Deposition of ZnO:Al transparent conductive layers on polymer substrate by magnetron sputtering

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Aluminum doped zinc oxide (ZnO:Al) is an attractive inexpensive material for transparent conductive electrodes and IR reflective coatings. ZnO:Al layers were deposited on 100 μm thick PET (polyethylene terephthalate) film by magnetron sputtering of ZnO/Al_2O_3 2 wt.% planar ceramic target (225x100) mm^2 in Ar/H_2 atmosphere under $(1–5)\cdot 10^{-3}$ Torr pressure in the vacuum chamber. RF (13.56 MHz) and DC power sources were used separately. The PET film was fixed on a rotated water-cooled drum. The substrate surface was cleaned by an ion gun before ZnO deposition.

The investigation shows that properties of ZnO layers depend mainly on the type of power source, power levels applied to the target and concentration of hydrogen in the gas mixture.

ZnO layers must be structured in order to get maximum conductivity. When depositing zinc oxide on glass [1] this goal is achieved both by heating the substrate and by increasing sputtering power. Contrariwise, during the deposition of ZnO layers on the polymer film we observed the opposite trend. For both types of the sources resistivity of ZnO layers decreased while reducing sputtering power until it reached a certain limit. Optimum levels of power were 200 W for RF-source and 100 W for DC-source. Unbalancing of the magnetron allowed additional reducing of ZnO resistivity while working in the optimum range of the power level. A further decrease of power did not lead to resistivity decreasing.

Adding H_2 to the gas mixture initially caused a relatively rapid decrease of resistivity of ZnO layers. The optimum concentrations of hydrogen were about 1 vol. % and (10-12) vol. % for the RF- and DC-sources respectively. Further increasing of hydrogen content led to slow raise of resistivity. It is known [2] that hydrogen incorporated into ZnO can act as a donor. The fact that the optimum concentration of H_2 is much lower when the RF-source is used could probably serve as indirect evidence that in this case the crystal structure of ZnO layers is more perfect.

As a result ZnO layers on the PET film of conductivity 7×10^{-4} **Ω.**cm (RF-source) and 1.3×10^{-3} **Ω.**cm (DC-source) were obtained. The best samples have optical transmittance (82-83)% for λ (360-600) nm and ZnO thickness (350-400) nm. The layers are crack-free and have good adhesion to the substrate.

1. O.Graw, U.Schreiber. Transparent conductive zinc oxide film and production method thereof, EP 2180529 A1, 2010
2. C. van de Walle. Hydrogen as a cause of doping in ZnO, Am.Phys.Soc., Ann. March Meeting, March 12-16, 2001, abstr.#c5.004