Study of metal plate evaporation using LPS source for AMOLED

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Abstract

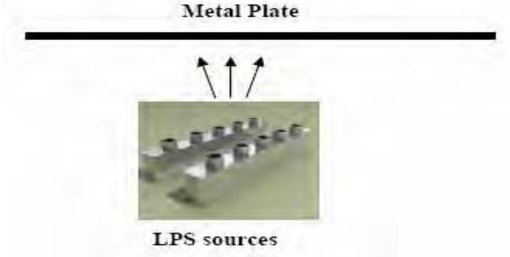
The Gaussian thickness profiles in metal plate evaporation using LPS sources have been studied for the first time. Based on our experimental data, it simulates the organic thin-film uniformity of 3% and very high material usage of 81% for large size AMOLED manufacturing.

1. Introduction

The organic thin film of the AMOLED device is mainly made by vacuum thermal evaporation techniques. The existing evaporation source such as point source and linear source gives very low material utilization(5%-20%) because the distance between the sources and a substrate goes far in order to obtain better film uniformity of the large size substrate. It also keeps for the productivity of AMOLED very low in manufacturing industry.

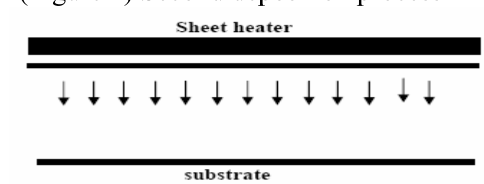
In order to solve these problems, using multiple LPS sources as shown in figure 1, the organic vapor can be emit to firstly deposit on the metal plate with high material utilization of over 93%. [1]

(Figure 1) First deposition process



After this, the sheet heater makes for the metal plate (copper) worm up to evaporate the organic material primarily deposited on and it secondly deposit on a TFT substrate as shown in figure 2. [2]

(Figure 2) Second deposition process



In this thesis, we report, for the first time, the study of Gaussian thickness profiles of the multiple deposition processes in metal plate evaporation using LPS sources.

2. Material Utilization

2-1. Simulation

The simulation has been done for material usage for 370x470mm substrate as shown in Table 1. It appears that the material usage of the point source goes lower as the distance between substrate and source (TS) longer. The offset distance was fixed as 0mm. Also, the film uniformity shows so bad as expected.

(Table 1) Simulation of the material usage

TS (mm)	Uniformity (%)	Utilization (%)
100	99.6	97.9
200	92.4	80.3

300	73.9	59.4
400	54.5	43.1
500	39.7	31.8
600	29.6	24.1
700	22.7	18.7
800	17.8	14.9
900	14.3	12.1
1000	11.7	9.9

In order to maintain the organic film uniformity of less than 5% during deposition, the offset distance of the source maintains as 300mm and therefore the material usage becomes worse than the values shown in Table 1. Therefore, there is a need for the new concept of the evaporation sources to improve the material utilization and the film uniformity in OLED manufacturing.

2-2 Direct Measurement

In order to obtain the direct measurement of the material usage for the first time, the TS distance of the point source has been varied from 50mm to 300mm by evaporating many hours and the weight difference of the source crucible and the substrate has been measured as shown in Table 2.

(Table 2) Measurement of the material usage

TS (mm)	Source Weight (g)	Substrate Weight (g)	Material Utilization (%)
50	1.906	1.782	93.4
100	2.626	2.138	81.4
200	4.0	2.60	65.0
300	1.276	0.549	43.0

When the TS distance was 50mm, the material usage was as 93.4% and the Alq3 was used in this experiment. As expected, the lower the material usage the longer the TS distance. That is, the TS distance should be as short as possible to improve the material utilization.

3. LPS sources

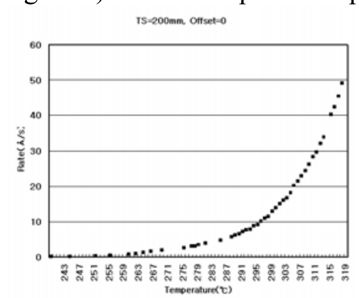
3-1 LPS Source with Single Nozzle

The LPS source with single nozzle is shown in figure 3. The organic gas emits through a nozzle from linear shaped crucible. [3]

(Figure 3) LPS source (one nozzle)

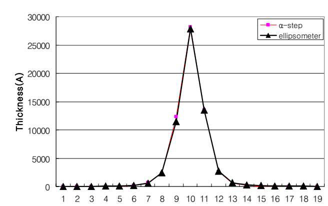
As shown in figure 4, the evaporation rate of Alq3 was measured as the crucible temperature was increased. The gas rate becomes to increases suddenly near 300C appeared as normal.

