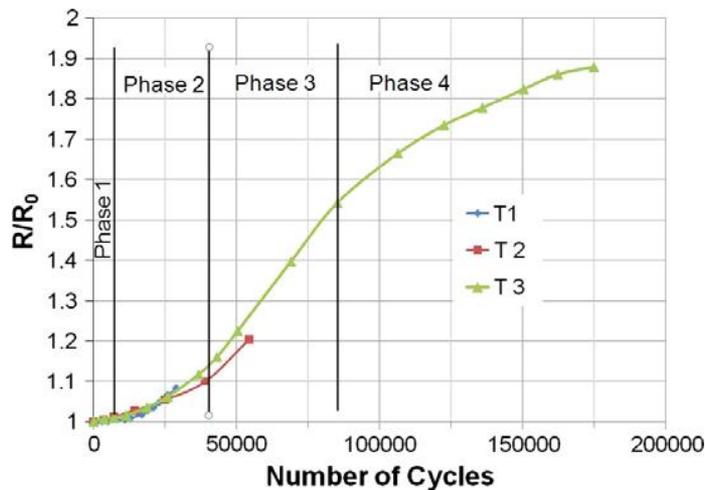
Sheet resistance evolution

4-point probe measurement

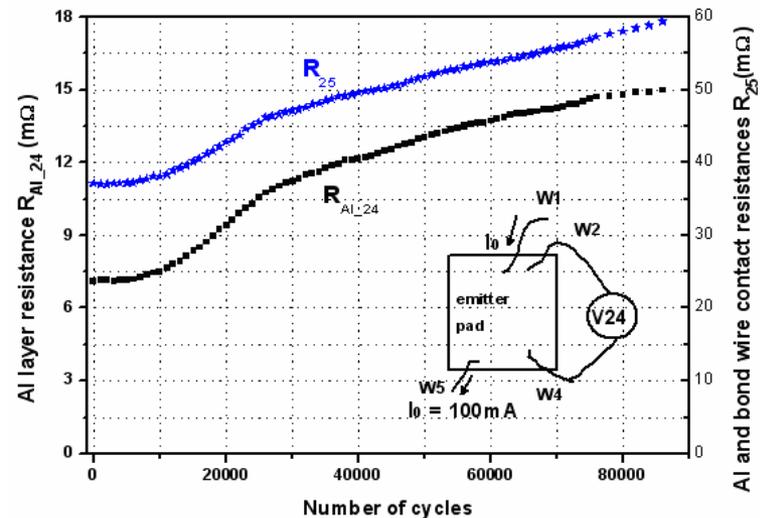


Sheet resistance evolution

- Diodes cycled in nitrogen environment exhibits more severe electrical degradation.
- Results are otherwise in agreement with results from others for actively power cycled components (see [1,2])



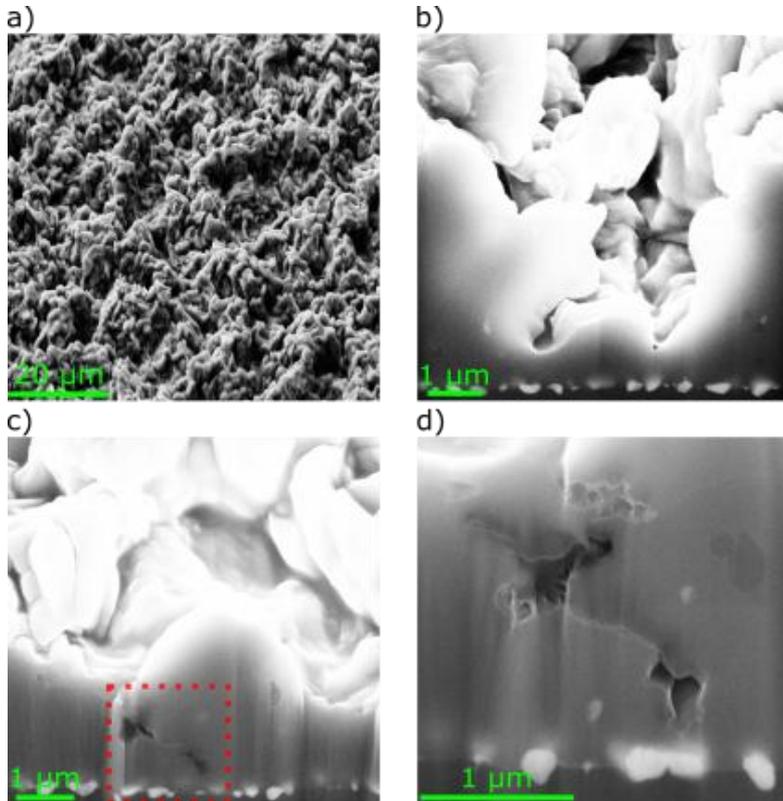
[1] Pietranico, S. et al. Microelectronics Reliability, 2011, p. 1824-1829.



