Enabling the energy revolution:

Leybold supports the ZSW in complex coating solutions for novel solar cells.

The goal of the energy revolution in Germany is to cover the private and industrial energy demand from renewable energies by 2045. The tense situation in Europe shows that this is beneficial for both the environment and the self-sufficiency of the entire European Union economy in general. The task is therefore to promote the generation of electricity from wind, water, and sun.

One of the leading energy research and development institutes in Europe is the ***Center for Solar Energy and Hydrogen Research*** (Zentrum für Sonnenenergie - und Wasserstoff-Forschung Baden-Württemberg [ZSW]) based in Stuttgart. The ZSW is dedicated to this very goal of achieving a 100% energy supply from renewables in Germany by 2045.

If renewable energies are weighted according to their availability, solar technology is considered core. Simply because the radiant power of the sun can be planned better than the power of the wind. An extra benefit is that solar power plants can be deployed in a decentralized way, i.e., away from the coasts in offshore wind farms or tidal power plants throughout Germany.

In addition to expanding the areas for solar parks, on the roofs of houses, etc., it is also important to increase the efficiency of each individual solar cell. In other words, to absorb more light from the incident sunlight.

The challenge: A conventional silicon solar cell reaches its theoretical performance limit at an efficiency of 29% (Shockley-Queisser Limit). This means that a maximum of 29% of the incident light energy can be converted into electricity.

Working together to achieve the goal: ZSW develops innovative tandem solar cell, Leybold ensures the enabling technology for coating

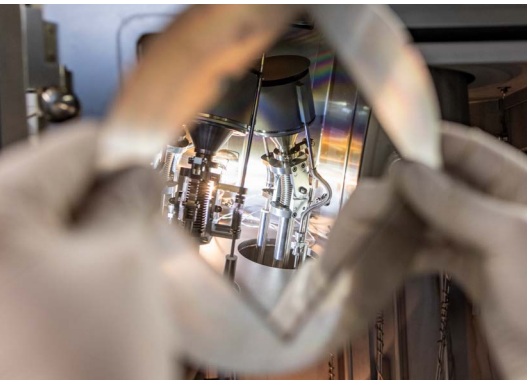
This natural limit of silicon could be overcome with a tandem solar cell.

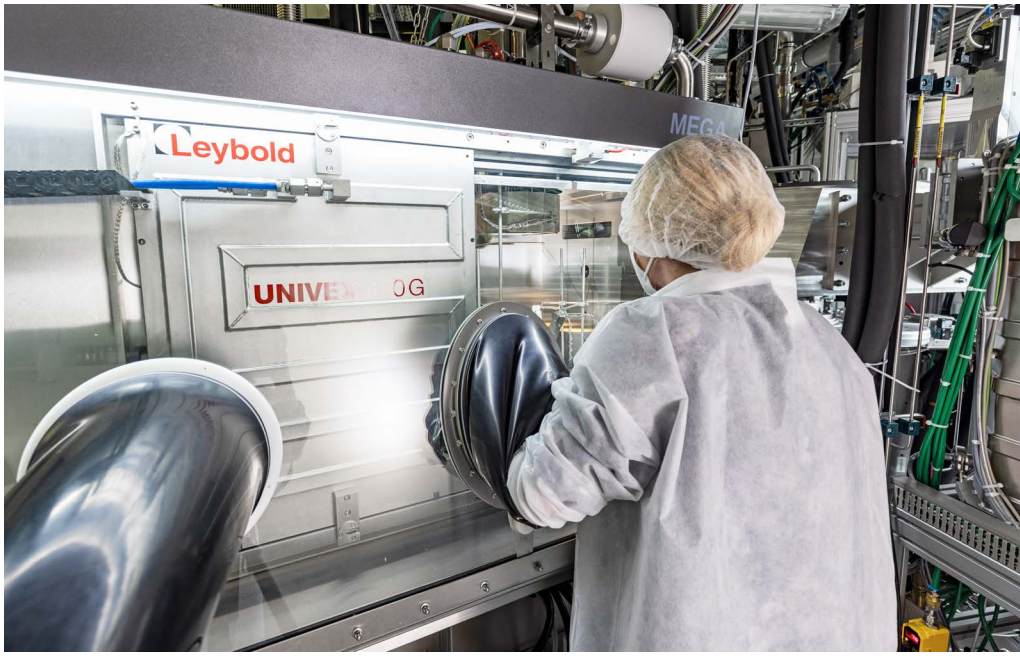
In promising tests performed by researchers at the ***CSEM*** and ***EPFL***, nearly 31.25% efficiency could be achieved with a tandem solar cell. Tandem solar cells are characterized by the fact that they use two absorber materials with different bandgaps which absorb the different spectral ranges of the solar spectrum and thus use it in a more efficient way. This leads to a significant cost reduction for each KWh produced. Also note that organometallic halides, such as methylammonium iodide are typically used.

At this point however, ZSW reached its limits with its own technical equipment because working with perovskite can quickly lead to unwanted chemical reactions such as chemical burns. For this reason, a partner from the industry was sought who could demonstrate years of experience in plant construction and vacuum expertise.

This is how the cooperation between ZSW and Leybold started. ZSW is an expert in solar technology and Leybold is an expert in high vacuum thin-film coatings and all systems are equipped with vacuum components developed in-house.

