Characterization of accelerated degradation modes: applying light and voltage bias during damp-heat exposure

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Institute of Energy Conversion

- •World's oldest solar cell laboratory (1972)
- •Integrated lab for fabrication, characterization, and analysis of CdTe, Cu(InGa)Se_2 (CIGS), and c-Si heterojunction solar cells and mini-modules
- •Research partnerships with 45 PV and supply chain manufacturers since 2005, also national labs, and universities
- •Multidisciplinary staff of scientists, engineers, technicians, and graduate students
- •Capabilities relating to accelerated life testing (ALT) and reliability studies
  - •Fabrication of baseline and custom-designed thin film and c-Si solar cells or mini-modules;
  - •Extensive device characterization and analysis: IV, IV(T), CV(T), QE, EL, LBIC
  - •Multiple chambers for controlled ambient (H_2/Ar, N_2, dry air) ALT w/ temperature, voltage, and light bias
  - •Multiple chambers for damp-heat (D-H) ALT with voltage and light bias
- •In-situ and post-mortem I-V characterization and diagnosis
- •Collaborated with over 7 US companies on ALT studies: device degradation, encapsulation, transient effects

ALT system 1: Controlled ambient light and electrical bias

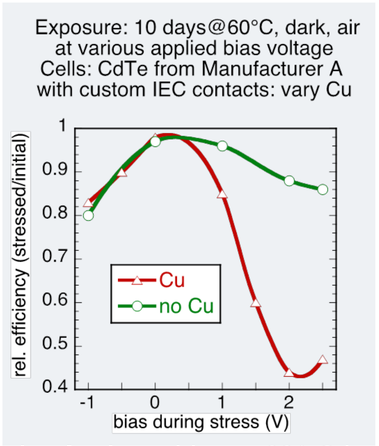
4 pods with 4 samples each, in-situ IV measurements

ALT system 2: Damp-Heat chambers with light and electrical bias

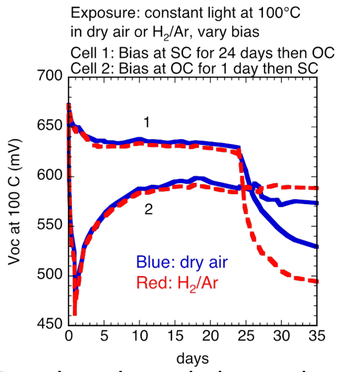
2 chambers, 20 samples each, in-situ IV measurements

Metastable effects in CdTe

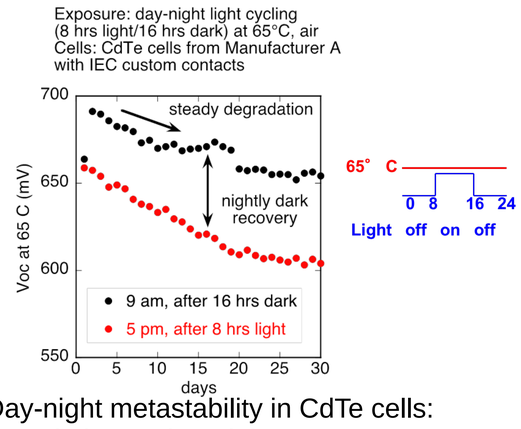
- •CdTe modules with good stability demonstrated in the field
- •Laboratory device commonly reported as unstable >1 week with fixed stress/bias ALT
- •Field and lab exposure differ in
  - •Daily temperature and light cycles
  - •Ambient: Encapsulated vs uncontrolled room air humidity



- •Role of voltage bias at 60 ° C in driving Cu-induced degradation

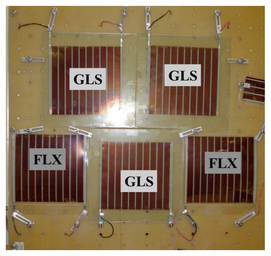


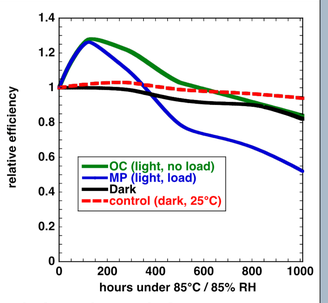
- •Transient degradation and recovery: Effect of bias and ambient in CdTe from manufacturer A



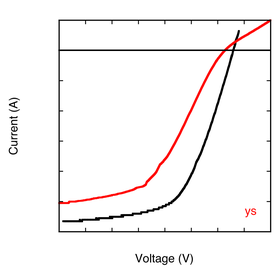
- •Day-night metastability in CdTe cells: degradation and partial recovery measured in-situ during exposure
- •Degradation increases with forward bias but magnitude varies with processing
- •Time constant for losses faster than recovery (@ 60-100°C)
- •Recovery within days after stress with dark storage: 'defect relaxation'
- •Device analysis (not shown) separates junction and contact degradation

