**ABSTRACT**

We present the results of our investigations of zinc oxide and titania based TCO thin film deposition on large area substrates. Undoped and doped zinc oxide (i-ZnO, ZnO:Al, ZnO:Ga) as well as doped titania (TiO₂:Nb) thin films were produced on large area substrates of (300 × 300 mm²) by direct current sputtering with high deposition rates using either single planar or tubular targets. The films were deposited dynamically onto glass using a vertical pilot scale in-line sputtering plant. This setup allows a reproducible preparation of the TCO films with excellent homogeneous properties under close to production conditions.

**SPUTTERING PROCESS**

- **Magnetron system**
  - Rotatable magnetron system (Soleris Advanced Coatings)
  - Planar magnetron system (Systec GmbH)
- **Target length**
  - Tubular targets: 780 mm
- **Target material**
  - i-ZnO, tubular target
  - ZnO:Al, Al 2 wt-%, tubular
  - TiO₂:Ga, Ga 3 wt-%, planar
  - TiO₂:Nb, Nb 4 wt-%, tubular
- **Powering**
  - DC sputtering (FMP)
  - Pulse DC sputtering (FMS)
  - Power impact of 9 kW/m.

Rotatable magnetron systems show some benefits compared to planar magnetron systems:
- Higher deposition rates because of higher power density
- Higher stability of process conditions, especially in the reactive mode
- Reduced particle generation during the process
- Higher utilization of material

**PROPERTIES OF TCOs AT FRAUNHOFER FEP**

- **Dopant**
  - 90% Al, 1% Ga, 2% Nb
- **Target**
  - Planar, tubular
- **Dissolution (nm/min)**
  - 40, 135, 100
  - > 225 nm
  - 100, 85, 60
- **Density**
  - 4.65 g/cm³
- **Resistance**
  - 1 x 10⁻³ Ωcm
- **Electrical and Optical Properties of High Deposition Rate Sputtered Zinc Oxide and Titania Based TCOs**

**SUMMARY**

For the cost effective deposition of zinc oxide based TCOs sputtering from oxidic tubular targets in rotatable magnetron arrangements is established. Through a suitable choice of the process parameters i-ZnO can also be deposited in DC mode with high deposition rates under stable process conditions. For ZnO:Al we reached a dynamic deposition rate of more than 225 nm/min at power impacts of more than 30 kW/m². Nb-doped titania films have been deposited in DC mode with high deposition rates using an oxidic tubular target under pilot scale conditions.

**TITANIA BASED TCOs**

- **Deposition at room temperature, thermal annealing at 450°C in vacuum.**
- **DC sputtering with maximum power impact of 16 kW/m.**
  - **Density** Dmax = 55 nm/min, ρmin = 1.34 x 10⁻³ Ωcm.
- **Adjustment of the stoichiometry by variation of the volume flow rate QO₂/(QO₂ + QAr).**
- **Dynamic deposition rates comparable with undoped TiO₂.**
- **Film thickness** 100 … 500 nm on Berolfin® glass.
- **The as-deposited films are X-ray amorphous.**
- **After annealing rutile films show high resistivity, while amorphous films have lowest resistivity.**
- **We observed at 150 nm thin films the lowest resistivity of 8.5 x 10⁻³ Ωcm, deposited at DC power impact of 9 kW/m².**

**ZINC OXIDE BASED TCOs**

- **Intrinsic Zinc Oxide – i-ZnO**
- **AI Doped Zinc Oxide – ZnO:Al**

**ELECTRICAL PROPERTIES OF DOPED ZINC OXIDE**

- **Density of resistivity, carrier concentration and mobility of i-ZnO doped with Ga, Al and Nb, after in-situ thermal annealing methods.**

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