Effects of metastabilities on CIGS photovoltaic modules

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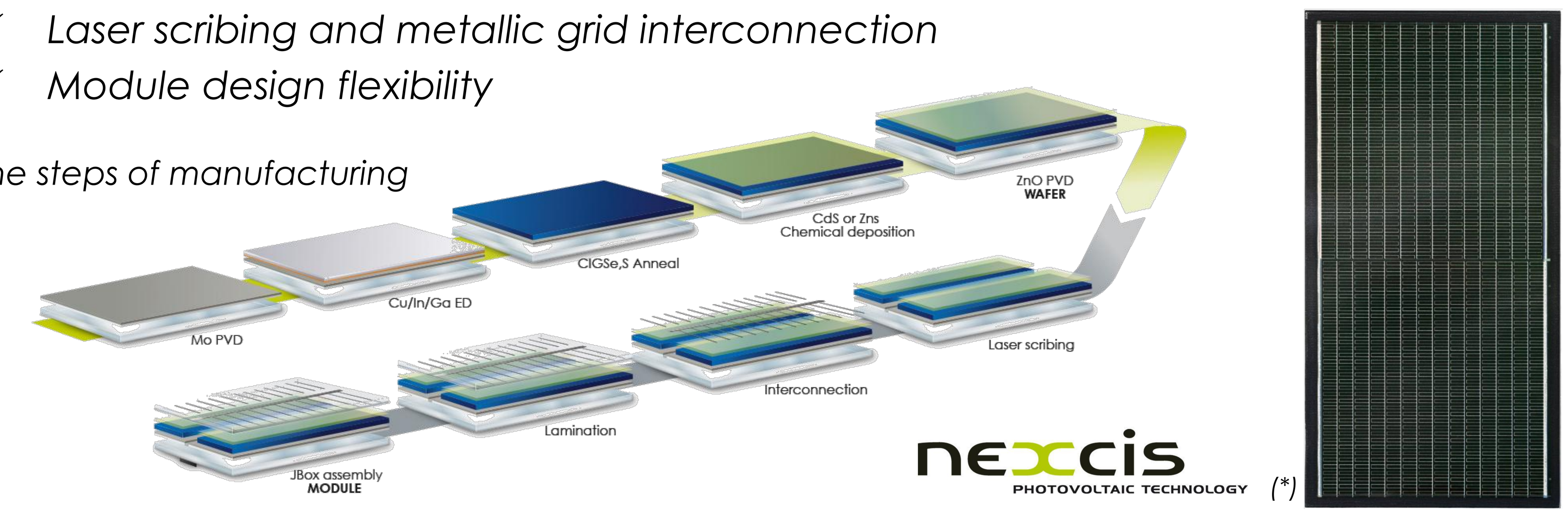
- *In this work, we have characterized metastabilities behavior on our CIGSe thin film module obtained by Electrodeposition and RTP process steps. We have carried out an understanding study of the driving force of the mechanisms which rules the different observed phases during storage, light exposition and annealing. The aim of this study is to obtain a better understanding of this phenomenon and hence a better evaluation of its impact on Panel Reliability and for qualification tests provided by IEC 61646 norm.*

- *Chalcopyrite $CuIn_xGa_{1-x}(S,Se)_2$ solar cell by 2-step process:*
  - *Electrodeposition CuInGa on Molybdenum-covered glass (ED)*
  - *Rapid Thermal Processing (RTP) with Selenium and Sulfur.*
- *Laser scribing and metallic grid interconnection*
- *Module design flexibility*

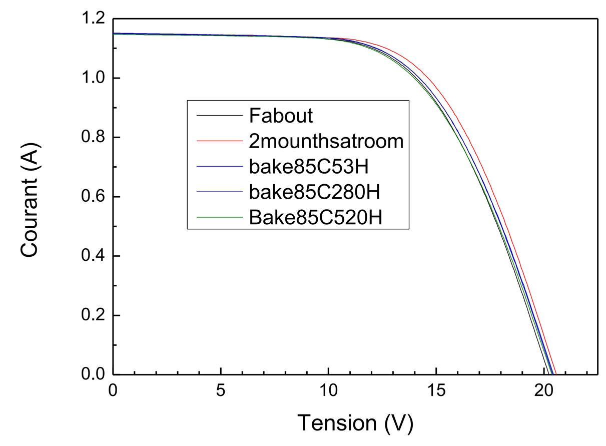
The steps of manufacturing



Characterization tools and methods

- *All experiments are performed with 30x60 cm² prototype modules (*).*
- *We use a calibrated flash solar simulator class AAA to obtain optoelectronic parameters. Before measurement, modules are stabilized at 25°C ± 1°C.*
- *Bakes are performed with a standard oven stabilized at 85°C ± 2°C.*
- *Illumination ageing study is performed in a dedicated chamber maintained at 30°C ± 2°C (Xenon lamp class C in term of spectral mismatch and time stability).*

- *We observe a gain after storage in fab room under ambient illumination. (+3/+4%).*
- *After a bake at 85°C in the dark, this gain is recovered.*

