Understanding and Optimizing Static Deposition Processes for TFT Manufacturing

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FPD manufacturing grew out of semiconductor technology, and as such, its methods have had the tendency to follow those used for semiconductors. Specifically, FPD manufacturing often involves "batch" or "cluster" type coaters, which utilize static deposition. However, as FPD substrate sizes increase, it's easy to assume that lessons from other adjacent markets could be adapted to improve the build process. The architectural glass industry may hold particular appeal in this regard because of its highly developed techniques for large-area coating. However, it's important to keep in mind the unique requirements of FPD devices such as TFTs (thin-film transistors). It's true that FPD can take advantage of many architectural glass coating methods, but certain techniques that are used with success for architectural glass coating are completely inappropriate for TFT manufacturing.

This paper compares static deposition, which is the standard technique for TFT manufacturing, with dynamic deposition, which is commonly used in architectural glass coating. This discussion underscores issues that are critical to successful TFT fabrication in order to identify opportunities for process optimization.

Static Deposition: Reduced Particle Generation

Why does the FPD TFT industry utilize a static deposition process? It is mainly due to the high material content of the resultant display, the higher technology associated with TFTs, and the corresponding importance of high yield.

Compared to TFT manufacturing, glass coating has a relatively high tolerance for particles, which often cause film defects. Because of this high tolerance, architectural glass has adopted a "dynamic" process, where the substrate moves continuously in front of the cathodes during deposition. During dynamic deposition, the giant carriers that move the substrate in front of the cathodes generate a significant number of particles due to vibration and contact with the guide.

However, TFTs, like semiconductors, are extremely vulnerable to particle contamination, which can devastate process yield and throughput. Therefore, dynamic deposition's high level of particle generation eliminates it as a viable method for TFT manufacturing. Instead, TFT manufacturing must use a static deposition method, in which the substrate remains "parked" in front of the cathodes. There is no substrate movement during deposition, and it is inherently a much more controlled environment. Therefore, fewer particles are created. This immediately impacts yield by eliminating a significant cause of film defects.

Static Strategies: Optimizing Your Manufacturing Operation

Although static systems are considered the norm for TFT manufacturing, it is still advantageous to study certain benefits that are inherent to dynamic systems. This information helps identify opportunities to optimize your static system with strategies such as the use of higher-technology, higher-reliability equipment in order to compensate for the static method's inherent vulnerabilities.

Film Quality

In dynamic systems, each cathode creates a different layer of sputtered material. If a defect such as a pinhole appears in one layer, it is possible that the subsequent layers may "repair" it by covering it up. In a static system, however, there is only one layer, so a pinhole in the substrate coating causes irrevocable damage. Because pinholes can be caused by arcs, the benefits of a strong arc-management strategy have a much greater impact on the overall success of a static system than that of a dynamic system.

Preventing Arc Damage

Your arc-management strategy should include a highly responsive and capable power supply, a short power supply-to-cathode cable length, and high cable quality.

Power Supply Response—Choose a power supply with highly developed arc-management technology. A high-quality power supply detects arcs quickly. The time between arc detection and response should be nearly instantaneous. The power supply should immediately remove energy from the arc, turning off just long enough to quench it completely. It must then turn power back on rapidly so that deposition can continue with minimal interruption. Additionally, the ability to vary the power supply's arc management features allows further process enhancement. The power supplies in your process should feature effective, easy-to-adjust arc management that is engineered with data from real-world manufacturing conditions.

Power Supply Capability—Even with the best power supply featuring top-notch arc management, some energy gets through before the arc is extinguished. The amount of energy that is provided to an arc depends on your power supply's capabilities as well as the energy stored within your cable (see *Cable Quality and Length* below). Delivered arc energy is proportional to the process power. As the industry moves toward higher and higher power levels, delivered arc energy therefore becomes even more critical because the aggregate energy delivered during an arc event can become too great for the process to tolerate.

Power supplies must have minimal stored energy (expressed as mJ per kW) after the turn-off following arc detection. A power supply with lower stored energy provides less energy to the arc before it is extinguished. Therefore, the arc causes less damage. For these reasons, it is important to choose power supplies with the lowest stored energy available, such as Pinnacle® power supplies, which store less than 2 mJ per 1 kW of output, and the Summit® power supplies, which deliver less than 1 mJ per 1 kW.

Cable Quality and Length—Energy is stored inductively in cabling, and cables have a specific amount of inductance per meter. Decreasing cable length and using a low-inductance cable are two measures that can reduce the stored energy in the power supply-cable-cathode system. Therefore, use the shortest, lowest-inductance cable possible between the power supply and cathode.

Process Productivity and Uptime

In a dynamic system, if a cathode goes down due to an equipment failure, manufacturing can continue, although at a slower rate. For example, in a system with four cathodes, such as the one shown in Figure 1, the substrate is coated with four individual layers of the same material, one per cathode, as it passes through. If one cathode goes down, the remaining three cathodes lay down three layers instead of four. By slowing down the speed of the substrate as it passes through the system, the process can compensate for the "missing" layer by thickening those that remain. As the substrate moves, the remaining cathodes "take up the slack" caused by the failure, and ultimately, although productivity is negatively affected by the manufacturing slowdown, the uniformity of the final product does not change significantly.

