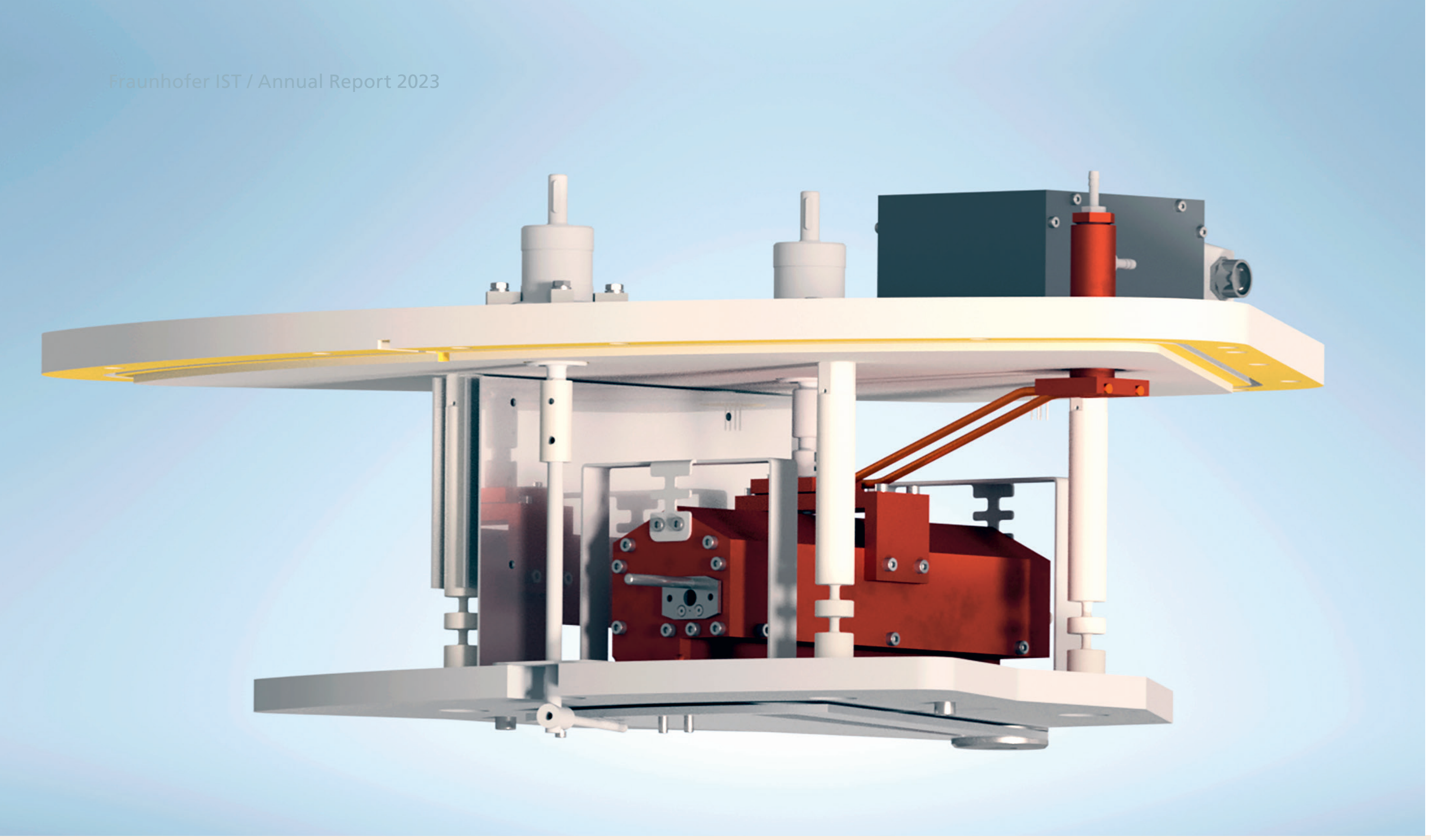


Design of the evaporator system.

