ABSTRACT

For glass coaters, the transmission cable which carries current from the AC power supply to the cathode is an important part of the overall power delivery system for the deposition chamber. This cable requires careful design consideration to optimize its performance and therefore the overall process result.

The ideal transmission cable exhibits little parasitic capacitance between individual internal cable conductors and also between the conductors and the cable shielding. However, transmission cables possessing high parasitic capacitance are becoming increasingly common in the glass coating industry. Cables designed for increased flexibility and reduced costs often provide minimal spacing between the shielding and current carrying conductors. The consequence of this tight spacing and the resulting high parasitic capacitance is the potential for electrical coupling through the capacitance causing undesirable ground loops and common-mode currents. Each of these can detrimentally affect power delivery to the process and/or the performance of the film deposition process.

In this paper, we review the potential issues that may result from cable induced parasitics and present supporting data showing the performance difference between transmission cables with small and large parasitic capacitances. Solutions are proposed to address a highly capacitive cable design in order to improve the quality of delivered power and therefore the overall performance of large area coating systems.

INTRODUCTION

Although the importance of the power transmission cable is sometimes overlooked, it plays a significant role in the coating system. The main idea is that there is some amount of power that must be carried from the system power supply to the system coating chamber. It stands to reason that the efficiency of this power transfer will be dependent on the quality of the transmission cable used. The quality of the transmission cable can be judged by its parasitic element characteristics. Generally, the lower the level of parasitic elements within a cable, the higher quality the cable is considered to be. This paper discusses some of the subtleties of transmission cables that are sometimes overlooked, specifically parasitic elements within the cable and their effects on system performance.

First, a discussion of why a low inductance cable is important in low-frequency applications is given. Two examples of low inductance cable are provided. Following this, a discussion of additional parasitic elements in the transmission cable and how they fit into the system as a whole is given. The undesired current paths which may result from these additional parasitic elements and the implications thereof are presented. Experimental results are given which illustrate the effect these parasitic elements have on the magnitude of the system ground current. Finally, methods are shown to reduce the amount of parasitic capacitance to ground of the transmission cable.

THEORY

A low inductance cable design is important in low-frequency applications for several reasons. It is important for the efficiency of power transfer from the power supply to the chamber, for the power supply’s ability to detect and suppress arcs at the chamber, and in some cases may influence the stability of the power delivered to the process. Figure 1 shows a simplified schematic diagram of the system. The power source is \( V_S \) and the process within the coating chamber is designated as \( Z_p \). \( R \) and \( X_L \) are the transmission cable parasitic resistance and inductance, respectively.

Figure 2 shows how the reactive impedance of the transmission cable increases linearly through the low-frequency range. Example cables of 500nH and 1uH are shown. The importance of this is in low-frequency operation there may be a significant impedance between the power supply and the process chamber, depending on the inductance of the cable used.
Another way to view the importance of the cable inductance is shown in Figure 3. This shows that for a fixed process supply voltage, operating frequency, process impedance, and cable resistance, the power delivered to the process falls off with increasing cable inductance. In the example of Figure 3, the delivered power falls off from 40kW to around 36kW, or 10%, over the range of cable inductance. “Good Cable” and “Poor Cable” here are simply referring to use in low-frequency applications where an example of poor (highly inductive) cable might be loosely routed locomotive cable.

Although the two transmission cables shown above are both good solutions for low-frequency applications in terms of their low inductance, the differences in their physical construction will give rise to differences in each one’s characteristic parasitic capacitances. To explain these additional parasitics, the system will be examined as whole and then where these parasitics fit in to the big picture will be illustrated. Figure 6 shows a system diagram.

FIGURE 6: SYSTEM DIAGRAM

Figure 6 shows the process power supply and the transmission cable which carries the power to the process chamber. Within the process chamber are two magnetrons configured for a dual
magnetron sputtering process and a glass substrate with an applied metal layer. The substrate is upon rollers which are connected to the chamber wall. Note the transmission cable is shielded and the shield is connected to ground at both the power supply and the process chamber. This ground is drawn into the schematic representation as well.

Figure 7 illustrates how the additional parasitic elements of the transmission cable exhibit themselves in the system.

There is parasitic capacitance between the two power conductors and this is represented by $X_c'$ in the schematic representation. There is also parasitic capacitance between the power conductors to the grounded shield. This is represented in the schematic representation as $X_c$ and is also shown in the system diagram. Because the two cables in the examples above exhibit largely different values in terms of the capacitance from the power conductors to the shield, it is this parasitic element that is chosen to be the focus of this document.

Figure 8 shows the desired AC current path in the system.

Figure 9 suggests the possibility of current being capacitively coupled to ground through the conductive coating on the substrate and through the rollers to chamber ground. The circuit is completed by the capacitive coupling through the cable shield to the power conductors caused by the parasitic ground capacitance in the cable. There are a multitude of possible capacitively coupled current paths including but not limited to current coupling directly to the chamber wall instead of to the substrate, and current flowing along the grounded cable shield and back to the power supply. The magnitude of the undesired current will be dependent upon the magnitude of the parasitic ground capacitance as well as the frequency of the coupled signal. For example, RF signals generated by mechanisms within the sputtering process will be coupled to ground with greater magnitude than other signals may be.

So what are the possible effects of these undesired current paths? One implication is defects at the edge of the substrate caused by arcing due to undesired current flow along the coated substrate. Another implication is ground currents causing ground potential EMI which can interfere with equipment in or on the process chamber or process power supply.

**EXPERIMENTAL SETUP AND RESULTS**

The experimental setup consisted of 20 meter pairs of the low inductance cables routed between a 120kW low-frequency AC power source and a vacuum chamber utilizing two 1.1 meter by 0.3 meter planar aluminum targets. For each case the cable shield was terminated to ground at the power source chassis on one end and the vacuum chamber chassis at the other end. An AC current probe was placed over the ground termination at the chamber side to obtain the ground current measurement. Table 1 shows the results of the experiment comparing the two styles of low inductance cables presented above.
The system using the twisted pair array cable exhibits significantly larger ground currents than does the system with RG8 array cable. This is attributed to the larger ground capacitance characteristic inherent in the twisted pair design.

There are methods to reduce the parasitic capacitance to ground of the transmission cable. The two methods presented below involve increasing the distance between the power conductors and shield thereby reducing the effective capacitance. Figure 10 illustrates one method of doing this.

The idea behind the method shown in Figure 10 is to change the thickness and material of the cable inner jacket which separates the power conductors and the grounded shield. Another method to reduce the parasitic ground capacitance is shown in Figure 11.

The method in Figure 11 involves shielding the multiple twisted pair cable in 1.5" flexible aluminum conduit. The conduit becomes the grounded shield and the inner braid is left unconnected. This increases the distance from the conductors to the cable shield and effectively lowers the parasitic ground capacitance.

Table 2 contains the same data as in Table 1 except that a column is added (center) for the twisted pair cable sleeved in an aluminum conduit shield. It is shown that this method can significantly reduce the magnitude of current on the system ground.

**CONCLUSION**

The power transmission cable is an important part of the overall system. In low-frequency applications, a low-inductance cable can be essential for process success. Of two low inductance solutions presented, one has different characteristics than the other. The differences may exhibit themselves in the magnitude of ground currents present on the system. This is a subtle aspect of the system and is often overlooked. Modification of cable construction can change the characteristics of the cable and influence the magnitude of ground currents present on the system.
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REFERENCES


