To the Media

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Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

Location: Meitnerstr. 1,
70563 Stuttgart
Germany

Boosting the Performance of Highly Efficient Thin-Film Solar Cells

Research team pinpoints potential for improving CIGS solar cells

The efficiency of today's thin-film solar cells with the compound semiconductor made of copper, indium, gallium and selenium (CIGS) has already topped the 23 percent mark, but now a further increase looks to be within reach. A team staffed with researchers from the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Martin Luther University Halle-Wittenberg (MLU) and the Helmholtz-Zentrum Berlin (HZB) recently identified a key point where the performance of thin-film solar cells can be improved for the cell to convert more sunlight into electricity. Published in the renowned science journal *Nature Communications* in August 2020, the results of this investigation reveal how manufacturers of CIGS thin-film solar cells can achieve even higher efficiencies.

Link to the article: www.nature.com/articles/s41467-020-17507-8

Great strides have been made in recent years towards CIGS thin-film solar cells' maximum theoretical efficiency of about 33 percent, but around ten percentage points of potential remains untapped. This shortfall is attributable to loss mechanisms in the CIGS solar cell in the functional layers and at diverse interfaces. Where exactly and why these losses occur has been a point of conjecture and the subject of much debate among experts.

Reducing the density of electrically active grain boundaries boosts performance

Scientists at the ZSW, MLU and HZB have now learned more about their origins. "Some of the losses occur at the boundaries between the individual CIGS crystals in the solar cell. Positive and negative electrical charges can neutralize each other at these grain boundaries, some of which are electrically active," says project manager Dr. Wolfram Witte from the ZSW. "This reduces the cell's performance."

Researchers were able to identify this type of loss mechanism by combining experimental measurement methods with computer simulations. The HZB analyzed a highly efficient CIGS solar cell with various electron microscopy techniques and optoelectronic measuring methods such as photoluminescence to provide realistic values to the two-dimensional device simulation developed at the MLU.

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The ZSW manufactured the CIGS cell in a co-evaporation process that deposits copper, indium, gallium and selenium simultaneously in a vacuum. The cell's efficiency was 21 percent without an additional anti-reflective layer. The physical microstructure of this cell and the values obtained in experiments with various analytical methods served as the input parameters for two-dimensional simulations.

Computer simulations showed that increased recombination at electrically active grain boundaries within the CIGS layer constitutes a significant loss mechanism. Above all, this decreases the open-circuit voltage and fill factor, which reduces the cell's efficiency. "What needs to be done to further improve the efficiency of CIGS thin-film solar cells and modules is to reduce the density of the electrically active grain boundaries and produce CIGS layers with larger grains," says Witte. This could be achieved with technical means, for example, by augmenting the CIGS layer with additives, adapting the substrate material or optimizing the temperature balance during coating. These would be promising points of departure for the photovoltaic industry's efforts to elevate the efficiency of CIGS modules.

The EFFCIS project

The findings described in *Nature Communications* were one of several partial results obtained in a joint project called EFFCIS. Funded by the BMWi, the German Federal Ministry for Economic Affairs and Energy, this research venture ended in 2020 after a run of around three and a half years. Nine partners teamed up in a consortium that had experts from research institutes, universities and industry working together under the leadership of the ZSW. Their efforts focused on localizing and learning more about the dominant loss mechanisms in CIGS thin-film solar cells and modules to then reduce or eliminate these losses with innovative measures. The partners used analytical tools with high temporal and spatial resolutions to determine the chemical and physical properties of the functional layers and interfaces in CIGS solar cells.

Nature Communications 11 (2020) 4189: "„Microscopic origins of performance losses in highly efficient Cu(In,Ga)Se_2 thin-film solar cells", Maximilian Krause, Aleksandra Nikolaeva, Matthias Maiberg, Philip Jackson, Dimitrios Hariskos, Wolfram Witte, José A. Márquez, Sergej Levcenco, Thomas Unold, Roland Scheer, Daniel Abou-Ras. DOI: 10.1038/s41467-020-17507-8

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About ZSW

The Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Centre for Solar Energy and Hydrogen Research Baden-Württemberg, ZSW) is one of the leading institutes for applied research in the areas of photovoltaics, renewable fuels, battery technology, fuel cells and energy system analysis. There are currently around 280 scientists, engineers and technicians employed at ZSW's three locations in Stuttgart, Ulm and Widderstall. In addition, there are 100 research and student assistants.

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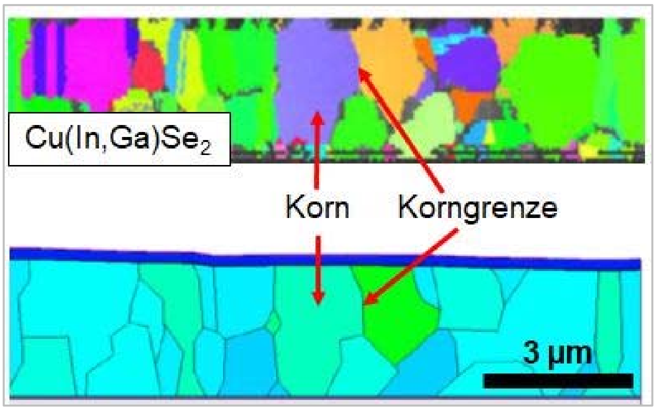

The top image depicts the measured grain structure of the highly efficient CIGS solar cell produced at the ZSW, with the colors indicating the grains' different crystallographic orientations. The bottom image shows the two-dimensional simulation based on these measurements.

Artwork: ZSW, based on the illustrations in the cited article published in *Nature Communications*

Lab plant for depositing the CIGS layer in a coevaporation process.

Photo: ZSW / Alexander Fischer

Images are available from Solar Consulting or at https://energie.themendesk.net/zsw/.

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