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Silicon solar cells with Low Environmental footprint and Advanced interfaces

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Project Scientific Abstract

The SiLEAN project explores leaner process for metallization and interconnection in silicon heterojunction (SHJ) solar cell by eliminating critical raw materials and reducing cost and carbon footprint. The project focuses on the development of indium-free contact layers using ZnO-based transparent conductive oxides (TCOs) deposited via PECVD, avoiding passivation damage from traditional sputtering. Silver-intensive front contacts will be replaced with copper-based metallization using scalable techniques such as electroplating and screen printing with copper or Cu/Ag-coated particles, supported by novel capping layers to enhance oxidation resistance. For the interconnection of cells, SiLEAN will develop a leaner multi-wire approach suitable for thinner wafers, by which interconnection and encapsulation can be done in a single step. The copper wiring and cell layout will be progressively optimized to reduce bismuth, ultimately enabling a completely Bi-free soldering. Additionally, metal-free contact schemes using carbon-based pastes will be explored for ultra-lean, solder-free modules. The resulting SHJ solar cells aim to reach >25.5% efficiency while enabling a 50% cost reduction in wafer production, indium-free contact layers, metallization and with all-in-one cell interconnection and encapsulation. These innovations pave the way for next-generation, resource-resilient module assembly processes that are scalable, low-cost, and sustainable at terawatt-scale production.

Public summary

Within the SiLEAN project, the partners develop alternatives to indium-containing contact layers as well as silver metallization in silicon heterojunction (SHJ) solar cells. It is one of the goals of the project to replace indium tin oxide by boron-doped zinc oxide, deposited by plasma-enhanced chemical vapour deposition, and to replace silver by screen-printed or plated copper for the metallization. The potential of carbon as a contact material is also to be explored. In order to test the compatibility of (and eventually adapt) the interconnection between those cells with new materials in module application, early-stage test cells with zinc oxide, silver and copper were fabricated by partners. The metalized cells were interconnected into modules using the TWILL multiwire technology following its standard procedure. These modules were characterized to evaluate their performance and then placed in reliability chambers for thermal cycling (TC) and damp heat (DH) testing. Their performance is being continuously monitored to assess the stability and long-term durability of the fabricated modules under accelerated aging conditions.

Initial results show that modules with Cu/Ag metallization exhibited excellent reliability, passing three times the IEC thermal cycling standard with minimal degradation, while AZO-based modules failed to meet IEC requirements under both thermal and damp heat stress. Reference ITO-based modules demonstrated stable performance in all conditions. Additionally, early work on a metal-free commercial carbon contact deposition set a baseline process with a commercial carbon paste, preparing the screen-printing know-how and electrical measurements to accurately evaluate the properties of the new graphene-pastes that are being developed within SiLEAN.

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Project partners:

#	Partner short name	Partner Full Name
1	FZJ	FORSCHUNGSZENTRUM JULICH GMBH
2	IMEC	INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM
3	TUD	TECHNISCHE UNIVERSITEIT DELFT
4	UNR	UNIRESEARCH BV
5	NXW	NEXWAFE GMBH
6	PVW	PV Works B.V.
7	GET	GraphEnergyTech
8	3SUN	3SUN S.R.L.
9	GUNAM	ODTU GUNES ENERJISI UYGULAMA VE ARASTIRMA MERKEZI

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