

# Outdoor Stabilization of Thin-Film Photovoltaic Module Performance

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## Introduction

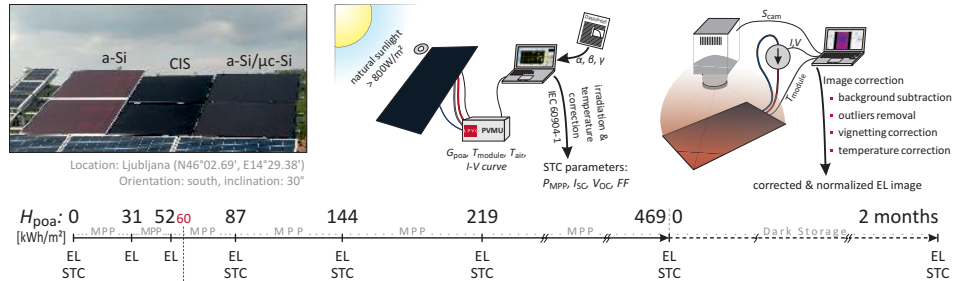
Thin-film (TF) photovoltaic (PV) modules go through the process of preconditioning before they reach the metastable and rated operating point. We expose six TF PV modules of three different technologies:

- amorphous silicon (a-Si a,b),
- micromorph tandem silicon (a-Si/ $\mu$ c-Si a,b) and
- chalcopyrite (CIS a,b)

to outdoor conditions to receive 500 kWh/m<sup>2</sup> of total solar irradiation ( $H_{poa}$ ) and monitor the STC performance and electroluminescence (EL).

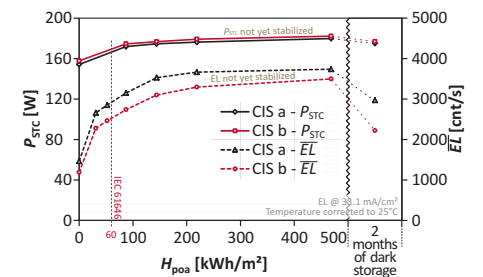
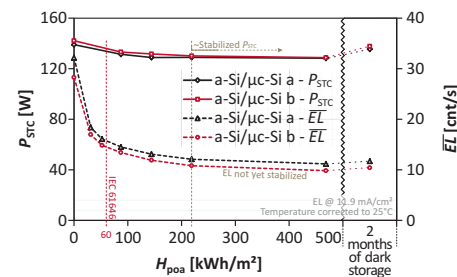
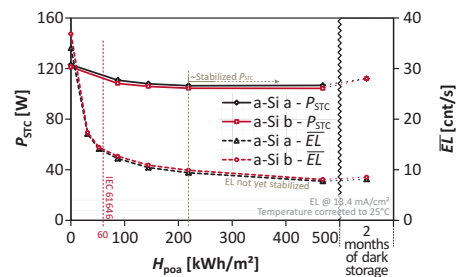
## Experimental

### Outdoor exposure STC performance Electroluminescence



## Results

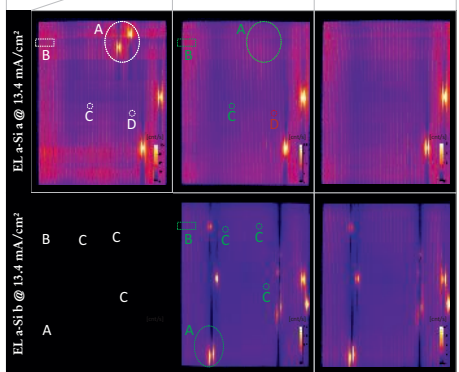
### Amorphous silicon



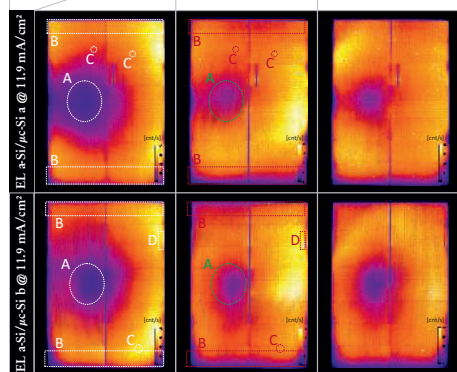
Module	Initial		After irradiation		After dark storage	
	$P_{STC}$ [W]	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]
a-Si a	123.0	106.7	-13.3%	112.0	+5.0%	
a-Si b	121.2	104.4	-13.9%	112.0	+7.4%	
	EL [cnt/s]	EL [cnt/s]	dEL	EL [cnt/s]	dEL	EL [cnt/s]
a-Si a	34.0	7.7	-77.3%	8.1	+5.1%	
a-Si b	36.8	8.1	-78.1%	8.5	+5.5%	

Module	Initial		After irradiation		After dark storage	
	$P_{STC}$ [W]	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]
a-Si/ $\mu$ c-Si a	139.0	128.3	-7.7%	135.4	+5.6%	
a-Si/ $\mu$ c-Si b	142.2	128.7	-9.5%	137.7	+7.0%	
	EL [cnt/s]	EL [cnt/s]	dEL	EL [cnt/s]	dEL	EL [cnt/s]
a-Si/ $\mu$ c-Si a	32.2	11.2	-65.3%	11.7	+4.9%	
a-Si/ $\mu$ c-Si b	28.3	9.8	-65.2%	10.4	+5.8%	

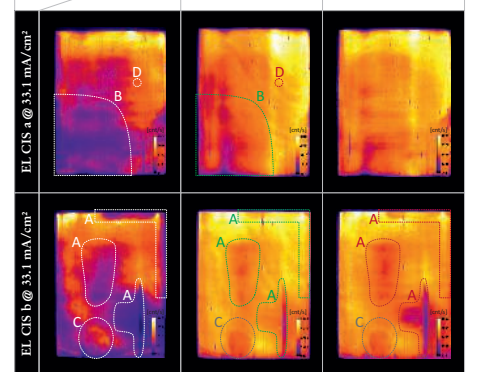
Module	Initial		After irradiation		After dark storage	
	$P_{STC}$ [W]	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]	$dP_{STC}$	$P_{STC}$ [W]
CIS a	154.2	179.8	+16.6%	175.0	-2.7%	
CIS b	157.8	182.2	+15.5%	176.8	-3.0%	
	EL [cnt/s]	EL [cnt/s]	dEL	EL [cnt/s]	dEL	EL [cnt/s]
CIS a	1464.6	3738.2	+155.2%	2970.9	-20.5%	
CIS b	1189.9	3497.3	+193.9%	2219.5	-36.5%	



- Inhomogeneity dynamics:
- A: insufficient P3 cuts . . . mitigation
  - B: systematic shunts . . . improvement
  - C: shunt . . . . . improvement
  - D: shunt . . . . . formation



- Inhomogeneity dynamics:
- A: large dark area . . . . . improvement
  - B: edge inhomogeneity . . . deterioration
  - C: bright spot . . . . . formation
  - D: shunt . . . . . formation



- Inhomogeneity dynamics:
- A: inhomogeneous area . . changes
  - B: inhomogeneous area . . improvement
  - C: „constant“ circle . . . . . constant
  - D: shunt . . . . . formation

## Conclusion

### Outdoor performance stabilization

- a-Si based TF PV modules initially **degrade**.
- CIS based TF PV modules initially **improve**.

### Dark storage shows the opposite behaviour

- a-Si PV modules **improve**, while CIS **degrade**.

EL exhibits higher sensitivity to changes than performance parameters.

- Some detected inhomogeneities show temporal changes, among them also mitigation and improvement.

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