From research

Sustainable, highly efficient perovskite-silicon tandem solar cells

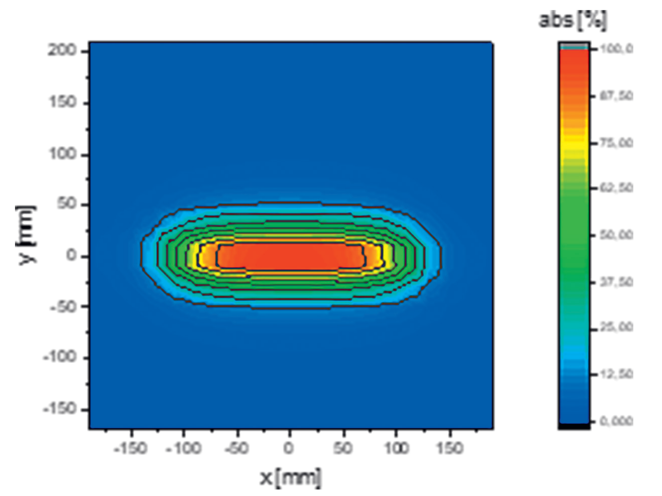
In order to slow down climate change, a huge expansion of renewable energies is necessary. The lowest costs for electricity generation are now provided by photovoltaics. Currently, however, the cost drivers are still the required storage technologies. In order to reduce overall costs, it is therefore necessary to further increase the efficiency of cell technology. A promising solution is offered by tandem solar cells based on silicon technology. With the low-cost silicon cell as a bottom solar cell and a top cell consisting of a perovskite structure, the solar spectrum of the sun can be better exploited. It is expected that within a few years, it will be possible to achieve significantly higher efficiencies of approx. 40 % and, as a result, considerably higher yields per utilized area.

Extract from the Annual Report 2023
To the website: www.ist.fraunhofer.de/en.html

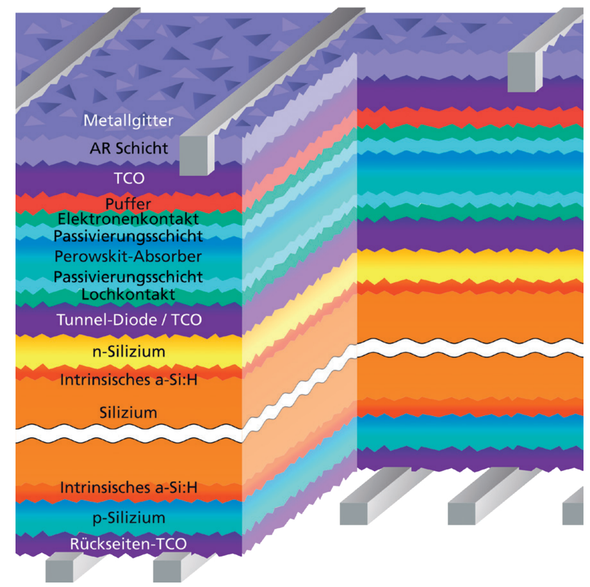
Within the framework of the Fraunhofer flagship project MaNiTU, the Fraunhofer IST has developed and investigated a multitude of necessary functional and contact layers as well as the associated system technology, and has scaled them up to areas of 210 mm², which corresponds to today's wafer sizes.

Particular challenges in the coating of perovskite absorber material

At more than 25 %, perovskite solar cells now achieve similar levels of efficiency to those of silicon solar cells. The perovskite absorber material, however, has a complex crystal structure and consists to some extent of organic components, which makes it sensitive to further coating. In addition, the tandem cells themselves also have a very complex structure.



Layer distributions of selected evaporator geometries can be determined in advance with the aid of PICMC simulations.

