Large-Scale Vacuum Technologies for 730X920 AMOLED Production; The world's largest OLED deposition system

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Abstract

Doosan DND, OLED manufacturing equipment maker, has developed the largest deposition system to produce 730X920mm size AMOLED devices for the first time in the world. It is necessary for producing 40" AMOLED panels to develop the large-scaled vacuum technologies including ICP plasma, stretching glass chuck, organic deposition, metal deposition and hybrid encapsulation processes.

1. Objectives and Background

Since the evaporation technique has been developed, the best concept of an evaporation vacuum system is known as "bottom-up way". That is, a target substrate is located at top area and an evaporation source is located at bottom plate inside a high vacuum chamber. Therefore, the vapor would be directed upward to a substrate surface. Under the gravity, this bottom-up way would be highly recommendable to operate the chamber system and for convenient maintenance, and not to have a particle issue in producing the display devices.

The known key technologies in OLED deposition system are an alignment assembly that aligns the substrate to a metal shadow mask[6,7], and a thermal evaporation source to deposit. When a large-size substrate such as 730mmX920mm is used to deposit inside an evaporation chamber, there are several troubles arose. The large sized glass substrate becomes easily bent and gives non-uniform organic and metal films onto. Also, it is impossible for the substrate to be aligned to a shadow mask with this glass bending. There is no existing of 40" sized shadow mask yet. This motivates for OLED manufacturers to use ink-jet printer and LITI technologies for fine patterning, and even to try to realize a 40" full color AMOLED device by processing White OLED deposition with a color filtered TFT substrate.

In this report, we will summarize the large-scaled vacuum technologies including ICP plasma, stretching glass chuck, organic deposition, metal deposition and hybrid passivation processes for producing a 40" AMOLED device what Doosan DND has developed for the first time.

2. Results

2.1 ICP Plasma[1]

The plasma is generally used for a pretreatment process of an OLED substrate. When the CCP plasma is used, there can be a self-bias of above

80V for high RF power between two electrodes and it causes damage on a TFT substrate. Therefore, the ICP plasma is the best candidate that can be used in low self-bias (1-3V) pretreatment process for AMOLED processes. It is well known that the ICP plasma has not only low working-pressures but also high plasma density. Furthermore, it needs to be necessarily developed for large-size RF antenna that can use without rotating the substrate during the plasma pretreatment process of a large-size substrate.

The ICP plasma uniformity of less than 10% is required for proper process and it can be achieved by developing the linear-type RF antenna. When the linear antennas are arranged, the standing wave phenomena should not be occurred. It can be preventing by having a certain gap distance between antennas.

Moreover, in order to get the higher plasma uniformity, the arrangement of linear type permanent magnet would be properly made along the linear RF antennas. It also provides even higher plasma density.

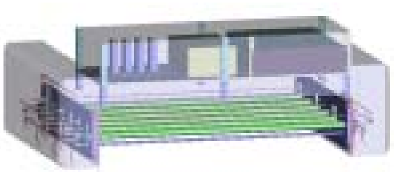

Fig. 1 Structure of ICP Plasma

The large-size ICP plasma for 730X920 substrate what Doosan DND developed has a “double comb” structure antenna and the plasma uniformity was measured as 6-7% as shown in Fig. 1, which is quite satisfied.

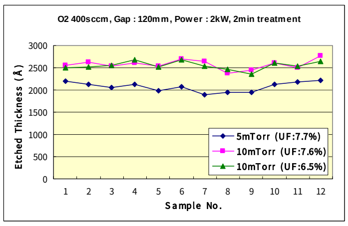

Fig. 2 ICP Plasma uniformity

2.2. Stretching Substrate Chuck[2]

To do a bottom up deposition onto a 730X920 glass substrate, as when the glass surface looks downward, the vertical bending distance is as long as 73mm at the center of glass where the glass thickness is as 0.7mm. This bending limits to get a required uniform film thickness on the large size glasses and the alignment accuracy we intend between the glass and a mask frame. And also, it is difficult for the bent glass to carry inside the high vacuum chambers by a robot.

In holding the glass, there are known a vacuum chuck and an electro-static chuck (ESC) technologies. However, the vacuum chuck cannot be applied because the system itself is in high vacuum and the ESC cannot be used inside the chamber because of its high voltage feed-through.

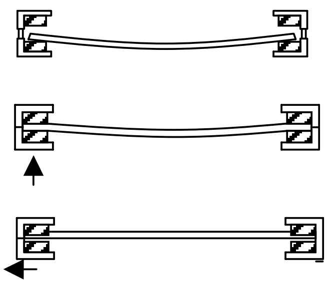

Fig. 3 Principle of Stretching glass chuck

To overcome the glass bending troubles, Doosan DND developed "Stretching glass chuck".[3] In principle, the clipping mouth bites end sides of the glass and stretch it out to make the bending glass flat as shown in Fig. 3. Then, the glass bending was measured to 1.5mm. Doosan DND is now deploying this stretching glass chuck technology to a 730X920 AMOLED production system as first.[4] (Fig. 4)

Fig. 4 Holder for 730X920 substrate.

