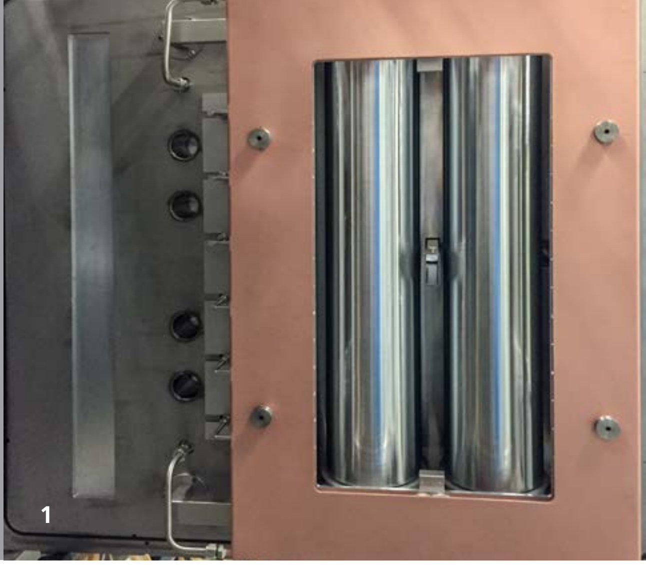
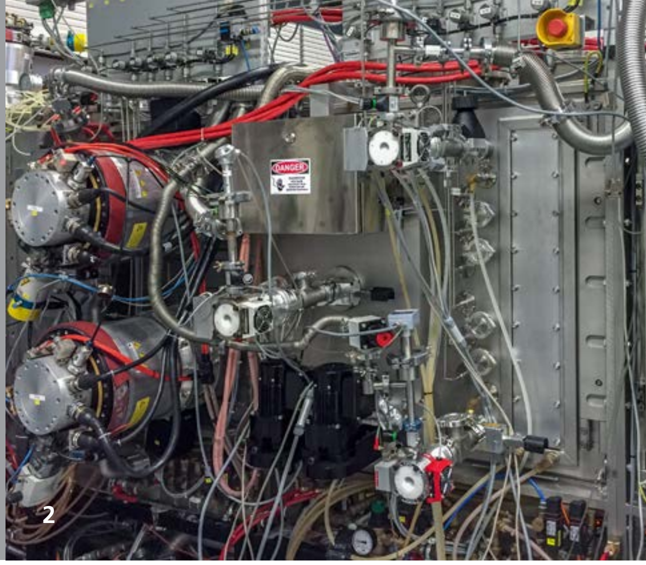

1


2

REACTIVELY SPUTTERED ZNO:AL WITH THE DOUBLE-TUBE MAGNETRON

Transparent conductive films (TCOs) are required as front contacts in the production of thin-film solar cells. The TCO production processes used on the industrial scale today are normally based on so-called DC sputtering from ceramic tube targets. However, to improve the competitiveness of German companies both a more efficient coating process – with lower material consumption and lower costs – and a greater effectiveness and longer service life is required. As part of the »TCO4CIGS« project funded by the BMWi (the Federal Ministry of Economics and Technology) a double-tube magnetron module has been successfully constructed for this process and tested.

The Fraunhofer IST's approach to a solution

The Fraunhofer IST has at its disposal a reactive sputtering process with metal targets that has the potential to replace the conventional DC sputtering process that uses ceramic targets. For this the following developments were necessary: firstly, an upscaling, and secondly, with the aid of a double tube, the integration of this reactive sputtering process into a production process for thin-film solar cells suitable for industrial application.

In upscaling the reactive sputtering process for ZnO:Al to a double-tube magnetron the institute was able to draw on years of experience. For some years now, reactive MF processes have been carried out at the institute with its planar double cathodes. In this particular case, the amount of oxygen required for the deposition of a stoichiometric film is supplied via the gas feed. At the same time, metallic Zn:Al targets are used, whereby transparent oxides based on ZnO:Al are created and deposited in the reactive sputtering process. To ensure a stable process along the entire target (even for a relatively long period) and thereby secure uniform deposition of oxides, multipled measures were taken. Firstly, a shared gas distributor as well as a specific gas supply were designed and integrated. Second, a suitable shutter environment for the double tube was fabricated. Third, a short-time process control in the milliseconds range was developed, and finally, a gas-flow quadrature regulator in the seconds range was introduced.

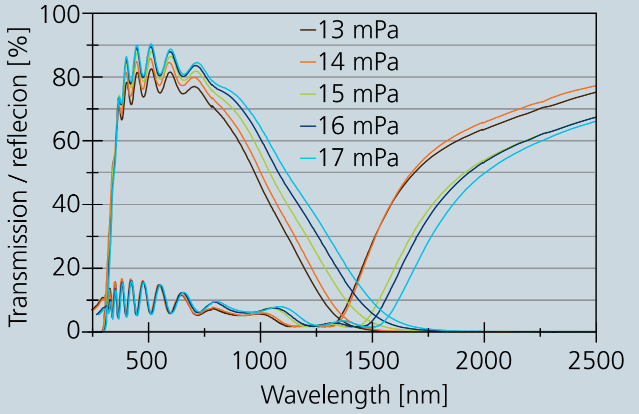
Results of ZnO:Al production

Zn:Al tube targets with an aluminum concentration of 1.75 wt.% were used in the production of the transparent oxide layers. With the aid of a lambda sensor closed-loop controller the oxygen partial pressure was stabilized at a firmly retained value by changing the power supplied. The graph opposite shows the transmission and reflection spectra of ZnO:Al films deposited on float glass for the specified values. The coating process took place at a substrate temperature of 200 °C. It can be seen that as the oxygen partial pressure rises, the charge carrier density falls. This is mainly due to a further oxidation of the aluminum but also to a reduced zinc evaporation from the substrate with increasing amount of oxygen because of the low vapour pressure of zinc. Along with the reduction of the active charge carriers, visual absorption also sinks while the specific resistance increases from 350 to approximately 500 µΩcm (see the graph opposite). For the data shown, the mobility of the charge carriers varies between 20 and 22 cm^2/Vs.

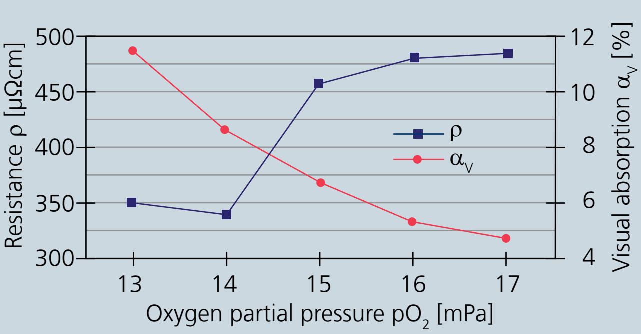
Outlook

Even when first put into operation, the new double-tube arrangement resulted in outstanding coating properties for the ZnO:Al deposited. Both the target environment and the process itself are to be further optimized in the next step in order to further increase the mobility of the charge carriers. The consequent improvements in film properties, such as reducing the specific resistance while simultaneously improving transparency, should then be transferred to CIGS absorbers.

Reflection and transmission spectra measured for coatings with different $p(O_2)$ values on Borofloat glass.



Specific resistance and visual absorption at $p(O_2)$.



1-2 Interior and exterior view of the new installation door.

CONTACT

Dr. Volker Sittinger

Phone +49 531 2155-512

volker.sittinger@ist.fraunhofer.de