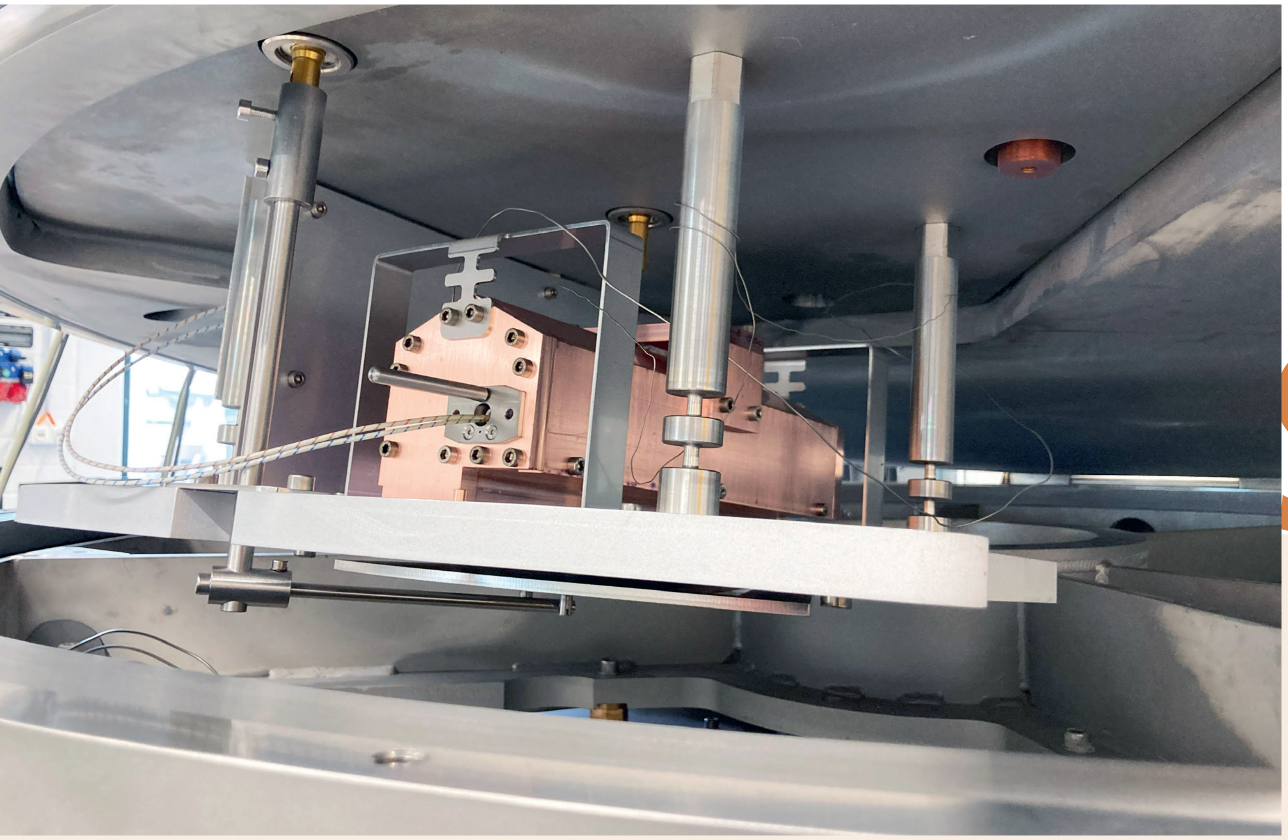


Structure of a perovskite-silicon tandem cell with Si-HTJ bottom cell.

They consist of a multitude of wafer-thin functional and contact layers that are deposited under, between and on top of the two absorbers. These layer systems are subject to stringent requirements that impede the upscaling and further optimization of the technology developed in the laboratory. The layers must be optically transparent, i.e. they must exhibit no or only minimal absorption. Moreover, the electrical properties must be adapted in such a way that the charge carriers reach the contacts. Furthermore, the interfaces must be free of defects across the entire surface. As the perovskite cell is temperature-sensitive, only temperatures below 100 °C may be used in the manufacture of the front contact system.

New technologies and processes for the coating of perovskite absorber material

For the development of functional layers for silicon heterostructure solar cells (Si-HTJ) and the coating of the perovskite absorber material, the Fraunhofer IST is able to draw on extensive experience in the production of functional and contact layers for S-HTJ and amorphous/microcrystalline silicon tandem solar cells. In the current project, selective charge-carrier layers suitable for large areas are being produced, as well as buffer and passivation layers and transparent conductive oxides (TCO). For the development of the electron contact system, a novel high-rate S-ALD hybrid system is being deployed.



The evaporator system is constructed in the hybrid area of the S-ALD.

S-ALD hybrid

This system can be used to produce tunnel layers on the basis of metal oxides on the perovskite absorber, as well as the subsequent electron contact layer by means of linear-evaporator technology developed in-house and the subsequent passivation layer.

The ensuing deposition of the front contact is then performed by means of a sputtering process. For the optimization of the front contact, the Fraunhofer IST first uses a serial co-sputtering process established at the institute. In the next step, the transparent front contact layers are deposited with the aid of the metallic alloy target with the previously determined optimum composition. Both technologies enable a high-throughput process.

A step towards a high-performance European photovoltaic industry

With the help of the technologies applied and developed at the Fraunhofer IST, the respective individual processes can be coordinated and optimized within the entire process chain. The technology of the Fraunhofer IST is transferable to the cell surfaces and industrial process chains required by the industry and allows the consideration and optimization of the entire solar cell stack in terms of efficiency and costs. A transfer to the plant constructors and also the cell manufacturers could sustainably improve their competitiveness and help to re-establish a strong European photovoltaic industry.

Outlook: Further efficiency increase and industrial utilization

As a result of the work carried out by the Fraunhofer consortium, efficiency levels of over 30 % have now been achieved for tandem solar cells, and methods for scaling-up the surfaces have been identified along with the potential for a simultaneous increase in efficiency. In order to involve industry in further development, the first collaborative workshop took place in October 2023. In addition, the first joint funding applications with industrial partners have been submitted in order to consolidate and industrially utilize the achieved results in the future.

The project

Within the Fraunhofer flagship project MaNiTU, five Fraunhofer institutes are pooling their globally unique portfolios of expertise. In addition to proven expertise in the field of solar cells and sustainability assessment, this also includes profound knowledge and experience in theoretical and experimental materials science, in process development and in the characterization of individual materials through to entire systems. The aim is to achieve technological leadership in the field of sustainable, highly efficient tandem solar cells.

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