Advanced TCO Sputtering for Display Technology

Playing a critical role in the flat panel industry, the transparent conductive oxide (TCO) layer is a key enabling technology in both display and touch screen applications. With the industry currently experiencing significant growth driven by increasing demand and intense downward price pressure, the quality and cost of the TCO layer is becoming increasingly important to optimize and control. To address these challenges, General Plasma has developed the Moving Magnet Planar Magnetron (MMPM™) thin film sputtering solution by which film quality is improved using an advanced magnetic design that reduce film bulk resistivity. Target material costs are also reduced by the use of a patented 2-axes motion profile of magnet array that improves target material utilization to above 55%. These are significant improvements given that conventional sputtering is limited to film conductivity that is half that achievable with the MMPM™ and target material utilization is typically less than 35% with traditional planar magnetron sputtering components.

The predominant TCO coating material for display technologies is indium tin oxide (ITO). The unique properties that make it attractive to the industry include its low bulk resistivity and high optical transparency. Magnetron sputtering is used to deposit precise thin layers of ITO. While ITO's advantages are compelling, one drawback is a high target material cost. For instance a 2m x 125mm x 8 mm (L x W x T) sputtering target can cost $11,500 (USD) and conventional planar magnetron cathodes have target utilization efficiencies no greater than 35%. Compromise in magnetic field strength is often required on conventional planar magnetron in order to improve poor target utilization which leads to lower quality film

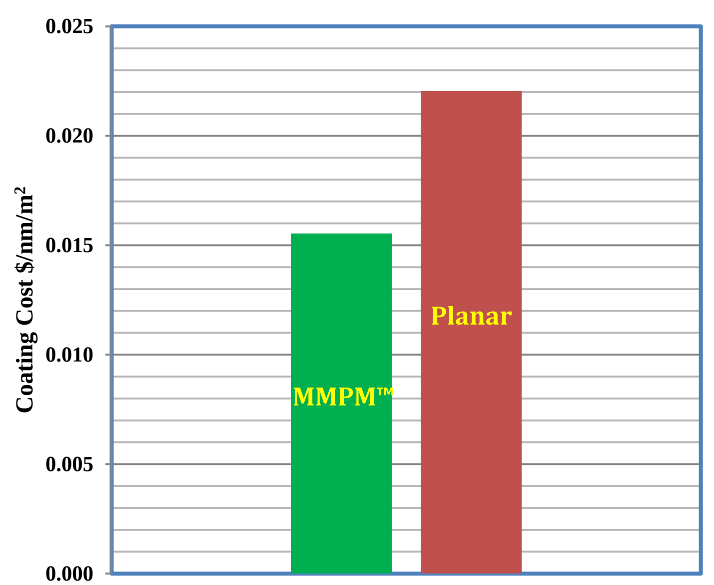

Figure 1. Cost comparison between MMPM™ and Planar Magnetron

properties. In contrast, the MMPM™ increases target utilization to greater than 55% while maintaining an ultra-strength magnetic field of >1100G at target surface to enable superior films.

MMPM™ *Performance*

Figure 1. ITO Target tile from MMPM™ Planar Magnetron.

MMPM™ incorporates an advanced magnetic design that improves the conductivity and quality of ITO layers. The magnetic design has two primary features: An intense, narrow racetrack and an exceptionally strong magnetic field. The narrow race track, when moving over the target surface, achieves excellent target utilization. The rastering technique has a proprietary motion profile that achieves target utilization in excess of 55%. An eroded ITO target tile profile is shown in Figure 2.