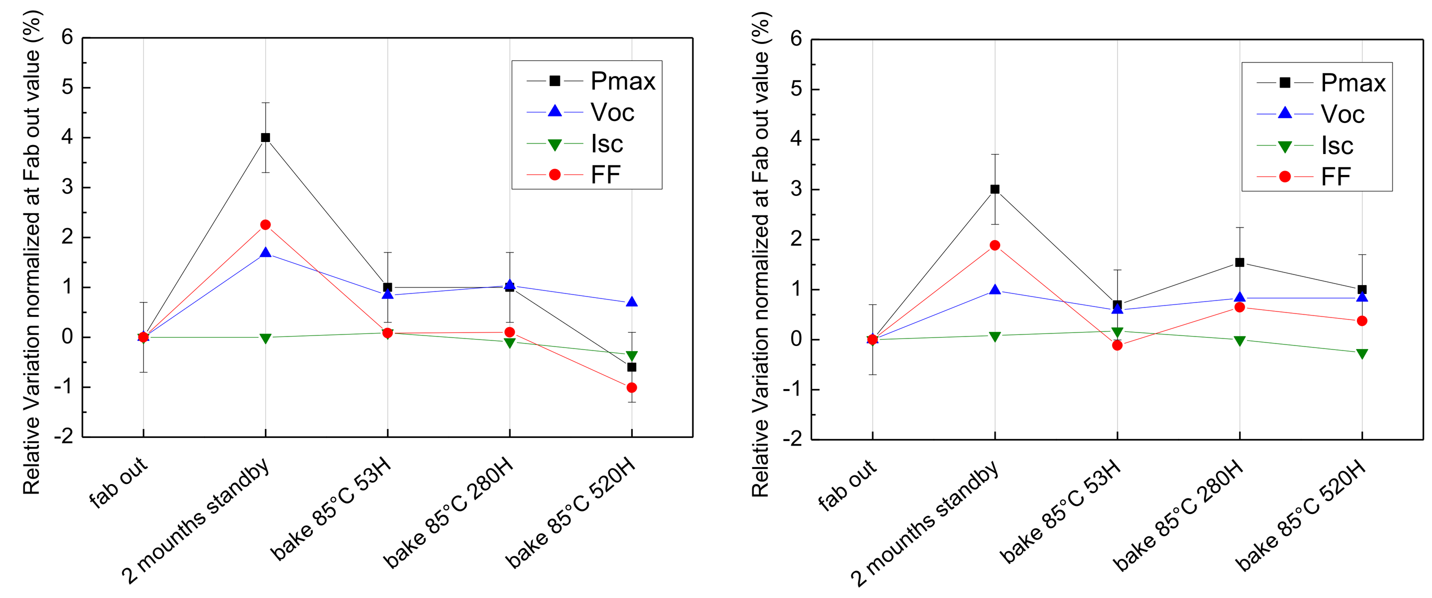


Storage time in fab room under ambient illumination : 2 months

Bake temperature : 85°C

Sampling : 53H, 280H, 520H

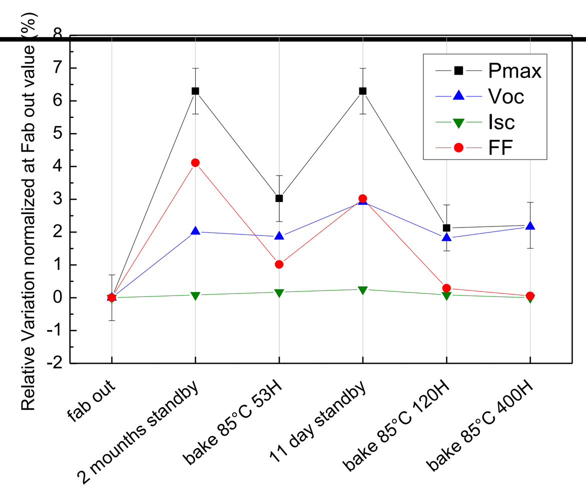
- *Phenomena is reproducible with some dispersion between modules.*



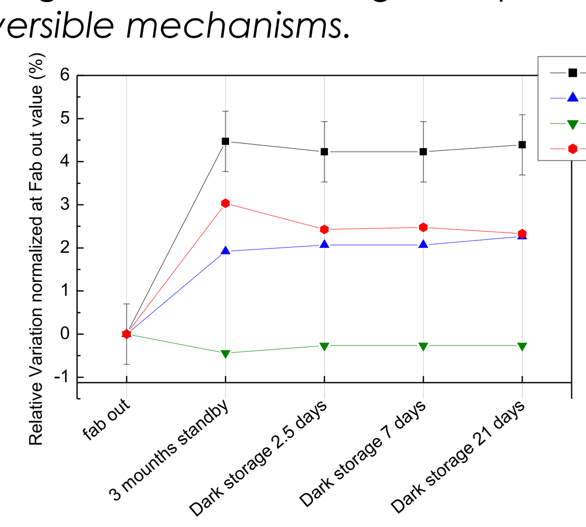
- *Similar phenomena have been reported in the literature for CIGS technology [1],[2].*