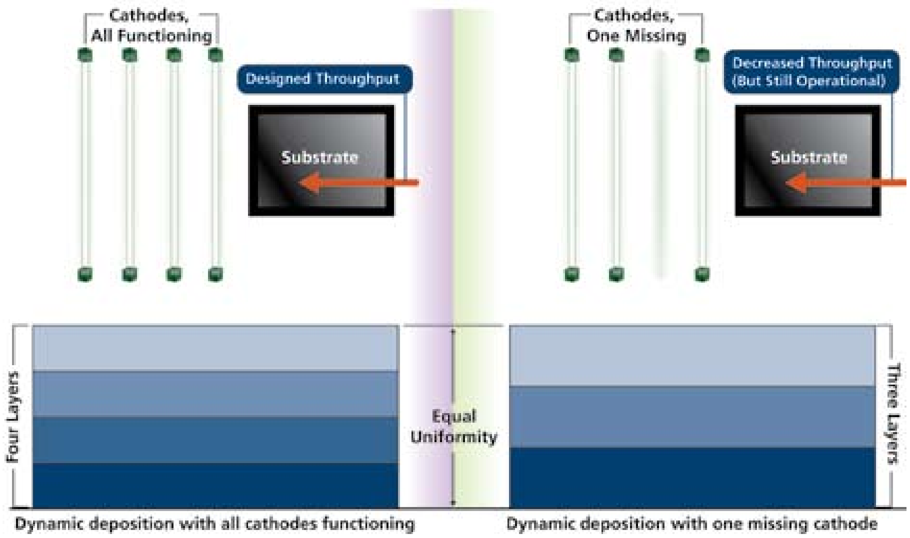

Figure 1. Dynamic system with one missing cathode—the system runs more slowly and creates three layers instead of four, but maintains overall uniformity. Therefore, production can continue, although at a slower rate

In dynamic deposition, each cathode corresponds to a specific layer over the entire surface of the substrate. In contrast, during static deposition, each cathode corresponds to a specific area of the substrate.

On the other hand, the failure of even one cathode during static deposition brings the entire system to a halt. Productivity is not just slowed down; it is immediately reduced to zero. Because the substrate remains stationary, only one layer is created during static deposition, with each cathode corresponding to a specific area of the substrate. When a cathode goes down, the corresponding area receives significantly less material, creating a large valley in the film (Figure 2). Production must be shut down completely until the cathode is restored. In contrast, during dynamic deposition, each cathode corresponds to a specific layer over the entire surface of the substrate, and the tool can compensate for the effects of a downed cathode.

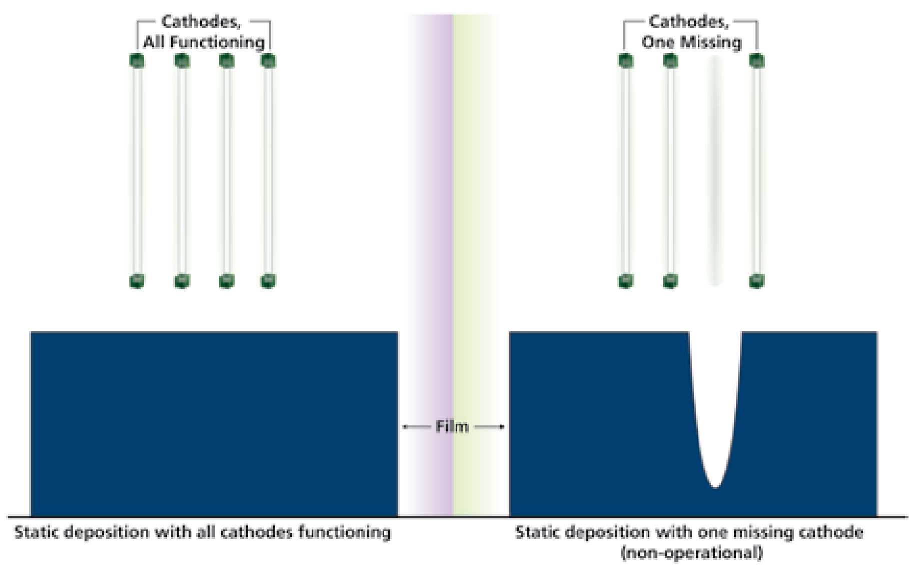

Figure 2. Static system with one missing cathode—continued operation creates a large valley in the film. Therefore, production must be shut down completely for repair

Maintaining High Productivity

The catastrophic effect of cathode failure in a static system increases the importance of equipment reliability. This, as well as the ability to repair or replace your equipment with speed and ease, is key to maintaining a static system's productivity and product quality. It is critical to choose power supplies with proven high reliability, which minimizes the chance that a cathode will go down due to power supply failure. In the event that a repair is needed, power supplies that are designed for easy access, service, and replacement can significantly minimize downtime. Also, it's critical to have access to a global support infrastructure that enables fast turnaround anywhere in the world in order to get your static system up and running as quickly as possible.

Conclusion

Although static deposition systems present unique issues during process set up and operation, an array of tools and technologies exist to help you easily resolve them. This enables you to fully benefit from the low particle generation levels that static systems provide.

For more information on AE solutions for FPD manufacturing, please visit:
www.advanced-energy.com/en/Flat_Panel_Display.html

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ENG-FPDStaticDep-270-01 0M 10/08