(Figure 4) Rate of Alq3 vs. temperature



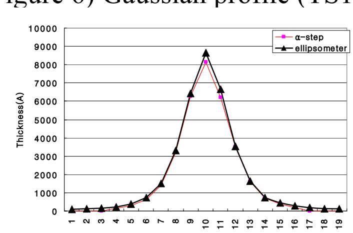
The copper plate has been placed above the LPS source and the distance (TS1) was 50mm from the nozzle top. The Gaussian thickness profile of the organic film ("Gaussian circle") deposited on metal plate is then measured by ellipsometer and alpha stepper as shown in figure 5.

(Figure 5) Gaussian profile (TS1=50mm)



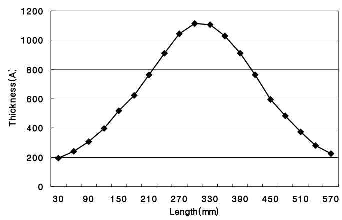
When TS1 sets as 100mm, the following Gaussian profile is shown in figure 6. As expected, the line width of the Gaussian profiles goes wider as the distance between the metal plate and LPS source becomes longer.

(Figure 6) Gaussian profile (TS1=100mm)



For the second deposition process, the Gaussian thickness profile condensed on a glass substrate is shown in figure 7. The substrate was 370x470mm and the distance between the metal plate and the substrate (TS2) was 200mm.

(Figure 7) Gaussian profile on substrate



Again as expected, the line width of the Gaussian profile is much wider than in first deposition process.

3-2 LPS Source with Dual Nozzles

The LPS source with two nozzles used in first deposition process is shown in figure 8 and the following Gaussian profile in second deposition is appeared in figure 8. [3]

(Figure 8) LPS source (two nozzles)

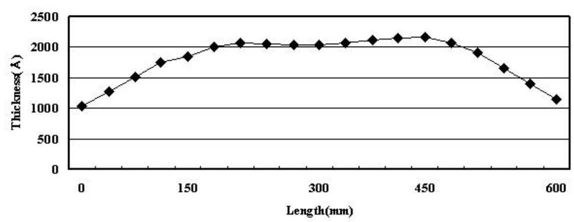
The two nozzles were separated by 260mm and the TS2 was 230mm. Two LPS sources were used and each two nozzles were open to emit for the organic vapor to deposit on the metal plate such as copper. The distance between the metal plate and LPS sources was intentionally kept at 50mm in order to deposit 93.4% of the organic material to the metal plate. The deposition features on the metal plate is shown in figure 9. [2]

(Figure 9) Gaussian Circles

We call this circular type of organic film as "Gaussian Circles". That is because they would have a gaussian thickness profile. After that, the metal plate was warmed up by using a sheet heater where it located at the back side of the metal plate. Then, the Gaussian circles sublimated to condense onto a glass substrate that placed at the lower area of the deposition chamber. When the temperature of the metal plate arrived to 180C, the Gaussian circles were completely sublimated. Therefore, we decided that there won't be any thermal dissociation of the organic materials during sublimation. Note that the sublimation temperature of 180C is lot lower than vapor temperature of 300C.

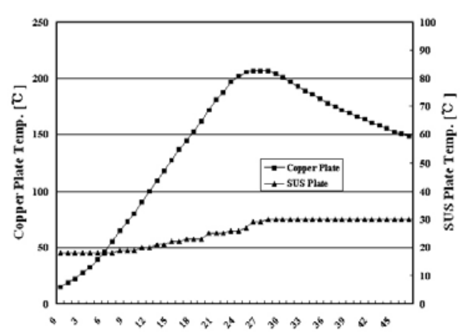
The thickness profile of the organic film formed on the substrate was measured as shown in figure 10. The distance between the metal plate and the substrate was 225mm. [3]

(Figure 10) Thickness profile



The film uniformity of the central area(300mm) in thickness profile has been measured as 2.2% and the material usage was 24%. The SUS foil plate of 30um thick was placed at the substrate position and the temperature on the foil plate was raised from 26C to 29C during sublimation process as shown in figure 11.

