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The effects of device geometry and TCO/Buffer layers on damp heat accelerated lifetime testing of Cu(In,Ga)Se2 solar cells

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Introduction and Motivation

•CIGS cells are moisture sensitive. Modeling studies [1,2] suggest that module encapsulation with water vapor transmission rate (WVTR) of 10^{-4} to 10^{-6} g-H_2O/m^2-day is needed for lifetime > 20 yrs

•Damp Heat (D-H) accelerated lifetime testing (ALT) at 85%RH/85°C performed at IEC on CIGS cells encapsulated with a glass or PET top sheet.

•WVTR of PET ~10g/m^2-day >>> greater than WVTR of glass (<< 10^{-6} g/m^2-day)

•Glass and PET sample degraded at the same rate. Why? Was it related to device structure?

Approach

• Devices (SL/Mo/CIGS/CdS/i-ZnO/ITO/Ni-Al grids) on glass with different encapsulation schemes:

- ❑ 6 pieces with PET, unscribed
- ❑ 6 pieces with glass, unscribed
- ❑ PET and glass top sheet bonded to cell with commercial thermoplastic encapsulant
- ❑ 3 Control pieces, un-encapsulated, 6 cells each, scribed

• Use IEC's CIGS baseline process with variation in cell patterning and i-ZnO integrity (i.e. scribing)

• Subject to D-H ALT for 2000 hrs under ~ 1 sun illumination, Voc.

•I-V characterization at regular intervals

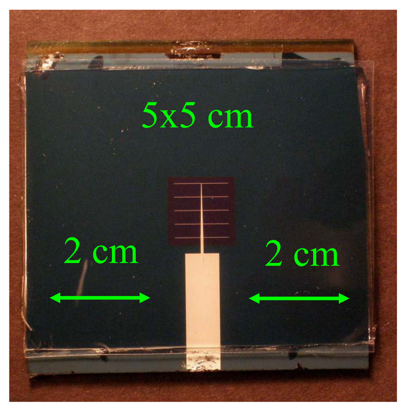
Device Layout

Layout # 1:

1 cm^2 devices, defined by ITO masking, no scribing, i-ZnO blanket deposition to the edge of substrate

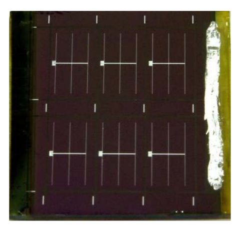
•4 devices (1 cm^2) fabricated on a 10x10 cm substrate, no scribing

•Cut into four coupons, 1 cell each



Layout # 2: 0.47 cm^2 scribed devices

•1"x1" substrates comprised of 6 unencapsulated devices ('bare')



Experimental Setup

Unique Environmental Chamber

•Metal halide lamp ~1sun illumination intensity

•Electrical contacts allow illumination monitoring and in-situ device testing

Device Structure: Layout #1

• Molybdenum back contact patterned to extend from device to edge of glass (reduces shunting)

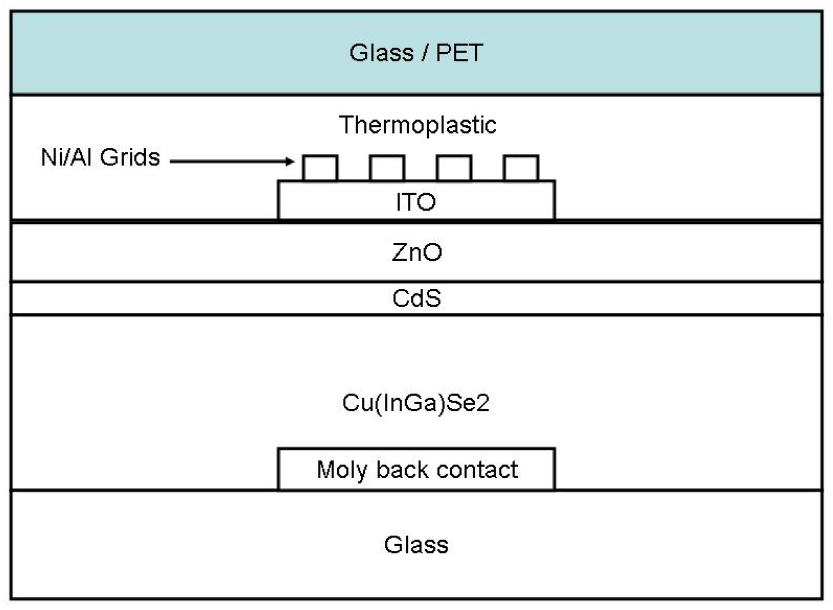
• CIGS deposited on glass/Mo using multisource evaporation: EG ~ 1.2 eV, thickness ~ 2 um

