GENERAL PLASMA INC.™

White Paper

Advanced TCO Sputtering for Display Technology

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Playing a critical role in the flat panel industry, the transparent conductive oxide (TCO) layer is a key enabling technology in both displays and touch screens. With the industry currently experiencing tremendous 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 (Mov-Mag™) thin film sputtering solution by which film quality is improved using an advanced magnetic design that increases film conductivity (at lower thickness). Target material costs are also reduced by the use of a magnet array oscillation technique (patent pending) that increases 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 Mov-Mag™ 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 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 two meter long, 8 mm thick sputtering target can cost $11,500 (USD) and conventional magnetron cathodes have target utilization efficiencies no greater than 35%. This means that, for the example above, only $4,000 of material is used from the target leaving the remaining $7,500 of material to be recycled at a loss. In contrast, the Mov-Mag™ increases target utilization to greater than 55%. For our example, this reduces the target material loss from $7,500 to $5175/target. By normalizing these numbers to deposited film thickness the material cost per nm of coating on each square meter of substrate can be calculated as shown in Figure 1 for both conventional planar magnetrons and Mov-Mag™ magnetrons.

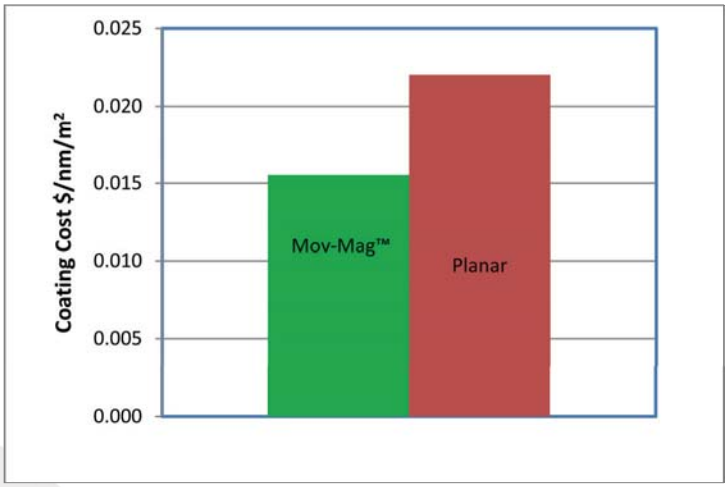
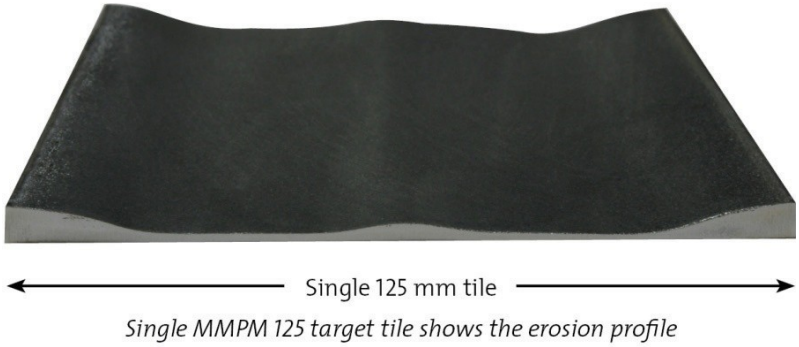


Figure 1. Cost comparison for Planar Magnetron & Mov-Mag™.

Mov-Mag™ Performance

General Plasma's Mov-Mag™ 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 rastered 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.



Single MMPM 125 target tile shows the erosion profile

Figure 2. ITO Target tile from Mov-Mag™ Planar Magnetron.

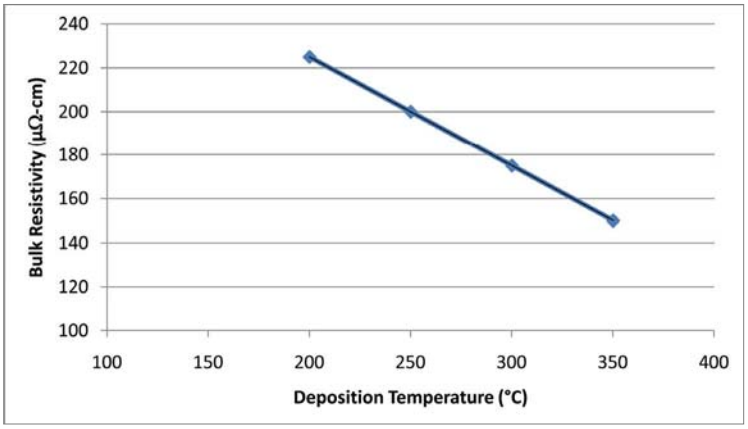


Figure 3. ITO Bulk Resistivity for Mov-Mag™ sputtering process. Temperature aids the performance of the ITO conductivity. All films deposited to 90 nm thickness and bulk resistivity measured by 4 point probe.

The Mov-Mag™'s 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 400 gauss. This results in an operating voltage of 350 volts. The Mov-Mag™'s high magnetic field, in excess of 1000 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 two lower bulk resistivity (1). The strong magnetic field also produces a beneficial high flux of low energy 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 Mov-Mag™ on 1600 mm substrates between 200 and 350 °C. The magnetron was operated at 3 millitorr of pressure, with clamped non-bonded targets (as shown in figure 2) 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 Mov-Mag™'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 Mov-Mag™ deposited ITO means the Mov-Mag™ delivers the performance required for display applications. The uniformity of the Mov-Mag™ 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 Mov-Mag™ technology demonstrates yields in excess of 95%. This is well within the tolerance level required for both capacitive and resistive display applications.

