Transparent Conductive Oxides

Inorganic thin film materials for intelligent coatings

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A transparent conductive film is a material that is highly transparent in the range of visible light, and at the same time, electrically conductive. The interest in these transparent conductors can be traced back to the early 20th century when reports of CdO films first appeared. Since then there has been a steadily growing interest in these materials with their unique properties.

It is well known that non-stochiometric and doped films of oxides based on e.g. Tin, Indium, Cadmium, Gallium, Copper and Zinc and their blends exhibit high transmittance and conductivity. Products such as flat panel displays, solar cells [Pict.1], optoelectronic and electronic components and thermally insulating architectural glass have one thing in common: they have to combine the opposing material properties transparency and electrical conductivity [1].

Transparent conductive films can be produced by multi layer coatings based on thin metal films or by a homogeneous coating based on wide band gap semiconductors.

Transparent Conductive Oxides are key components in flat panel displays and solar cells. The main deposition technology used for large area deposition is the Physical Vapor Deposition (PVD) technology. Such “intelligent” films can be produced by using conductive oxides based on n-type TCO’s and p-type TCO’s in well defined layer stacks, which will lead to new applications in the field of transparent electronics and optoelectronics, like transistors, diodes, active sources and detectors.

For many manufacturing companies of TCO films it is the aim to achieve stable film properties for large area coating processes with low film resistance and high transmittance within the visible spectrum range. A lot of efforts were made to develop technologies to produce TCO coatings by reactive sputter technology [2]. With adding oxygen or nitrogen gas into the coating chamber it is possible to produce oxydic or nitridic dielectric layers from metal targets. But all of these reactive sputter coating processes suffer from the fact, that a chemical reaction takes place not only at the produced layer, but at the metal target as well. Additionally a homogeneous gas flow and gas distribution in the coating chamber is necessary to achieve high quality TCO coatings. For several applications the substrate geometry is limiting the gas distribution as well.

This has led more and more to coating machines with highly sophisticated in situ process measurement and gas flow control systems to stabilize the reactive sputter process. Mainly due to quality and cost reasons more and more manufacturing companies were using conductive oxides which are easier to handle than pure metal
targets. For the last three decades Indium Tin Oxide (ITO) has been the most popular n-type TCO material used for layer stacks for these applications. It is well known that ITO is an expensive coating material in the thin film market and for quite some time a substitute that could provide cost savings while provide similar properties was missing. This forced the use of ITO and has kept many companies at the mercy of price fluctuations of the raw material. In addition to this the process controls necessary to have long term production has been an inherent problem.

GfE has discovered a potential solution in the field of n-type TCO’s which would eliminate these process and price issues, and has developed a unique ZnO/Al₂O₃ (AZOY) material that has already been tested and approved for production use. Today ZnO/Al₂O₃ films are commonly used as transparent front contact in solar cells [3] and as film for thermal insulating architectural glass. In combination with CIGS Cu(In,Ga)Se₂ absorber layers solar cells with efficiencies of 18,8% have been obtained [4].

Recently, more and more manufacturing companies have discovered that GfE’s AZOY is not only a good replacement for ITO, but these manufacturers are also enjoying the major advantages of using GfE’s solution (AZOY) namely cost savings and good film properties through stable, more easy to control and reproducible production runs. AZOY can be deposited for instance under 100% Argon atmosphere and is resistant against hydrogen, thus the coating process can be much more easily controlled. The AZOY films have a high stability against heat cycling.

To provide high thermal and electrical conductivity, as well as a high target yield the density of the AZOY is higher than 95% of the theoretical density (TD= 5.62 g/cm²). The material can be deposited by electron beam deposition as well as by DC and MF sputtering and variable RF sputtering.

Films were deposited under 100 % Argon on glass substrates and polymers by DC Magnetron sputtering. The film resistance was measured with 4,3* 10⁴ (Ohm*cm) with a film thickness between 800 and 1000 nm. The refractive index was measured with 1,87 to 2,01 at a wave length of 300 to 550 nm and a transmission of > 90%.

With the development of conductive ceramic target material for the PVD sputter process GfE offers a coating material which already includes the desired layer composition. The use of the non reactive mode offers new possible applications for AZOY.

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Picture 3. Solar Cell
Picture 1: Solar Cells

Picture 2: AZOY target bonded on copper backing plate

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