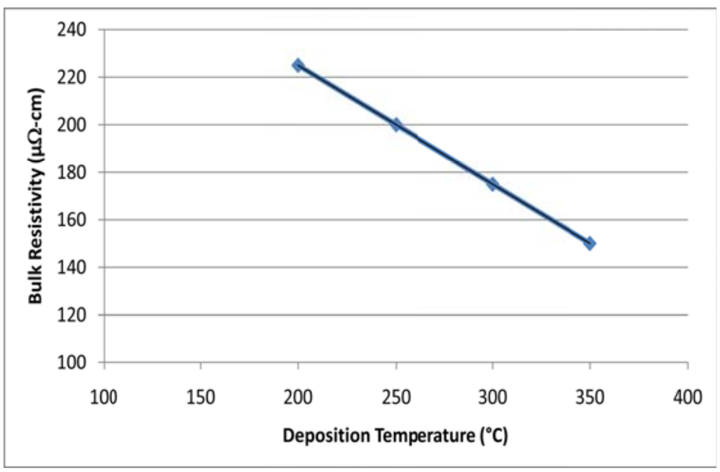

Figure 3. ITO Bulk Resistivity vs Temperature with MMPM™. All films were deposited to 90 nm thickness and measured for sheet resistance.

The MMPM™ strong magnetic field results in significantly reduced operating sputtering voltage. A typical planar magnetron has a magnetic field strength at the target surface of about 300-400 gauss. This results in an operating voltage of 350 volts. The MMPM™'s high magnetic field, in excess of 1100 gauss, allows an operating voltage of only 275 volts. *Ishibashi et. al.* have shown that a reduction of 75 volts in sputter target voltage for ITO results in up to a factor of 2x lower bulk resistivity *(1)*. The strong magnetic field also produces a beneficial high flux of energetic ions to the growing thin film *(2)*. In figure 3 we show the results of the measured bulk resistivity for a set of 90 nm films deposited by a MMPM™ on 1600 mm substrates between 200 and 350 °C. The magnetron was operated at 3 mTorr of pressure, with clamped non-bonded targets and operated at 2.4 W/cm^2 power density. The decrease in bulk resistivity with temperature is consistent with published data by *Ishibashi (1)*.

Importantly, the optical performance of the coating is not compromised by the MMPM™'s improved conductivity. In *Figure 4* we show the transparency for a 90 nm ITO coating deposited at 200°C. The high transparency of the MMPM™ deposited ITO means the MMPM™ delivers the performance required for display applications. The uniformity of the MMPM™ is also exceptional. On a 1600 mm substrate the uniformity is ± 3.5% as shown in figure 5. A 1600 mm width production coater equipped with the MMPM™ technology demonstrates yields in excess of 95%. This is well within the tolerance level required for both capacitive and resistive display applications.

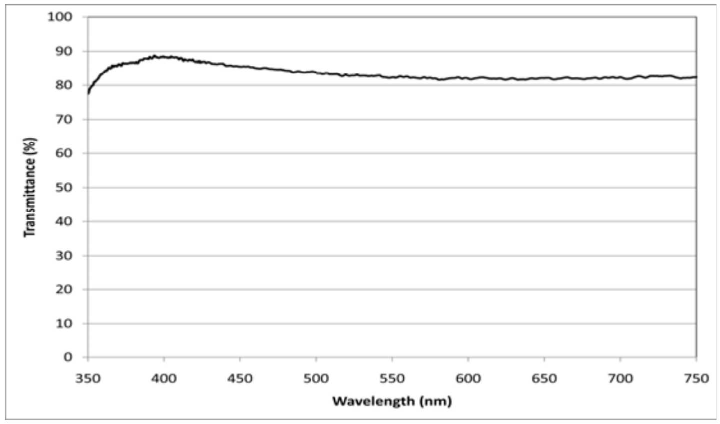

Figure 4. Transparency of 90 nm ITO coating deposited at 200 °C.

