In-Line Manufacturing Tool Using Linear Belt Source Evaporation for Large Size Lighting OLED and Flexible OLED

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Abstract

We introduce the inline type mass production tool for the large size lighting OLEDs and flexible OLEDs. The manufacturing tool includes the linear belt source what is new concept for the organic deposition processes and the deposition operation combines directly to the encapsulation operation in a tool. The linear belt source evaporation in deposition processes is performed during the substrate transferring to innovatively improve the productivity in manufacturing.

1. Introduction

The deposition operation in OLED manufacturing uses the shadow mask process for fine pixel patterning. However, the lighting OLED does not use fine patterning process so that the manufacturing operations are more simple than OLED display. In order to produce the lighting OLED, the most important factor is the high yield in manufacturing industry and the manufacturing tools need to be developed for the commercial purpose of the lighting OLED with the high material utilization.

In order to realize the high productivity of lighting OLED, the organic deposition tool, which is main process, should handle the large size substrate. Recently, the new concept technology for the deposition process what is called the belt source [1,2] has been developed. The belt source is shown in figure 1. The belt source uses thin metal plate such as tantalum and the organic vapor emitted from the LPS source is deposited on the metal bottom. The deposited metal belt transfers to the substrate and warm up to re-evaporated the organic vapor toward the substrate at the bottom.

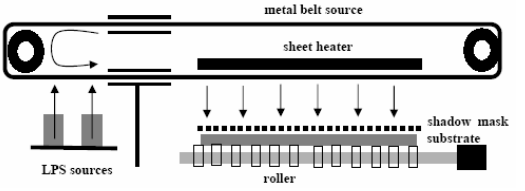

Fig.1. Belt source evaporation

Using the belt source evaporation, the large size substrate has high film uniformity (2%) and high material utilization of 68% and the deposition rate is high enough so that the tool provides high yield.[3,4] In particular, because the substrate is transferring through the rollers, the large size substrate does not bent and the substrate chucking and mask chucking are not necessary contrary to the conventional equipment. The deposition chamber with the belt source becomes very simple. [5]

In this report, using the belt source evaporation, the modified belt source what is called “linear belt source” and the inline manufacturing equipment are introduced for manufacturing of the large size lighting OLED and flexible OLED as well.

2. Linear belt source

The device structure of lighting OLED is shown in figure 2. On a TFT (or ITO) substrate, the multilayer of HIL, HTL, EML, LiF, and Al is formed and a polymeric layer exists for the passivation purpose, covering by a bare glass at the top for physical protection.

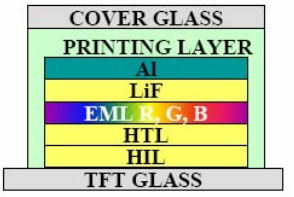

Fig.2. Lighting OLED

In manufacturing of lighting OLED, the glass substrate previously cleaned by wet processes is loaded, plasma-pretreated, ITO sputtered, organic film deposited, LiF and metal film deposited, and screen printed for passivation, glass encapsulation processed, and finally UV curing processed. Beside, effective unloading of the panels and insertion of encapsulation glass are required.

The most important process is the deposition process for the organic materials such as Alq3, NPB and ADP, etc. The material utilization should be high and the productivity is supposed to be high as well in manufacturing. As shown in figure 3, the modified belt is continuously transferring and the organic gas emitted from the LPS source is deposited on the metal (Ta used in here.) made belt. During transferring the belt, the linear type sheet heater emits radiation to warm up the belt and the organic film evaporates toward the moving substrate on the rollers. Note that the belt evaporation and substrate transferring are simultaneously occurred.

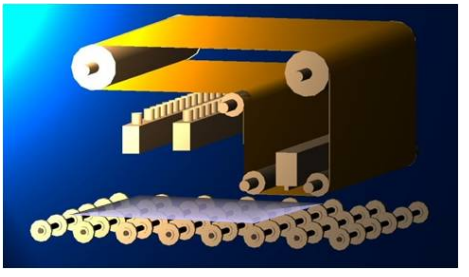

Fig. 3. Linear belt source

Because the substrate is not staying during deposition for the shadow mask alignment and pixel patterning as shown in figure 1, The deposition duration becomes as short as Roll to Roll process. Furthermore, the thermal damage to substrate from the belt heat is minimized. As shown in figure 3, the modified belt source is called “linear belt source”. In this continuous operations, the material utilization improves as high as 70% in simulation and the substrate size is not an issue any more because there is no bending of thin substrate.[6]

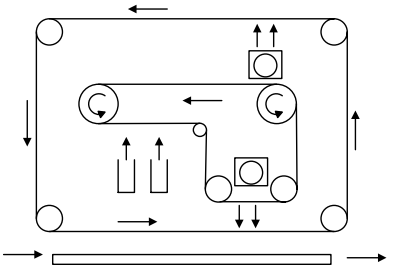

Fig. 4. Operation of the belt type open mask

The lighting OLED does not need a shadow mask process like OLED display, however, it needs to deposit for the effective area on the substrate by using area mask (or open mask). As shown in figure 4, the belt type open mask can be transferring around the linear belt source using four numbers of rollers while the linear belt and the substrate are moving. An example of the belt type open mask is shown in figure 5. The speed of the belt source, the belt mask and the substrate needs to be properly synchronized. [7]

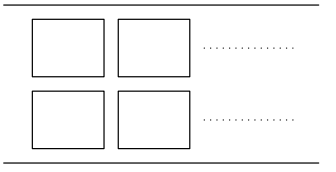

Fig. 5. Belt type open mask

3. Inline tool for lighting OLED

The inline manufacturing tool for lighting OLED is shown in figure 6. The in-line type equipment for large-size lighting OLED manufacturing consists of a number of chambers designated for the loading of glass substrate, ITO deposition, pre-treatment, linear belt evaporations for organic depositions (HIL, HTL, RGB), metal depositions for LiF and Al,

screen printing, glass encapsulation, UV curing, and panel glass unloading.[7]