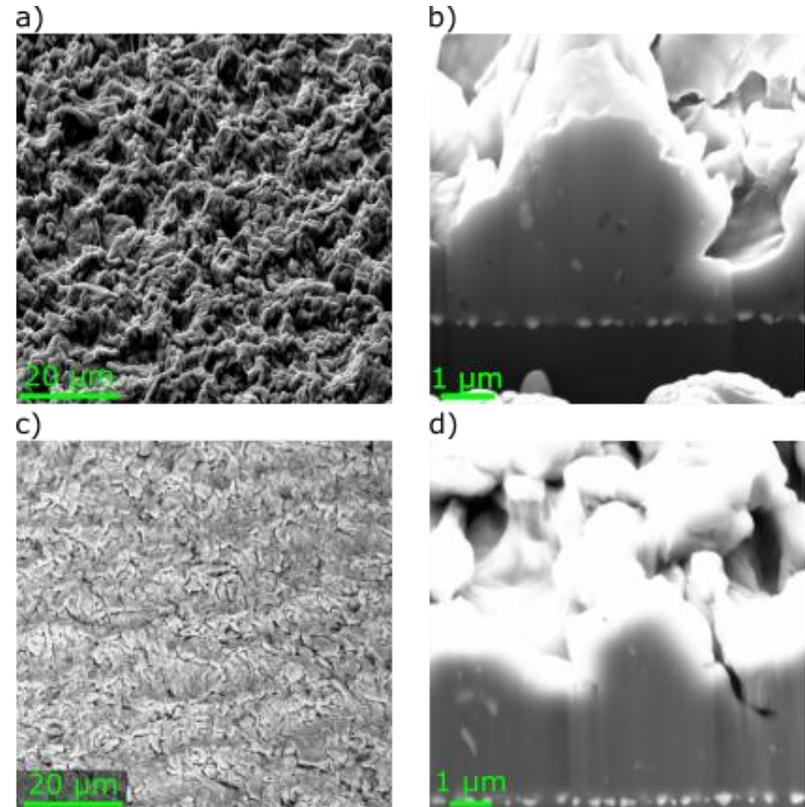
[2] Arab, M. et al. 2008 IEEE Power Electron. Spec. Conf., IEEE; 2008, p. 4355-4360.