(Figure 11) Temperature of the foil plate

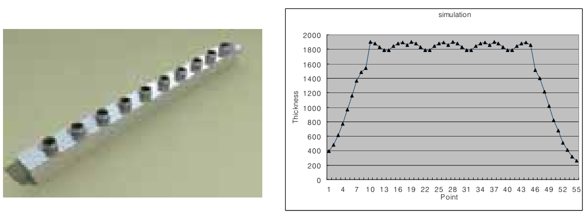


Note that no thermal damage on the substrate and shadow mask is expected. [4]

3-3 Simulation for Multiple LPS Sources with 10 Nozzles

Based on the experimental data, the film uniformity and material usage were simulated for the deposition processes using an array of 10 LPS sources with each 10 nozzles. The film uniformity was then 3.1% and the material usage was 81% which is very high. (Figure 12) [4,5,6]

(Figure 12) LPS with 10 nozzles and simulation



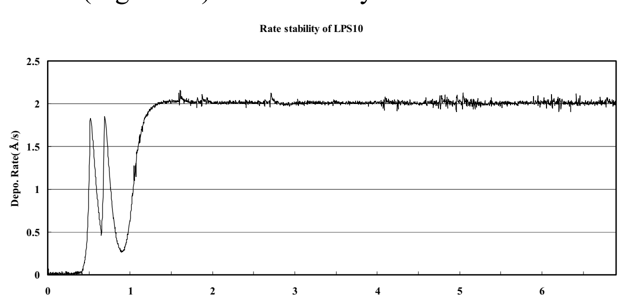
3-4 LPS Sources with 10 Nozzles

To see the experimental data, the LPS10 (LPS source having 10 nozzles) was made as shown in Fig. 13 and the copper plate deposition was done to have 10 numbers of Gaussian circles as shown in Fig. 16.

(Figure 13) LPS with 10 nozzles

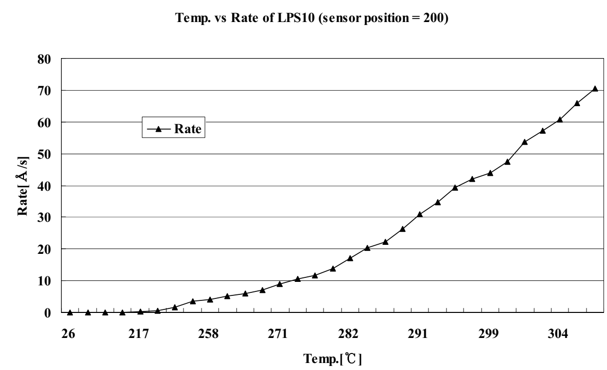
The rate stability for the LPS 10 source has been measured as shown in Fig. 14. In the beginning of this measurement, the auto tune process shows two peaks feature for the PID processes for first half an hour and it takes another 30 min. for the 2A/s stability. The sensor was positioned at 300mm from the center of the LPS10 in this experiment and Alq3 was used as usual.

(Figure 14) Rate Stability for LPS10



The vapor rate was measured as deposition rate versus the crucible temperature as shown in Fig. 15. The vapor began to measure from 217 C and the 10A/s was shown at 271C which is quite low temperature as not in LPS2 and conventional point sources. Therefore, we decide that the low evaporation temperature in LPS10 provides us for the measure-able vapor rate and it will give less thermal damages on the organic materials during the thermal evaporation processes.