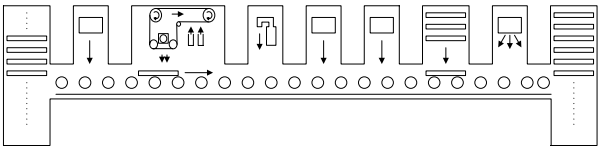

Fig. 6. Inline tool for lighting OLED

In order to continuously transfer the substrate between deposition chambers, the substrate is linearly transferring by rollers in which operates via non contact magnets as shown in figure 7. Then, the particles are suppressed to be generated during operating inside the high vacuum chambers. Also, roller moves the substrates as fast as 200mm/s.

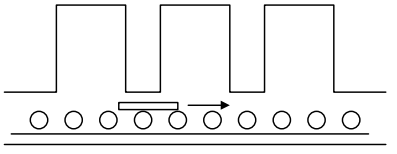

Fig. 7. Roller transferring of the substrate

The deposition chambers are connected in a row with gate valves in between each chamber as shown in figure 8. However, gate doors does not open and close all the time the substrate moves cross the chambers. For an example, the ITO process is low vacuum while the belt source process is high. When doing these processes, the gate door is closed to isolate the chamber to maintain their vacuum pressure. For other chambers with same vacuum pressure, the gate doors keep open during processes because there won't be cross interference.

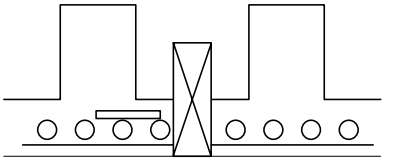

Fig. 8. Gate valve connection

4. Inline tool for Flexible OLED

When manufacturing the flexible OLED devices, the substrate becomes film roll as shown in figure 9. That is, the film unwinds from the film roll and the linear belt source deposits organic materials to the film to wind back to the film roll.[7]

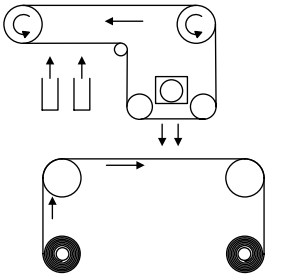

Fig. 9. Film roll and linear belt source

The inline manufacturing tool for flexible OLED is shown in figure 10. The in-line type equipment for manufacturing of the large-size flexible OLED consists of a number of chambers designated for the unwinding of film roll, ITO deposition (or barrier coating deposition), pre-treatment, linear belt evaporations for organic depositions (HIL, HTL, RGB), metal depositions for LiF and Al, screen printing, film encapsulation with peeling roll, UV curing, and panel film winding with roll.[7]

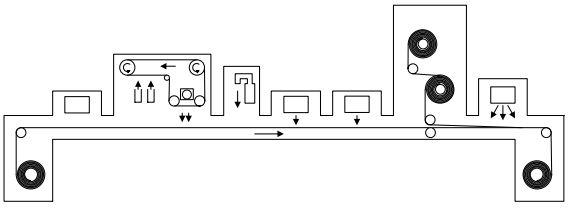

Fig. 10. Inline tool for flexible OLED

The deposition chambers are connected in a row, however, the gate valves are not used to isolate the chambers with different vacuum pressures. In order to maintain each pressure while processing each chamber, the "buffer valves" are used. As shown in figure 11, the buffer valve has the "knife edged baffles" for the cross flying particles to pump down

from low vacuum chamber to high vacuum chamber.

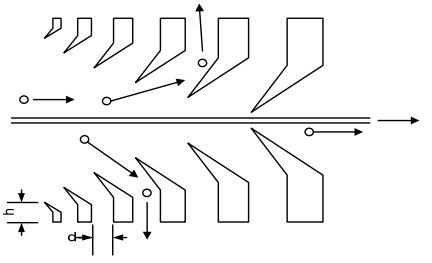

Fig. 11. Knife edged baffles

The several numbers of buffer valves are connected in a low in between each chamber to maintain each pressure as shown in figure 12.[7] If needed, more number of buffer valves should be used to "differentially" pump out the cross flying particles. Note every buffer valve has own pump at the behind as shown in figure 12.

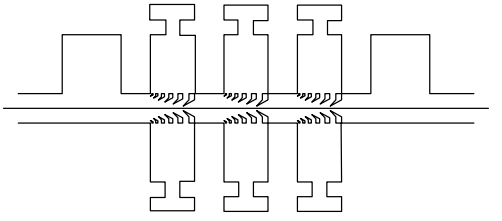

Fig. 12. Buffer valves

5. Conclusion

In this report, the inline tools for manufacturing of lighting OLED and flexible OLED is proposed by using linear type belt sources. The inline equipment includes the deposition process and the encapsulation process altogether to be simple and cheap. In addition, because the glass substrate even roll films keeps transferring while deposition operation in this inline process, the productivity becomes as innovatively high as R2R processes.

The major specification of the linear belt source is summarized in table 1.

Belt source material	Ta, STS304
Substrate size	Up to 8G
LPS source	1 host, 2 dopant
Film uniformity	< 3%
Material usage	> 70%
Ultimate pressure	10^{-8} Torr
Module material	STS304
Belt speed	1 ~ 300mm/s
Belt operating temperature	RT ~ 800℃
TS (Target to Substrate)	50 ~ 100mm
Substrate temperature	< 30℃

Table 1. Specification of linear belt source

6. References

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