The goal of this collaboration: create an experimental vacuum setup so that hypotheses surrounding the mode of action of the tandem solar cell can be tested as quickly as possible. For this purpose, four process chambers





with different coating methods have been built and installed. This was an exciting challenge since most systems in plant engineering only require one process chamber.

Fully functional experimental line in a vacuum: the Leybold UNIVEX C 900

The UNIVEX series comprises multi-purpose coating systems for the production of functional PVD coatings. Features such as modular design, variable chamber sizes and numerous accessories make the coating systems more flexible. Over the past 50 years, Leybold has installed over 800 of these unique systems worldwide.

The necessary functional scope for this task is provided by the Leybold UNIVEX C 900, which has been customized to match the needs of the ZSW.

In general, two overriding uses of the systems can be derived:

- Setups for experimentation and research which are optimized for flexibility, so they are able to represent as many test scenarios as possible,
- Systems for production which coat the largest possible number of substrates in an output-optimized manner.

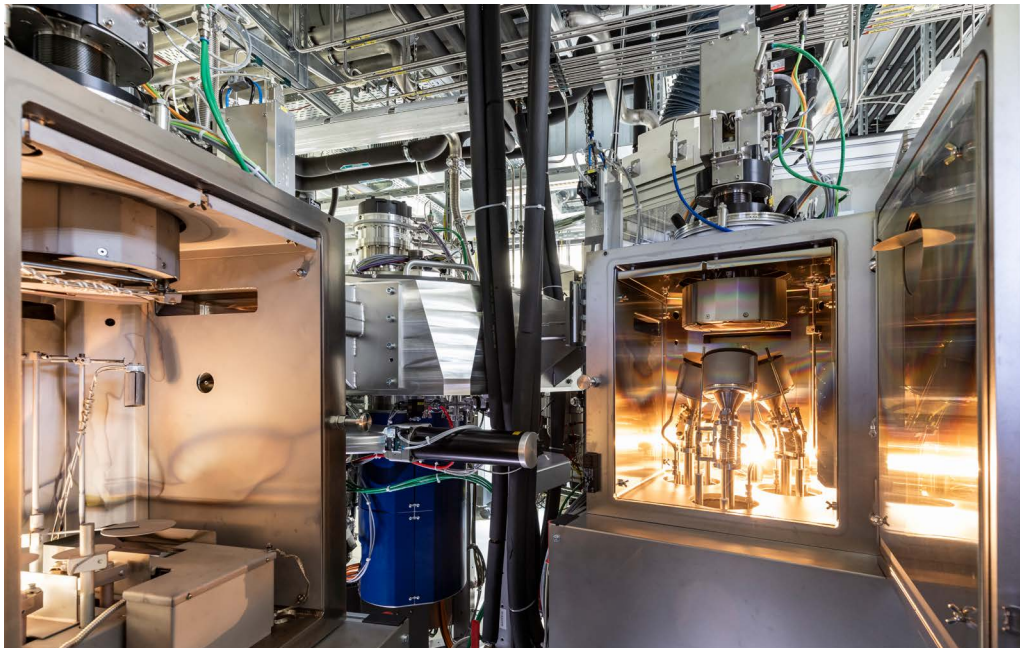
The special feature of the UNIVEX C 900 set up at the ZSW is its flexibility due to modularly arranged process chambers.

The following coating methods can be carried out in the four chambers:

1. Process chamber 1: Sputtering chamber - 3 sputter sources apply the coating to the substrate.
2. Process chamber 2: Thermal-organic evaporation chamber.
3. Process chamber 3: Electron beam evaporator chamber - is able to deal with materials melting at very high temperatures. It is ideally suited for material-saving applications, for example, because the material to be applied is expensive.
4. Process chamber 4: This one is especially important for the tandem solar cell because it is the chamber where perovskites are evaporated. Since they can be aggressive to other materials and to humans, the focus is on operator safety.

For reasons of safety, timesaving as well as protecting the materials from water (which is present in ambient air), it is possible to operate the system completely in a vacuum thanks to two additional chambers:

- **A transfer chamber** with a telescopic robot arm. This chamber is located at the heart of the whole system between the process chambers: its roles is to move the substrates through the system with millimeter precision.
- **A magazine:** the storage area where substrates can be kept. Here the robotics fetches replenishment when the previous substrate has been finally processed.



The energy revolution can only succeed when experts work together across industries

The evaporation of perovskite solar cells is a key application for future technologies and renewable energies. In addition to the further development of these specific processes, a long-term partnership is envisaged between ZSW and Leybold, which is regularly joining forces with various teams from this and other institutes to collaborate on new projects.

Once set up, the UNIVEX C 900 enables fully automated process control with highly reproducible results. We are confident that the ZSW will use the UNIVEX system to increase knowledge through high experimentation density and that together we contribute to the successful energy transition.

We look forward for ZSW and many other research institutes to support the world's energy transition. We strongly believe we can only master this radical transformation by working together.

About Leybold

Established in 1850, Leybold is a pioneer in vacuum innovation. Our inventions have paved the way for many modern-day vacuum technologies, including our range of next-generation vacuum products. We are recognized globally as a leader in the manufacture of vacuum pumps and systems for industrial and scientific vacuum applications, that are supported by our specialized and globally accessible Service solutions.

We are proud to live up to our brand promise - Pioneering products, Passionately applied.

Founded in Cologne, Germany with sales and service locations around the globe. We are a part of the Atlas Copco Group. For more information, visit leybold.com.

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Leybold GmbH | August 2022