• CdS from CBD thickness: ~50 nm

• Intrinsic ZnO: ~50 nm, sputtered on entire area

• ITO: 150 nm, sputtered through mask, defines cell

• Ni/Al grids e-beamed through mask



•ITO: $R_{\square}$ = 27Ω/□ ; i-ZnO: $R_{\square}$ -insulating

•Molybdenum back contact and Ni/Al front contacts run to edge of 5x5 cm substrate

•Encapsulation: 5 mil sheet of PET or glass lid

•Bonding: industrial grade thermoplastic applied at 150°C under pressure

Device Structure: Layout #2

•Same as above except i-ZnO/ITO sputtered over entire 1x1 inch substrate, cell area defined by scribing

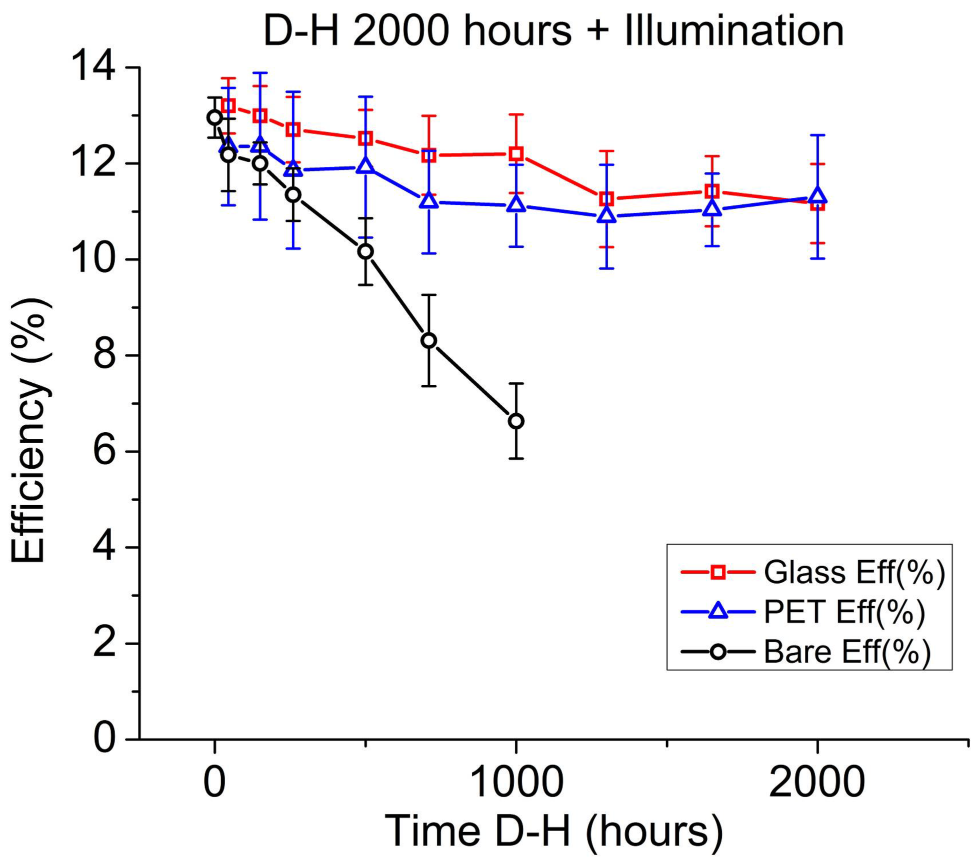
•No encapsulation

Test Results from D-H ALT

Efficiency for 2000 hours of illuminated D-H

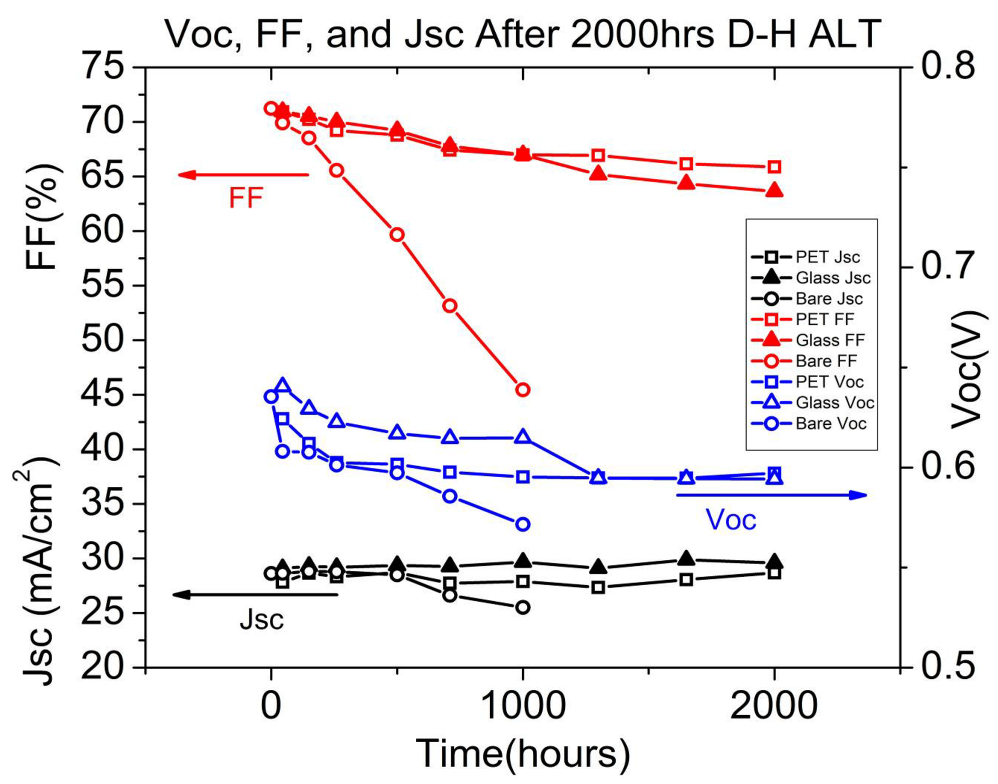
•Layout #1: Average of 6 devices each glass or PET

Layout #2: average of 18 devices, bare, scribed

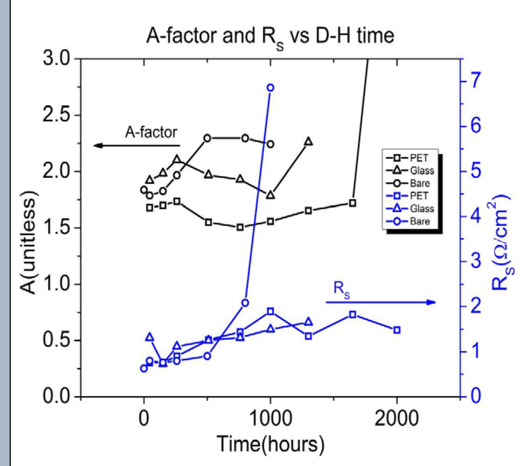


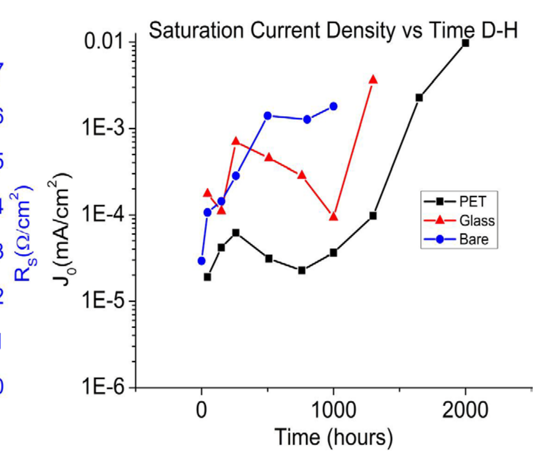
•Glass and PET devices retain 92% initial efficiency after 2000 hours D-H despite very different WVTR

•Bare samples degrade to 52% original eff at 1000 hours, similar to PET samples in previous study [3]



