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Transparent and low emissivity coatings based on aluminum doped zinc oxide

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Making transparent and conductive interconnects on surfaces is a must for a large number of applications (solar cells, architectural and automotive windows, liquid crystal displays and light emitting diodes). After initial investigations involving toxic Cd and Pb, the search for optimal materials has led to indium tin oxide (ITO). Since the abundance of indium is close to that of silver and the consumption is steadily increasing, an extensive worldwide-research for alternative materials is going on for more than one decade. Zinc is 1000 times more abundant than indium and aluminum is the most abundant metal. Zinc oxide is transparent and easy to produce but doping with metals is necessary to make it conductive with Al as one of the best choices. Physical vapor deposition (molecular beam epitaxy, pulsed laser deposition or magnetron sputtering), chemical vapor deposition (at high-temperature, metal organic or atomic layer) and chemical (spin coated or solution process) methods have been investigated as candidates to deposit aluminum doped ZnO (AZO). When ITO was developed the magnetron sputtering turned out to be one of the most efficient methods for deposition. The main reason is that plasma provides energetic species that can dissociate the oxygen and assist the growth of crystalline films at high deposition rate and large surface coverage. Nowadays, large substrates are coated with ITO in scanning (more than 15 m^2 glass) or roll-to-roll (heat sensitive polymers) configurations. Consequently, the easiest way to reduce the cost will be to replace the ITO with a cheaper material. The resistivity of ITO used now is 10^{-4} Ωcm, for large substrates, while that of ZnO doped with aluminum or gallium is five times higher, with a record-low value of 2×10^{-4} Ωcm, only for very small areas near the edge of the substrate. This effect was observed since ‘98 and has been associated with energetic negative ions of oxygen. The aim of this work is to investigate the plasma parameters during magnetron sputtering of AZO and correlated it with the film properties (resistivity, mobility, carrier concentration).

The AZO films are deposited in a large sputtering chamber that can accommodate 8 samples (1×6 cm) on a rotating stage. The sputtering cathode was operated in RF (13.56 MHz) using a 2 inch target (Kurt Lesker) of ZnO doped with 2% of aluminum. Probes, optical emission spectroscopy and mass spectrometry are available for diagnostics. The sheet resistance, the optical transmittance and the film thickness were measured with a spatial resolution of 1 mm along the 6 cm long sample. Smaller samples of 3×3 mm were along the large sample to measure the XRD pattern, the carrier concentration and charge mobility.