- *In order to understand metastabilities origin, we have performed a set of experiments to dissociate dark, light and temperature effects.*

1) Reversibility and stability of this phenomenon



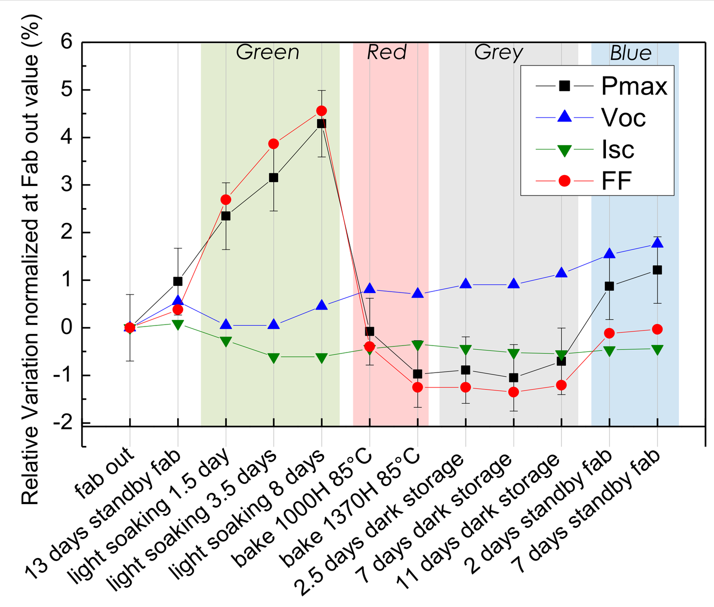
- *The metastabilities gain under illumination (for various intensities) and the metastabilities recovery in dark storage conditions at high temperature (85°C) are both reversible mechanisms.*



Dark Storage at 25°C

- *The metastabilities gain obtained remains stable during the time in dark storage conditions at room temperature (25°C ± 5°C).*

2) The driving forces of the associated electrical behavior

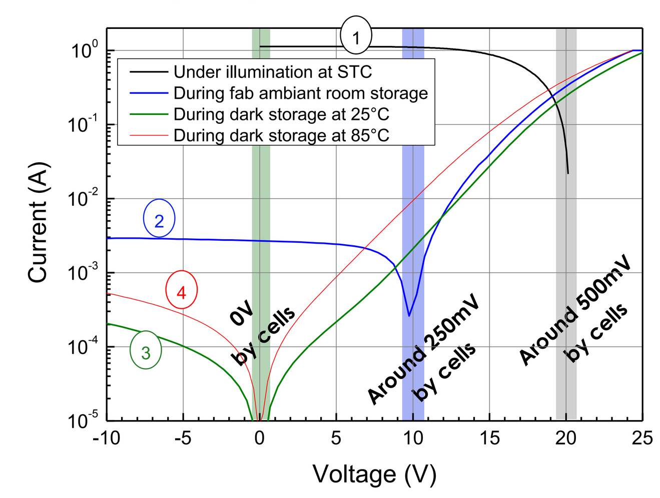


The performed tests show that :

- *Metastabilities gain is accelerated at standard illumination conditions (1000W/m²) (green area).*
- *Metastabilities recovery is accelerated in temperature if we compare dark storage at 20-30°C (grey area) and 85°C (red area).*
- *Metastabilities gain is generated under low illumination conditions too (<10W/m²) (blue area).*
- *The recovery phenomena is also observed at 60°C.*

3) Study of Storage conditions characteristics

- *Respective electrical field conditions comparison. For all ageing tests, we are in open circuit condition (I= 0A).*



Studied conditions description :
1) IV under illumination
2) IV in fab ambiant room storage
3) IV in dark storage at 25°C
4) IV in dark storage at 85°C

- *For illumination condition(black IV curve 1) and fab ambient room storage condition (blue IV curve 2), the thermodynamic equilibrium is modified by generated electron flux which can be responsible of the metastabilities gain.*
- *In the case of dark storage at 25°C (green IV curve 3), 60°C and 85°C (red IV curve 4), electron flux is negligible. The metastabilities recovery mechanisms is highly activated in temperature (diffusion mechanisms?).*
- *Perspectives :*
  - *Extraction of the activation energy of metastabilities recovery mechanisms.*
  - *Bias soaking study to better characterize metastabilities gain mechanisms.*

Conclusions

- *All these studies allow a better understanding of the metastabilities phenomena linked to our panel. To realize reliability evaluation and qualification tests, we have to deal with these aspects.*
- *Light soaking is a well known phenomenon for CIGSe technology.*
- *Metastabilities defects have to be controlled to properly address reliability issues.*
- *Bias soaking effects and recovery thermal activation have to be investigated to continue this work.*

[1] Light Soaking Effects on PV Modules Overview and Literature Review , M. Gostein and L. Dunn Atonometrics, NREL PV Module Reliability Workshop, February 2011

[2] Analysis of Alternate Methods to Obtain Stabilized Power Performance of CdTe and CIGS PV Modules J.A. del Cueto and Al. NREL, NREL PV Module Reliability Workshop, February 2011

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