Impact of Proton Irradiation on TMO-Based Solar Cells.

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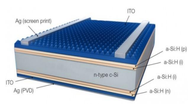
MOTIVATION

Solar cells able to work under harsh conditions (space missions) → III-V multijunction solar cells → High cost

Alternative

TMO-Based Solar Cells



- Manufactured at lower T (°C) than traditional Si homojunction
- Long-term stability of the solar cell/lower degradation
- Reduced cost / local work

→ **Evaluate and understand the effect of TMO-based solar cells in the space-like conditions**

TMO: Transition metal oxide

FABRICATION

FBRICATION PROCESSES

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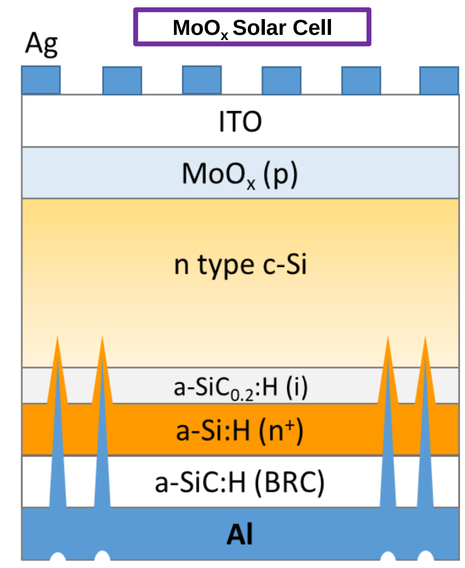
- 2 µm of Ag upper contact — Thermal evaporation
- 80 nm layer of ITO — RF magnetron sputtering
- 15 nm of MoOx layer — PECVD (SiH4 + Ar 5%)
- **Crystalline silicon substrate with a resistivity of 2.6 Ωcm**
- 4 nm intrinsic a-SiCx:H (x~0.2) passivation layer — RCA bath (HF 1%)+ PECVD (SiH4 + Ar 5%)
- 80 nm of stoichiometric a-SiCx:H (x~1) — PECVD (SiH4 + Ar 5%)
- 1 µm thick Al layer by evaporation on laser firing contacts — Laser firing contact treatment

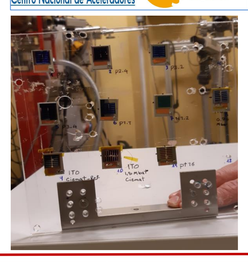


EXPERIMENTAL

Radiation Process

RADNEXT

CNA Centro Nacional de Aceleradores — Infraestructuras Científicas y Técnicas Singulares



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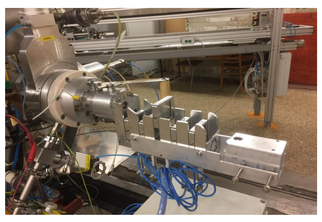
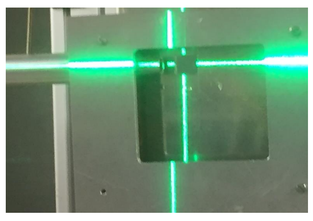




Date	Radiation step	Total Fluence (p/cm²)	Energy (MeV)	Individual Equivalent Displacement damage (1-MeV neutrons/cm²)	Total ionizing dose (krad)
Winter 2022	CNA	1.26×10^{10}	15.00	4.25×10^{10}	5.12
Spring 2023	CAS	2.1×10^{9}	16.04	6.91×10^{9}	0.81
	Total			$\mathbf{4.94 \times 10^{10}}$	**5.93**

The radiation absorbed by the cells in the two processes is equivalent to 8.5 years of the equivalent radiation in Low energy orbits (LEO)

CHARACTERIZATION TECHNIQUES

The samples were characterized after deactivation of radioactive isotopes

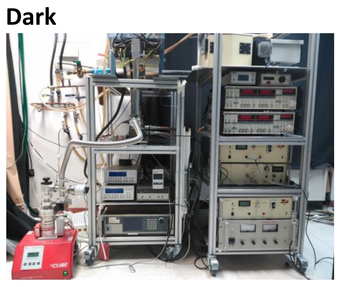
illumination — Ciemat

P_{in}= 1367 W/m²

Temperature: 25 ºC

Objective: Obtain I-V curves in illumination

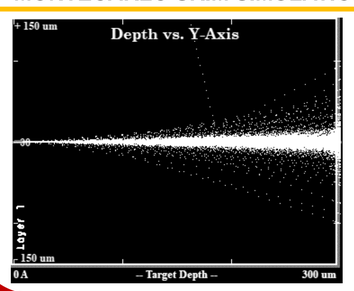
Dark



Samples mounted in an optoelectronic characterization system.

