OLED Displays

MKS has the most comprehensive set of solutions for flexible and rigid OLED manufacturing

Introduction

Displays are undergoing an evolution in mobile consumer devices, TVs and automotive applications. Previously, the biggest display technology shift was from curved Cathode Ray Tubes (CRTs) to flat Liquid Crystal Displays (LCDs). Organic Light Emitting Diodes (OLEDs) are the next innovative display technology shift. OLEDs are gaining traction in mobile consumer applications such as smart phones and wearable devices like smart watches and AR/VR (Augmented Reality/Virtual Reality) headsets because of their higher brightness and resolution, lower power consumption and form factor capabilities like edge to edge, curved and foldable displays. TVs are leveraging OLED's increased brightness and thinner form factor. Traditional automotive instrument panels and center consoles are being replaced with OLED displays, enabling better ergonomic and aesthetic interior car spaces.

OLEDs are enabling innovation in applications that can leverage the features and benefits of the technology. New display technology creates new manufacturing challenges that must be overcome. MKS offers a broad portfolio of products including Lasers, Motion, Power and Reactive Gas solutions for some of the more challenging process steps in small, rigid and flexible OLED display manufacturing.

MKS solves key OLED manufacturing challenges

in LTPS manufacturing, Fine Metal Mask creation, Cutting and Repair, and Thin Film Encapsulation with high performance solutions in:

- Lasers
- Motion
- Optics
- Direct Pressure Measurement
- NDIR
- Power Meters
- Ozone
- Remote Plasma Systems

Process Challenges in OLED

Flat panel displays use different backplane technologies. Small and medium OLEDs for mobile phones use a low temperature polysilicon (LTPS) backplane which is created by laser annealing amorphous silicon (a-Si). OLED TVs use a metal oxide backplane. Both backplanes use deposited thin films which must be highly uniform and contamination-free to maximize electrical performance. The OLEDs are evaporated or deposited and encapsulated to reduce degradation caused by water vapor and oxygen exposure. Encapsulation uses either strengthened glass or thin films, depending on whether the OLED is rigid or flexible. Dissimilarity of materials within the rigid and flexible stacks make cutting and singulation of individual display devices a challenge. The highly complex nature of this process can induce defects, decreasing throughput and yield.

Challenges in OLED manufacturing include:

- Contamination-free thin films
- Precise cutting with minimal damage to surrounding areas or structures
- Low throughput
- Yield

MKS Solutions

The LTPS backplane conducts electric current to the OLEDs so light is emitted. This layer is created by vacuum deposition of a-Si either directly on strengthened glass or onto a polyimide layer attached to a glass carrier. The thin film is then laser annealed to create the crystalline LTPS structure. To ensure the correct composition and uniformity of the a-Si thin film, it is important to directly measure pressure within the deposition chamber. **Direct Pressure Measurement** devices from MKS operate in situ, with low pressure measurement drift and EtherCAT® communication. This makes it highly reliable and quick to communicate with the overall system ensuring correct composition and uniformity of a-Si thin films.

Surface cleanliness prior to a-Si deposition is important to ensure contaminates don't negatively impact the thin film electrical properties. MKS **Ozonated Water Delivery Systems** provide pure, high flow and high concentration ozone that rapidly oxidizes organics including metals and particles. Exposure to ozone at this stage of the manufacturing process improves the grain size and uniformity of the LTPS thin film layer improving the backplane's electrical characteristics. It is important to clean with ozonated water after laser annealing to ensure no new contaminates have been deposited on the surface prior to the RGB evaporation step.

Routine cleaning of the vacuum deposition chamber using MKS **Remote Plasma Source** (RPS) systems reduces potential film contamination by removing chamber wall contaminates. The RPS delivers productive NF_3 over a broad pressure range from 5-40 Torr and with low volume up to 50 slm. This results in increased speed of chamber clean and equipment uptime. To shorten chamber cleaning time, our Non-dispersive Infrared (NDIR) **Chamber Clean Endpoint System** senses SiF_4 down to 1 ppm, optimizing chamber clean time by measuring process byproducts.