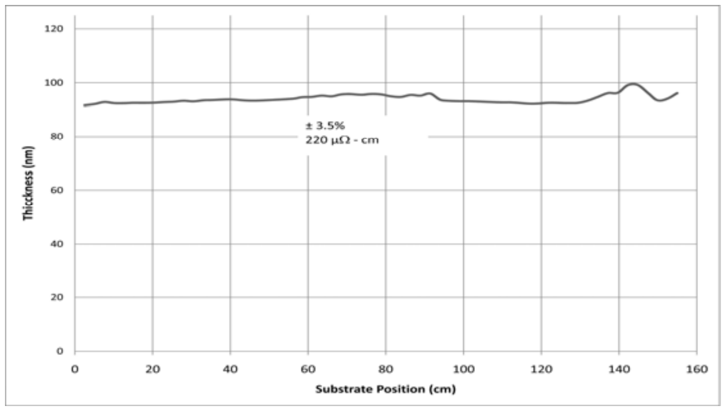

Figure 5. Uniformity of 90 nm ITO film with a bulk resistivity of 220 µΩ-cm.

MMPM™ Value Proposition

The MMPM™ provides a rapid ROI over a conventional planar magnetron. We have calculated the ROI period of the MMPM™ with the following assumptions:

1. Planar Target Utilization of 35%
2. MMPM™ Target Utilization of 55%
3. ITO Target Cost of $0.00597/mm^3$
4. Coater operating time of 160 hrs/week
5. 30 nm film of ITO @ 1 m/min
6. 1 hour for target changes at a labor rate $35/hour
7. Clamped Targets (non-bonded)

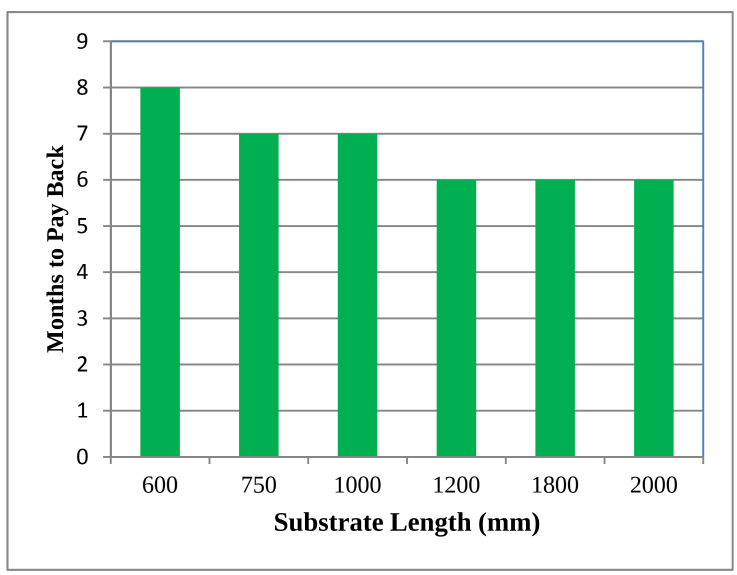

Figure 6. ROI periods for different substrate lengths.

Given these assumptions, the savings derived from higher target utilization, lower energy usage and greater uniformity of the MMPM™ result in a ROI period over planar magnetron sputtering for the most common substrate widths as shown in *Figure 6*.

In all cases the MMPM™ technology is paid back within less than one year. Considering that the MMPM™ can deliver better film performance and quality, this ROI time may be realistically shorter in practice.

Summary

The display market utilizing ITO thin films is growing and this trend is predicted to continue at least through 2015. Between 2009 and 2013 Displaybank has ITO film capacity expanding by an average of 19.8% annually, production growing by an average 23.6% annually, and the ITO market in dollars growing by 21.6% annually. In spite of this tremendous growth manufacturers are faced with increased competition and quality requirements. General Plasma's MMPM™ addresses both the cost and quality challenges of ITO deposition. The MMPM™ is ideally suited for retrofits of existing coaters as well as new installations.

Figure 7. MMPM™ 2 meter cathode and flange assembly.

References

(1). Ishibashi, Higuchi, Ota and Nakamura; "Low resistivity indium-tin oxide transparent conductive films. Effect of sputtering voltage on electrical property of films", J. Vac. Sci. Technol.A., Vol. 8, No. 3, 1990.

(2). Window and Savvides; "Charged particle fluxes from planar magnetron sputtering sources", J. Vac. Sci. Technol. A., Vol. 4, No. 2, 1986.

(3). Displaybank - www.displaybank.com

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