Temperature sweep 340 K - 220 K

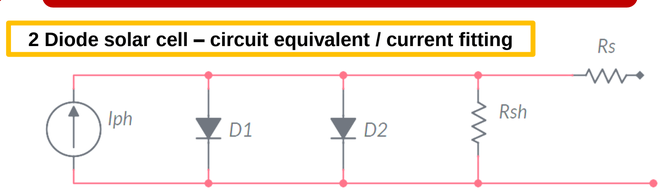
MONTECARLO SRIM SIMULATION



Ion Energy (MeV)	dE/dx Elec	dE/dx Nucl	Projected Range (µm)
11.0	3.23E-2	1.64E-5	709.23
13.0	2.84E-2	1.41E-5	1120
15.0	**2.54E-2**	**1.24E-5**	**1440**
16.0	**2.42E-2**	**1.17E-5**	**1610**
18.0	2.20E-2	1.06E-5	1990

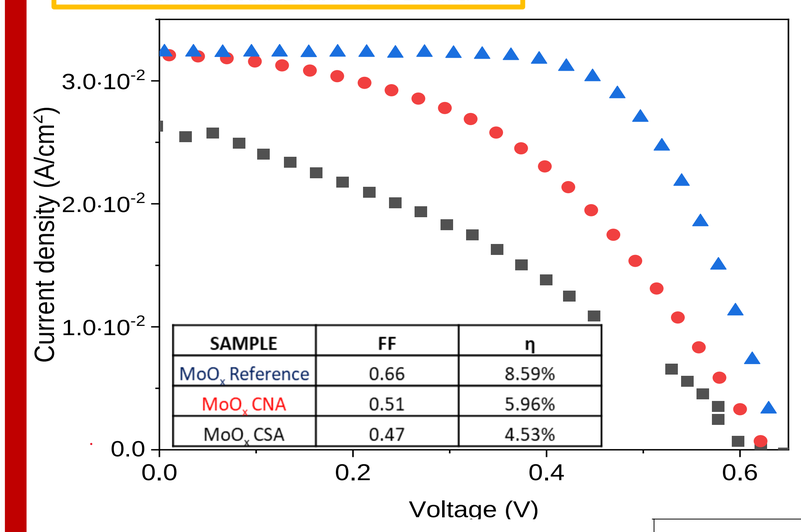
RESULTS

2 Diode solar cell – circuit equivalent / current fitting



$$I = I_0\left[exp\left(\frac{qV}{nkT}\right) - 1\right] - I_{ph}$$

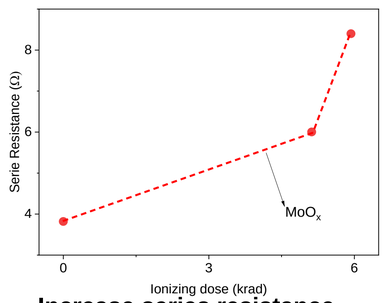
ILLUMINATION PARAMETERS FF & EFICIENCY



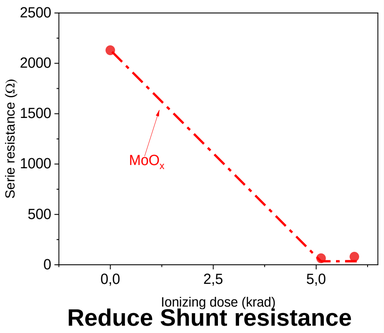
$$\eta = \frac{I_{SC}V_{OC}\,FF}{P_{in}} \qquad FF = \frac{I_{Max}V_{max}}{I_{SC}V_{OC}}$$