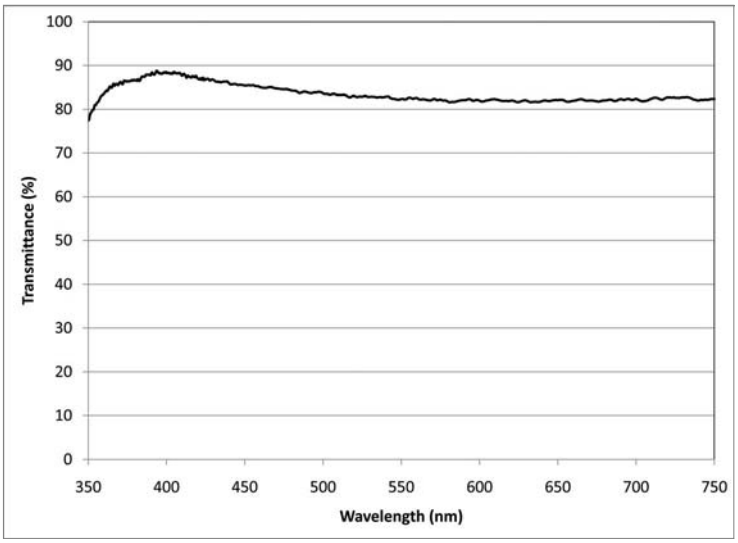


Figure 4. Transparency of 90 nm ITO coating deposited at 200 °C.

Mov-Mag™ Value Proposition

The Mov-Mag™ provides a rapid pay back over a traditional planar magnetron. We have calculated the pay back period of the Mov-Mag™ with the following assumptions:

1. Planar Target Utilization of 35%
2. Mov-Mag™ 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)

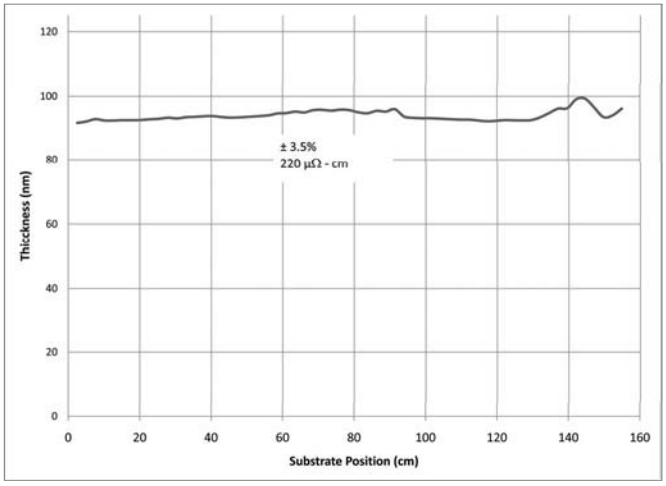


Figure 5. Uniformity of 90 nm ITO film with a bulk resistivity of 220 µΩ-cm.

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

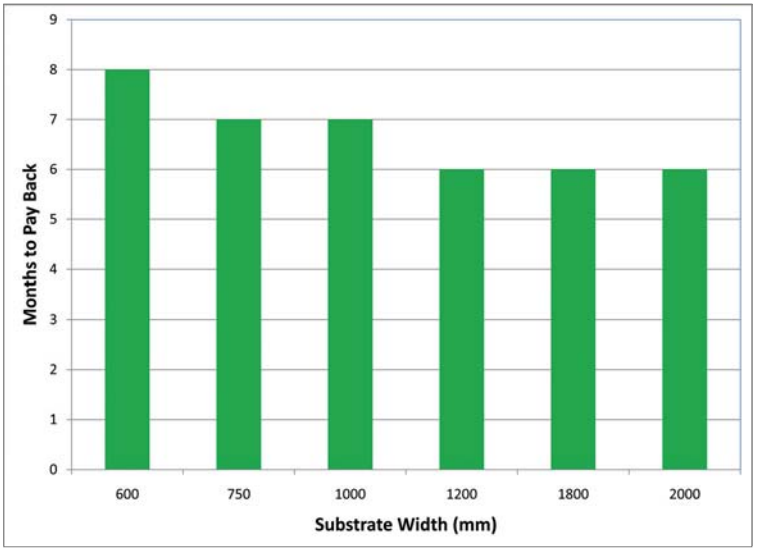


Figure 6. Payback periods for different substrate widths. Assumptions are described in the text.

In all cases the Mov-Mag™ technology is paid back inside one year. Considering that the Mov-Mag™ can deliver better film performance and quality, this payback time may be realistically shorter in practice.

Summary

The market for display products utilizing ITO thin films is growing and this trend is predicted to continue at least through 2013. 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 Mov-Mag™ addresses both the cost and quality challenges of ITO deposition. The Mov-Mag™ is ideally suited for retrofits of existing coaters as well as new installations. Contact General Plasma for more information.

Figure 7. Mov-Mag™ 2 meter cathode and flange assembly.

References

(1). Ishibashi, Higuchi, Ota and Nakamura; "Low resistivity indium-tin ocide 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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