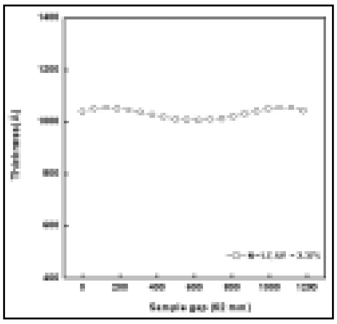

Fig. 5 Alq3 Film Uniformity

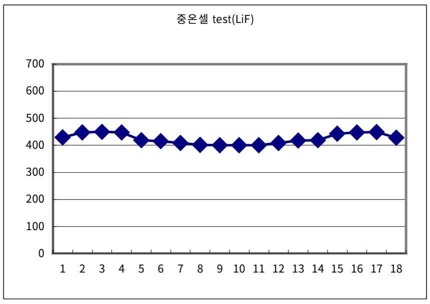

Fig. 6 LiF Uniformity

2.3 Organic Deposition

The film uniformities of organic and LiF are required as less than 5%. Doosan DND has develop "Inner Nozzle point source" in which the organic vapor gas emits through the cylindrical shape nozzle. The diameter and length of an inner nozzle were adjusted to give proper cosine distribution of Alq3. The distance from the source to a substrate and the offset distance were also adjusted to provide the highest organic-film uniformity and LiF uniformity. During 4RPM rotational speed of a substrate holder, Alq3 layer was deposited to give 1000A of film thickness and measured as 2.7% in film uniformity.(Fig. 5) The LiF uniformity was 3.4% at 400A.(Fig. 6)

2.4 Metal Deposition

The "direct boat heating" was used to deposit an Al anode for 730X920 substrate. The distance from the PBN boat to a substrate and the offset distance were properly adjusted to provide the highest Al film uniformity of 5.2% at 3000A (Fig. 7). The dual wire feeder for continuous Al supply to a boat was used.[8]

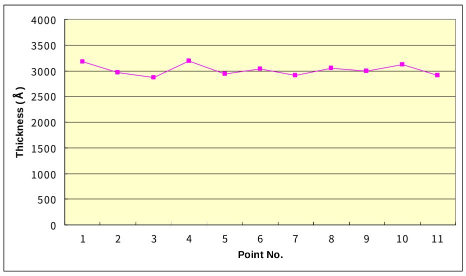

Fig. 7 Al uniformity(5.2%)

The sputtering techniques was developed to deposit a cathode metal film for 730X920 substrate. In the optimization test, the distance from the Al target to a substrate was properly adjusted to provide the highest Al film uniformity of 1.9% at 2000A (Fig. 8) The substrate was scanned back and forth to minimize the thermal damage from Al target.

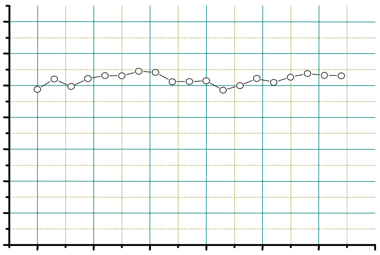

Fig. 8 Al uniformity(1.9%) in sputter deposition

2.5 Hybrid Passivation

A "thin film passivation" technique[5] has been developed to protect the deposited film from air molecules such as water and oxygen. This process is known to be multi-layers structure of inorganic and organic coating. On the other hand, "Hybrid passivation" process was defined as a single organic coating process plus a uniform pressing of a cover glass to a panel glass. Therefore, the multi-layer processes were not necessary to be made in our case. (Fig. 9) The coating process of organic layer was performed by the screen printer where located in low vacuum chamber and the cover glass pressing was finished by following of UV curing process. The thickness of cover glass was as same as the panel glass (0.7mm).

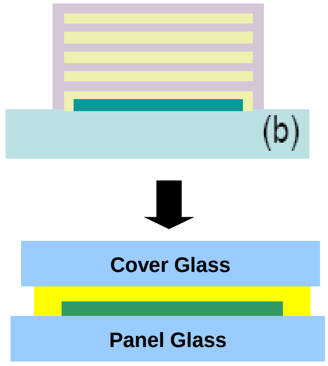

Fig. 9 Hybrid Passivation

3. Impact

Doosan DND has successively developed the key vacuum technologies for the 730X920 AMOLED production for the first time in the world. In addition, Samsung Electronics have recently demonstrated the world's largest 40" AMOLED TV(in Boston) produced in using Doosan DND's large-scaled vacuum technologies. This means that all the break through in large-scale OLED deposition technologies has been penetrated and the possibility of mass production of large-size AMOLED TV becomes much higher now.

4. Acknowledgements

Authors express many thanks to all the Doosan DND's members with their endurance and creativities.

5. References

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