- **Correlation between the degradation of the open circuit voltage (V_{oc}) and the reduction of the shunt resistance (R_{sh})**
- **interface damage plays a role in the degradation of V_{oc}**
- **R_{sh} as an indicator of damage at the interfaces between the different layers of the solar cell junctions.**
- **Damage at these interfaces can introduce additional recombination centers**

- **Increase the reverse saturation current in each radiation process.**
- **Possible new recombination centers**
- **Lower carrier concentration.**
- **reduction in the diffusion length of the photogenerated minority carriers.**
- **Appearance of new diffusing elements of the total cell current, especially at low temperatures.**

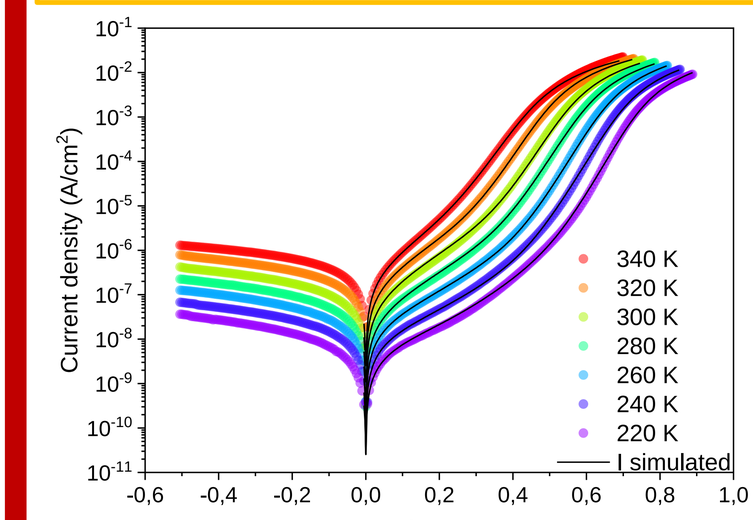


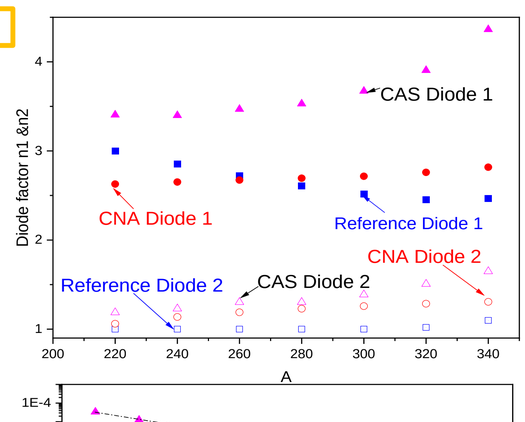
Increase series resistance

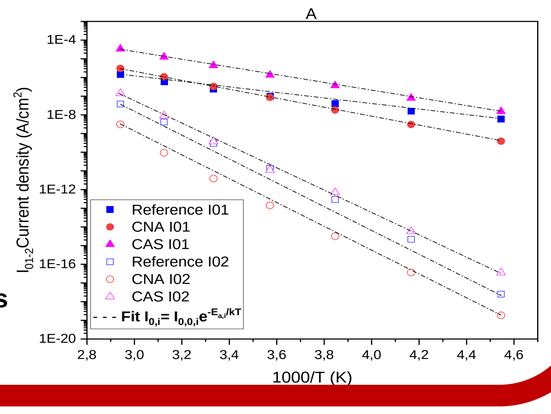


Reduce Shunt resistance

Dark Parameters and I_0 & diode factor Circuit equivalent parameters







- **Possible tunnel activation mechanism in MoOx solar cells**
- **Value close to the ideal is maintained at n=1**
- **Corresponds to the trend of reverse saturation currents with temperature.**

CONCLUSIONS

- An expected degradation response has been found in Si based solar cells. About 50% in 8.5 years radiation environment.
- A promising line of research is the use of Si-based solar cells with TMO in space conditions.
- The appearance of multiple defects in the cells makes it necessary to continue research on this topic.

References

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