Roll to Roll Sputtering Machine with All Rotary Cathodes And Easy Access to Cathode And Substrate Section

G. Mahnke, E. Lietke, H. Rost, H. Buchberger, T. Bergmann, H. Stoll, and G. Loebig
Schmid Vacuum Technology GmbH, Zeche Gustav 8, 63791 Karlstein, Germany
Outline

- Introduction to Roll to Roll sputter web coaters
- Machine concept
- Process for touch panel applications
- Process for window film applications
- Conclusions and outlook
- Disclaimer
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INTRODUCTION
Roll to Roll Web Coaters

- First application of roll to roll vacuum web coating was the thermal evaporation of Aluminum in the 50’s
- Major stake of all web coating is still thermal evaporation of Aluminum for packaging and other applications
- Sputtering allows to deposit more demanding materials with better layer quality e.g. Transparent Conductive Oxides (TCO), Semiconductor Oxides (SiO$_2$) or Metal Oxides (TiO$_2$ etc.)
- Thermal evaporation or e-beam evaporation can be done with dynamic deposition rates > 50,000 nm*m/Min while sputter web coating is limited to a few 100 nm*m/Min deposition rate
- Coating speed is in the range of m/Min rather than m/sec compared to evaporation machines
Roll to Roll Sputter Web Coaters

- The requirement for TCO coatings made of ITO pushed the demand for sputter web coaters in the recent years
- Nowadays process used for low emissivity coatings and solar control windows are transferred to flexible substrates increasing the demand for sputter web coaters
- The development of flexible electronics and smaller structures for printed circuit boards drive the demand for sputtered layers such as Copper
CONCEPT
System Outline

- Winding System
- Vacuum chamber
- Cathode system
- Temperature control system
- Observation window
- Sputter power supplies
Substrate and Cathode Section

- Masking around substrate and cathodes need to be exchanged for maintenance
- Easy access reduces maintenance time and lowers cost
- The system has two independent trolleys
- Cathodes are mounted on one trolley
- Substrates and winding system are located on the other Trolley
- Simultaneous access to both of them is possible
XL Coating Drum for Complex Layers

- System is built for in a „600“ series for up to 680 mm coating width and a „1600“ series for up to 1670 mm coating width
- The „1600“ series allows to cut up to three 500 mm slices from the end product
- Coating drum diameter is 1400 mm allowing to arrange five pairs of rotary cathodes for the coating of complex layer stacks
- Cathode arrangement allows operation as MF twin rotatable or independent control using DC power supply
- Coating drum is temperature controlled between -15° C and +80° C
Cathode Assembly WF- Application

Trolley with Cathode assembly. The ten cathodes are arranged around the coating drum.
Trolley with Cathode assembly. The ten cathodes are arranged around the coating drum.
Winding System

- Winding system has five driven rolls
  - Unwinder
  - Coating drum
  - Rewinder
  - Two tension rolls allowing to independently control tension at unwinder, coating drum and rewinder

- Two spreader rolls (before and after coating drum) enable winding and rewinding substrates

- Coating is possible during forward and backward winding

- Maximum winding speed is 20 m/Min
Other Features

- Substrate can be pre heated for improved outgassing before coating
- Plasma pretreatment cathode is available for substrate treatment for improved adhesion
- Inline Eddy current measurement system for 0.5 to 5 Ohm/Square or 5 to 500 Ohm/Square are available
- Inline optical transmission and reflection measurement „Optoplex Web“ can be used for inline evaluation of optical properties of coated layers
- Magnetically levitated TMP pumps for fast pump down and high process stability
- Meissner traps with a surface of 4 m² effectively remove moisture outgassing from the substrate
PROCESS RESULTS
Touch Panel Applications

- Typical layer stack for touch panel application uses Indium Tin Oxide (ITO) transparent conductive oxide coating.
- Layers of SiO$_2$ and Nb$_2$O$_5$ are used to obtain neutral color ("invisible ITO").
- ITO layer needs to be crystalline for high conductivity at low layer thickness.
- Target composition 95% In$_2$O$_3$ and 5% SnO$_2$ is best compromise between conductivity and crystallinity.
Ar Pumping Speed

High effective pumping speed allows stable control of reactive processes due to narrow hysteresis. Additional cold traps for pumping water evaporating from the substrate. Two TMPs per pair of cathodes.
Layer stack shows +/- 2.2 % resistance uniformity after annealing. Coated at 2 m/Min, T >= 90 %
Process Results – MF vs. Bipolar-Pulsed

MF-AC Wave Form

- Fully reactive sputtering of non conducting layers in DC is not suitable since sputtering anodes will be coated.
- A pair of cathodes powered with alternating current is used instead.
- Current developments in power supply technology enable exchange of Mid-Frequency AF-Powersupplies by Bipolar pulsed power supplies.
- Bipolar pulsed power supplies have several advantages.
Advantages of Bipolar Pulsed PS

- Frequency of the power supply can be set by software. No manual change of matching network required.
- Powersupply can easily switch from Bipolar pulsed operation to DC power increasing process flexibility
- Arc detection and management can be much faster compared to MF-AC PS
- Powersupplies are more compact at the same power rating
- MF-AC distributes power symmetrically on both targets, Bipolar pulsing allows to run different duty cycle on different targets
- First experiments run depositing SiO$_2$ in Voltage control mode
Bipolar Pulsed – Hysteresis Loop for Si

Hysteresis loop for bipolar pulsed PS is more narrow indicating more stable process control. Transition to oxide mode occurs for the same O2 flow. No significant change with pulsing frequency.
Window Film

- Single low E-stack include one conducting layer with high transparency between two dielectric layers
- Depending on application and budget various dielectric layers can be coated, e.g., AZO, Nb$_2$O$_5$, TiO$_2$, SnO$_2$ and many others
- The active layer is typically a thin metal, preferably silver or a transparent conductive oxide

Nb$_2$O$_5$ Target Structure
Window Film – Thin AZO Layers

Reflection Change for 45 nm AZO with different ArO2 flow
Window Film – Change of \( T \) with \( O_2 \)

Transmission Spectra for 45 nm AZO with various \( \text{ArO}_2 \) flow

- \( 0 \) SCCM
- \( 25 \) SCCM
- \( 50 \) SCCM
- \( 100 \) SCCM
- \( 200 \) SCCM

\( T \) [%] vs. Wavelength [nm]
Window Film Cu Uniformity

Sheet resistance uniformity for Copper films better +/- 4%
High Deposition Rates – High Productivity

- SiO$_2$ deposited with up to 95 nm*m/Min from sprayed Si target on one pair of cathodes using MF-AC power
- AZO deposited with up to 90 nm*m/Min from single target in DC
- Nb$_2$O$_5$ deposited with up to 60 nm*m/Min in MF-AC
- Cu deposited at 75 nm*m/Min @ 15 kW MF and R<0.4 Ohm/square, higher power available
CONCLUSIONS AND OUTLOOK
Conclusions and Outlook

- Roll to Roll sputtering system with up to 1680 mm coating width
- Easy maintenance due to independent trolley for cathodes and substrate
- Rotary cathodes for high process stability and target utilization
- High pumping capacity for high productivity and good process stability
- Layer stack for touch panel with good ITO Rs and uniformity
- Coating materials for window film such as AZO, SnO$_2$ are available
- Study of materials for window film applications and bipolar pulsed power ongoing
- Experiments on TiO$_2$ and Ag are under preparation
Thank you very much for your attention
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