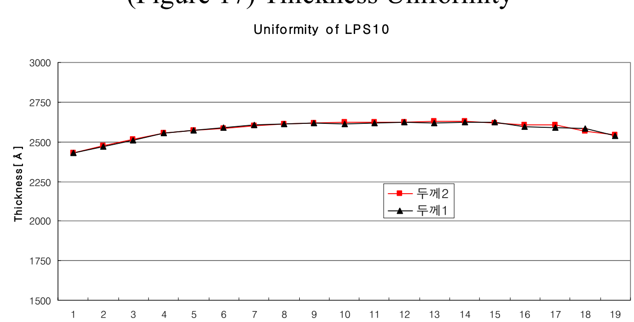
(Figure 15) Rate to Temperature for LPS10



(Figure 16) Gaussian Circles using LPS10

The Gaussian circles are then transferred to the glass substrate at the sublimation distance of 100mm (TS2=100) and the thickness uniformity was measured as 2.9% over the 600 mm length. (Fig. 17)

(Figure 17) Thickness Uniformity



Therefore, we conclude that the thin film uniformity would be less than 3% for the 600x600(mm) substrate.

In order to directly measure the material utilization, the evaporation was done for couple of hours on the Cu plate and the primary deposition organics were sublimated on the glass substrate. The weight difference before and after the evaporation was measured for the source crucible and the glass substrate as in Table 3.

(Table 3) Measurement of the material usage

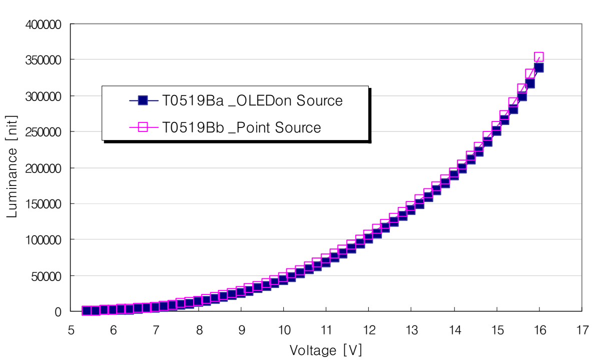
TS2 (mm)	Source Weight (g)	Substrate Weight (g)	Material Utilization (%)
100	0.4	0.26	65.0
200	0.7	0.33	47.1

At the TS2=100, the material utilization was 65% what is striking result compared to the conventional point source case (5%). At TS2=200, the material utilization was 47%. Because the stainless steel of 30um in thickness was 40C at 100mm during the sublimation process, we suppose that the shadow mask process could be done at this high without any thermal expansion.

4. Device R&D using Plane Source

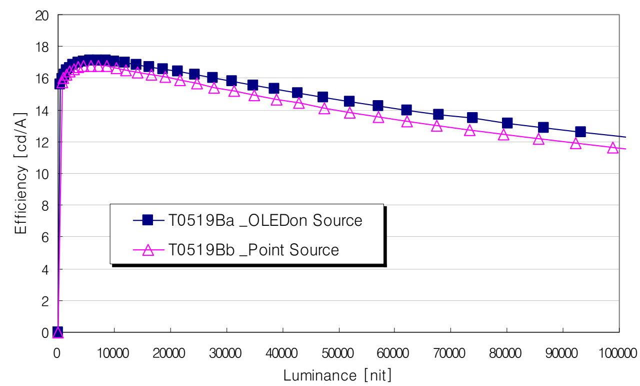
In order to make a sure for the multiple deposition process we have discussed so far, the device was made by a metal plate plane source. Actually, the ETL layer was deposited by the plane source and others such as EML and HTL layers were made by the conventional point sources.

(Figure 18) Luminance vs. Voltage



As shown in Fig. 18 for the comparison, the luminance to voltage data gives that there is no difference. The current density in cd/A to luminance data in Fig. 19 made another sure for the plane source technology to keep on going.

(Figure 19) Current Density vs. Luminance



5. Conclusion

As we apply the innovative deposition techniques discussed here, 1)if we use 5 LPS source with each 5 nozzles, the material usage would be 60%, 2)if we use 10 LPS source with each 10 nozzles, the material usage would be 80% (experimentally 65%). Also, this new techniques can be deployed for the in-line deposition system for the very large-scale AMOLED manufacturing and it will be discussed in elsewhere.

The Gaussian thickness profiles in metal plate evaporation using LPS sources have been studied for the first time. This new technique can provide the large size AMOLED manufacturing possible in the very near future.

6. Acknowledgements

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7. References

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