Microstructural evolution

SEM images



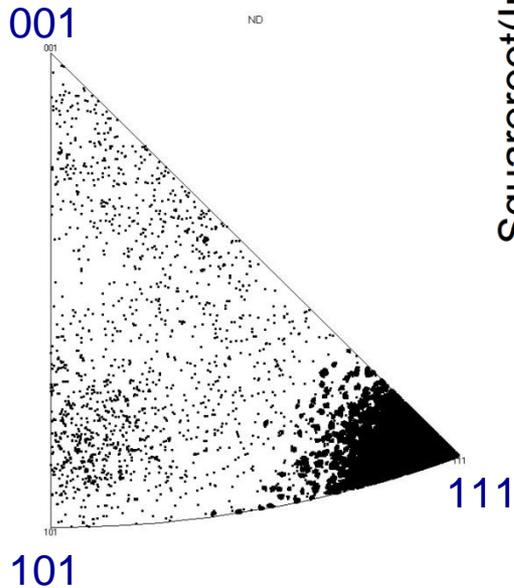
145 kilocycles in nitrogen environment



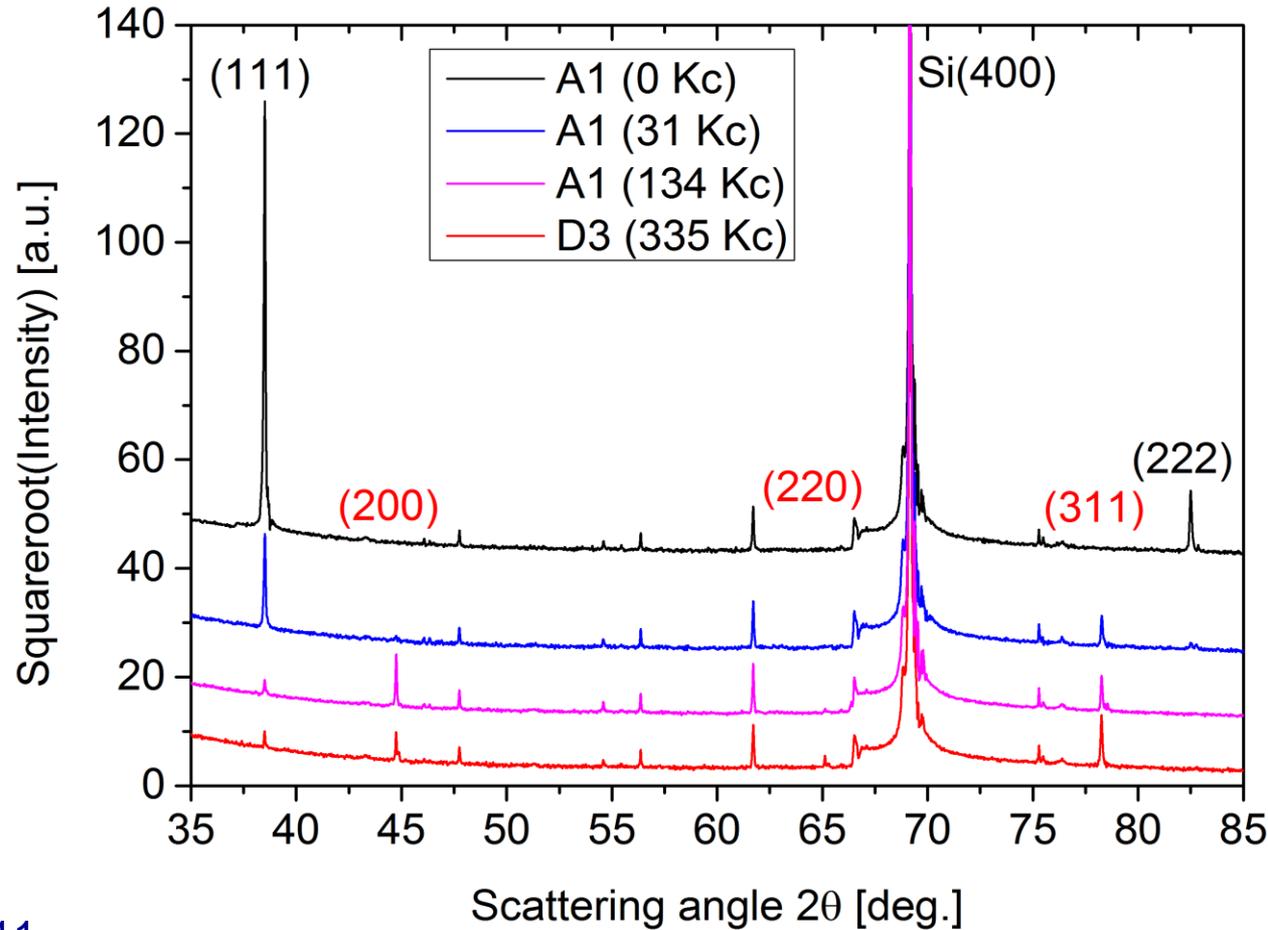
110 kilocycles in atmospheric air

Grain texture evolution

EBSD map



XRD measurement



Grain texture evolution

- The reconstruction is correlated to the initial grain orientation of the film
 - As grown, the film has a clear $\langle 111 \rangle$ texture
 - During cycling the grains reconstruct away from the $\langle 111 \rangle$ texture towards a $\langle 200 \rangle$, $\langle 220 \rangle$, and $\langle 311 \rangle$ texture
 - Similar phenomena have been observed in previous work, e.g. [3,4]

[3] Heinz, W. et al, Materials Science and Engineering A; 527 (2010), p. 7757-7763

[4] Heinz, W. et al, Surface and Coatings Technology; 206 (2011), p. 1850-1854

Conclusions

- A passive thermal cycling setup operating under controlled atmospheric conditions has been developed
- Clear reconstruction of Al metallization is observed and correlated to changes in sheet resistance
- Diodes cycled in nitrogen environment exhibits faster electrical degradation.
- EBSD and XRD measurements indicate that the reconstruction process is correlated to the initial grain texture of the metallization

Outlook

- DFT calculation of grain bond strength with different impurities, i.e. O, N, Si, Cu, S etc.
- FE calculation of microscopic stress distribution of thin films with different grain texture
- Temperature-stress curves at different degradation levels
- Cycling of in-house grown Al films with different thicknesses and controlled composition

Thank you for your attention!

- Any questions?

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