•Degradation: FF most, V_{OC} some, J_{SC} negligible





•All show increase of A and J_o but 'bare' has largest

•All show small but steady increase in R_S

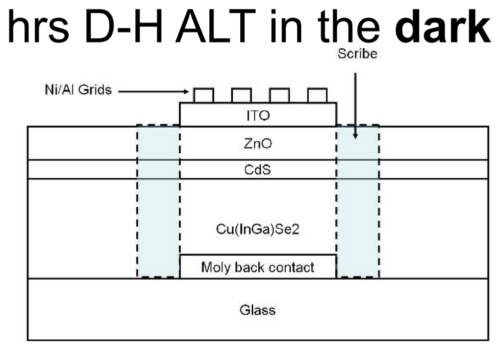
•At 500 hrs, large increase in R_S for 'bare' scribed

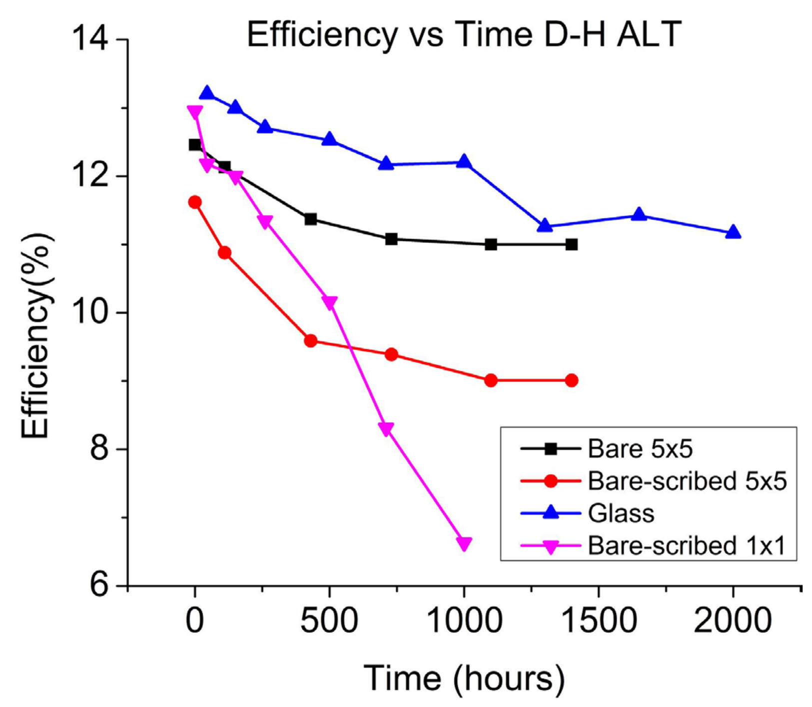
Effects of scribes on D-H degradation

- In [3] i-ZnO deposited through a 1x1cm mask
- Now over entire 5x5cm area (improved thermoplastic bonding adhesion)
- Two experiments to evaluate effect of i-ZnO
  - ❑ Measure WVTR of i-ZnO, ITO and i-ZnO/ITO stack
  - ❑ Two 5x5 cm samples for D-H ALT, no encapsulation or capping layer.

  Layout #3: same as #1, except area defined by scribe, no capping layer 'bare 5x5'

  Layout #4: same as #1, no capping layer, unscribed
- 1400 hrs D-H ALT in the **dark**





•'Bare 5x5' as stable as PET or glass encapsulated

•'Bare scribed 5x5' degraded like 'bare' until ~600 hours, and leveled out

- ❑ Possibly due to ratio of scribe length to device area
- ❑ Possible illuminated vs dark D-H effect

Conclusions and References

•TCO and buffer layers can harden CIGS cells to D-H conditions, up to 2000 hrs

•Scribe lines that provide water vapor a direct path to CIGS/CdS junction shorten device D-H lifetime

•With a WVTR of 2E-3 g/m^2-day, a i-ZnO/ITO stack is an effective water vapor barrier

References

[1] M. D. Kempe, Modeling of rates of moisture ingress into photovoltaic modules, Solar Energy Mater. & Solar Cell 90 (2006) 2720-2738.

[2] D. J. Coyle, H.A. Blaydes, J. E. Pickett, R. S. Northey, and J. O. Gardner, Degradation kinetics of CIGS solar cells, in Proceedings of the 35th IEEE Photovoltaics Specialists Conference (2009).

[3] P.F. Carcia, R.S. McLean, Steven Hegedus, Encapsulation of Cu(InGa)Se2 solar cell with Al2O3 thin-film moisture barrier grown by atomic layer deposition, Solar Energy Materials & Solar Cells **94** (2010) pp. 2375-2378

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