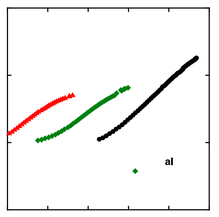
Characterization of TF module degradation

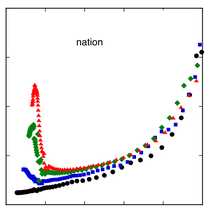




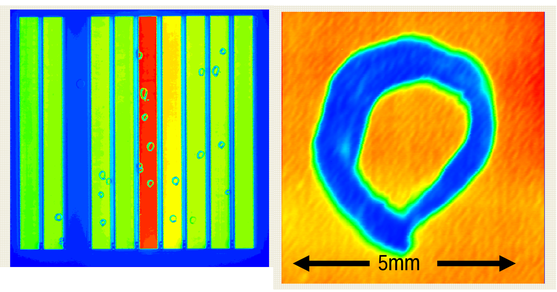
- •Organic PV minimodules (6x6") from US manufacturer, glass or flex encapsulation, 1000 hrs at 85°C/85 %RH, dark or light, max power (MP) or open circuit (OC).
- •Standard 85/85/dark ALT condition not representative of realistic load at MP, OC



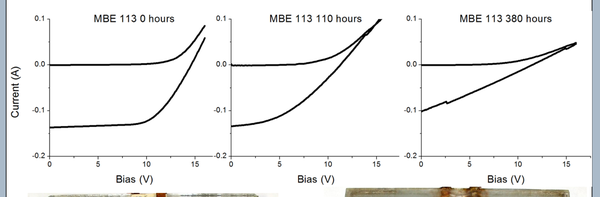


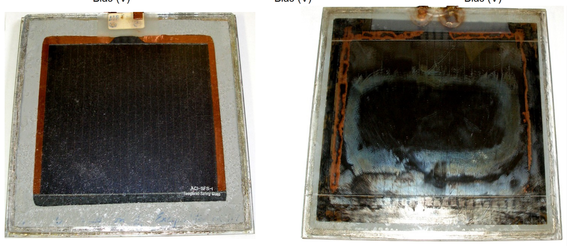


- •Device analysis of encapsulated thin film mini-module 1000 hrs 65°C/85 with light: increase in recomb.; develop blocking contact



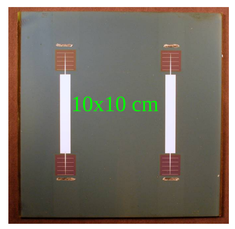
- •LBIC of OPV module after D-H stress showing localized degradation

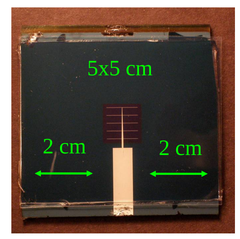


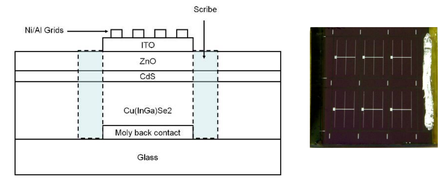


- •Commercial CIGS mini module showing increased series resistance with D-H stress from galvanic corrosion between back contact and conductive tape due to encapsulation failure.

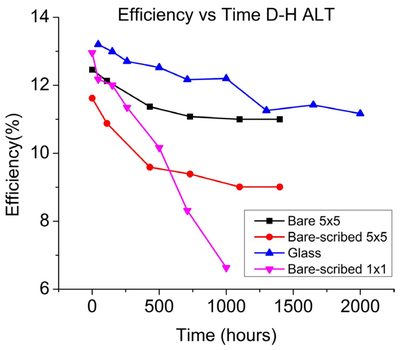
Test structures and device geometry



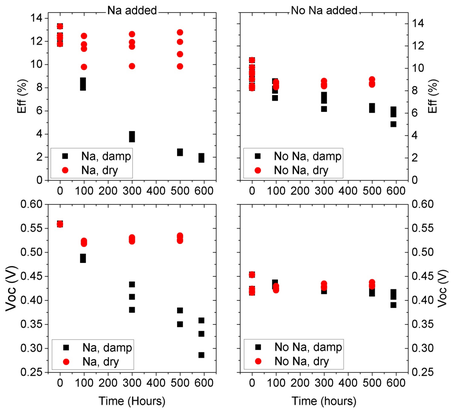




- •Custom CIGS test structures and device fabricated at IEC for encapsulation testing to compare effect of scribing, lateral geometry



- •TCO can act as water vapor barrier, scribes through TCO compromise D-H stability



- •CIGS on stainless steel from commercial manufacturer, effects of damp and dry heat on devices with and without Na

CONCLUSIONS

- •ALT under voltage and light bias critical to identify degradation and recovery modes
- •In-situ IV characterization provides valuable insight on transients
- •Device analysis separates junction recombination, series R, blocking contact
- •Large area scanning techniques (LBIC, EL) identify shunts and localized losses