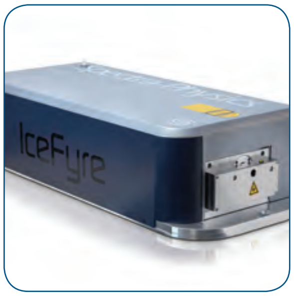
RGB pixels are evaporated on the LTPS backplane surface using an invar Fine Metal Mask (FMM). As OLED manufacturers push for >1000 pixels per inch (PPI) to support VR, a new way to create a fine metal mask with increased pixel density and feature accuracy is necessary. Our industrial ultrafast **Lasers**, with picosecond or femtosecond pulses and small, focused beam widths, create completely vertical pixel holes with no material buildup that could negatively impact feature geometry. Ultrashort pulses reduce excess heat buildup providing a minimal heat affected zone. This reduces mask warp and ensures all pixel holes maintain their shape. The laser's high output power, high beam quality and narrow bandwidth supports highly uniform beam splitting for parallel machining and increased throughput.

RGB pixels have a shortened life span when exposed to water vapor and oxygen. For this reason, the pixels must be encapsulated, either with glass for a rigid OLED, or with a series of thin films for a flexible OLED. Thin film encapsulation (TFE) uses alternating organic and inorganic thin films, created by inkjet printing and vacuum deposition respectively, to provide high resistance to water vapor and oxygen permeability. Plasma enhanced CVD (PECVD) and Atomic Layer Deposition (ALD) are potential inorganic vacuum deposition techniques. ALD is becoming more popular for inorganic TFE because it creates a thinner conformal film with fewer pinholes than is possible using PECVD.

Like deposition of a-Si for the LTPS layer, the ability to accurately and directly measure pressure during ALD is critical for deposition control and production of highly uniform thin films. Our direct pressure measurement device minimizes residual deposition and ensures low pressure measurement drift. The device is heated, making it thermally compatible with the ALD system for more

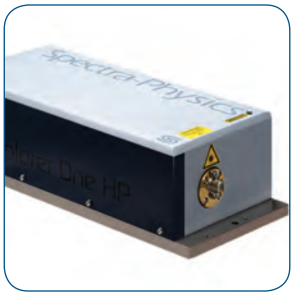
accurate system performance. ALD is using a wider range of chemical compounds to drive reactions and create highly tunable, uniform thin films. Water has been the traditional precursor, providing oxygen from its chemical breakdown. Increased use of oxides in ALD requires a higher purity O_2 source to reduce film contamination. MKS **Ozone Gas Generators**, with closed-loop operation for tight process control, create highly concentrated ozone that is ultra-pure, resulting in creation of a highly dense film with reduced hydrogen and carbon contamination when compared to a film created using water precursor. These products ensure the deposited film has the correct chemical composition, is highly uniform and is pinhole and contaminate-free. This reduces water vapor and oxygen transfer rate and results in yield improvements.

Our industrial femtosecond and picosecond **Lasers** are excellent for glass and film cutting. For cover glass and rigid OLED, they provide flexible pulse and burst control with precision, resulting in a micro-crack, chip-free edge, making the glass stronger and less likely to break if dropped. This reduces the need for post-cut polishing, increasing throughput by reducing the number of manufacturing process steps. For flexible OLEDs, MKS lasers with short pulse widths create a minimal heat affected zone and provide a clean cut through layers of dissimilar materials including various thin films, PET, and adhesives. Increased throughput is achieved from higher output power that speeds up the cutting process. The narrow kerf or cut and the low heat affected zone means more parts can be cut out of the same material.



High performance **Optics** from MKS have various coatings that are optimized for different wavelengths, enabling tight beam delivery—important for tight radius corner cuts for both glass and film cutting. Combined with our linear stages that have high, stable velocity with on-off laser synchronization, MKS is uniquely positioned to provide a variety of solutions that enable precise radius cutting at the micron level for both film and glass.

Repair is becoming more critical as the industry moves to more expensive OLED displays. Lasers are uniquely positioned to repair thin film transistors (TFT) and individual pixels. Ultrafast, nanosecond and femtosecond **Lasers** from MKS are highly stable for controlled removal of targeted materials. Ultrashort pulse lasers create a low heat affected zone ensuring no further damage is created during the repair. This process is contamination-free as ultrafast lasers do not create any new particles or debris during activation. With adjustable pulse parameters and high stability for precise control, MKS lasers focus down to the pixel level for repair. Our high calibrated power meters ensure laser output is accurately measured and adjusted to remain constant during processing thereby supporting quick and efficient repair.



MKS is a leading global provider of solutions in small OLED Display Manufacturing. *Our Lasers, Motion, Optics, Ozone, Remote Plasma Systems, and Direct Pressure Measurement products provide improved yield and higher throughput by reducing potential sources of contamination, shortening cleaning and equipment downtime, ensuring thin film composition and conformality, and enabling precise cutting, drilling and repair.*

We are committed to helping our customers solve their most complex problems. For further information, visit us on the web at www.MKSINST.com or call us at 978-645-5500.