Alignment System Development for producing OLED using Fourth-Generation Substrate

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ABSTRACT

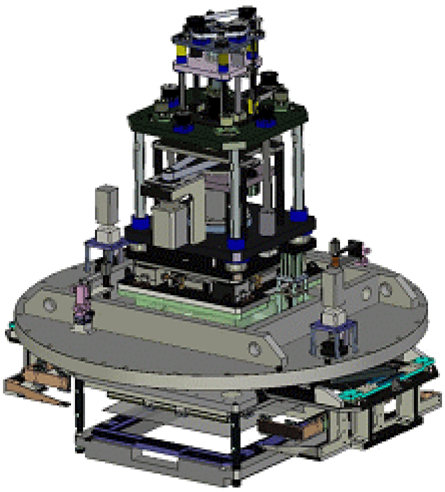
Doosan Mecatec has developed alignment system for Organic Light-Emitting Diode (OLED) display production using large size substrate. In the present article, The alignment system between the substrate and the mask, which is a core technology for producing the OLED product using the fourth-generation substrate with 730×920mm^2 or more, will be described by dividing into a substrate loader, a magnet unit, a CCD camera, etc. The substrate loader is optimized through the simulation where the central portion of the substrate droops by about 1.5mm by clamping each of a long side (920mm direction) and a short side (730mm direction) thereof by 6 point and 4 point. A magnet unit using a sheet type of rubber magnet is constituted and a CCD camera model with the specifications capable of minimizing the errors between a clear image and the same image is selected. The system to which an upward evaporation technique of small molecular organic materials will be applied has been developed so that repeatability and position accuracy becomes ±1㎛ or less using an UVW type of stage. Also, the vision accuracy of the CCD camera becomes ±1㎛ or less and the align process TACT becomes 30sec. or less so that the final alignment accuracy between the substrate and the mask becomes ±3㎛ or less. In order to meet an extra-large glass substrate, an evaporation system using an extra-large AMOLED substrate has been developing through a vertical type of an alignment system.

1. Introduction

Recently, OLED display companies have competitively announced that they earnestly start in pursuit of a large LCD and PDP TV market. Sony in Japan mass-produces the AMOLED TV to begin selling its 11-inch product December this year. Samsung SDI has announced a road map that and will develop small and midsize products and then 14, 15, and 21 inch products by 2009 and 40 and 42 inch products as large products by 2010.[1] Also, CMEL in Taiwan has already developed 25 inch and has show off technical prowess that can mass-produce the AMOLED TV from the second half of 2009.[1] Also, Seiko Epson has announced the plan to produce a 8 inch panel for top emission from the end of the year in order to replace a small LCD used in a retail store including a car navigation and a policy to produce 21 inch henceforth.[1] Most OLED display companies have concentrated a development of large products with high definition and high resolution such as a monitor, a TV from a cellular phone and small applications. At this resolution point in time where an upward evaporation technique using small molecular organic materials is a major technique of a producing technique, in order to develop and produce a midsize and large OLED display, the technique development of the evaporation system using the large substrate has been accelerated. In particular, the alignment technique and the alignment system between the high definition mask and the substrate, which is one of core producing techniques for producing large OLED products, performs an important function. The present article will describe the development contents and the characteristics of the large area alignment system by dividing the alignment system between the substrate and the mask into a substrate loader, a CCD camera, and a magnet unit, as a core producing technique system for producing the OLED products using the fourth-generation substrate with 730×920mm^2 or more.

2. Large Area Alignment System Development

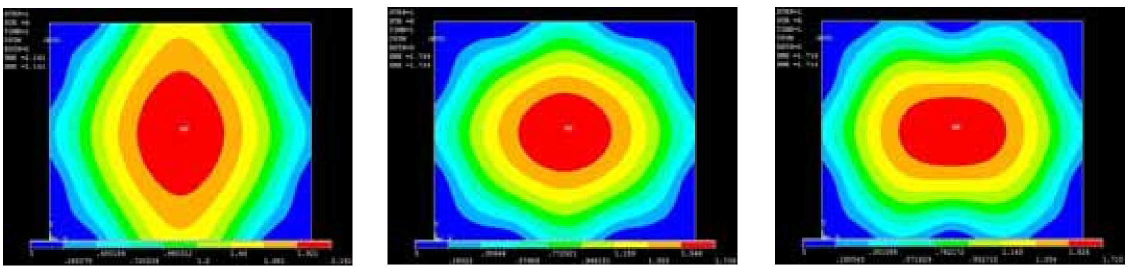
[FIG. 1] is a schematic view of an alignment system for producing an OLED display using a large area substrate (730×920mm^2).



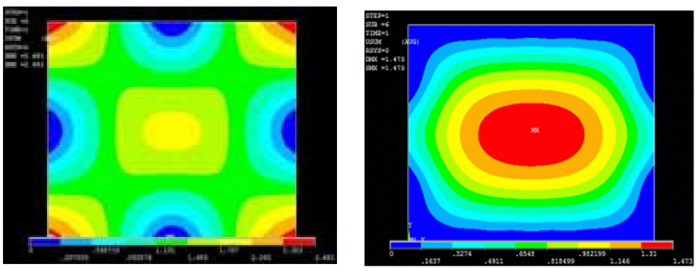
[FIG. 1] A schematic view of a large area alignment system

2.1 Substrate loader

Maintaining the large area substrate in its original shape, that is, in a flat shape without being bent or curved is a core technique of an alignment system. However, this technique has a dead space of only about 5mm capable of supporting the substrate so that it is difficult to maintain the substrate in a flat shape by supporting the outermost portion of the substrate. This leads to the interference with the mask frame positioned on the lower portion of the substrate to have many limitations in configuring a precision alignment system. In order to solve these problems, Doosan Mecatec has developed a stretching method[2] and a clamping method as methods of applying force to a local area of the substrate, which are methods of minimally correcting the bending phenomenon of the substrate. The clamping method seizes the end of the substrate up and down to minimize the bending phenomenon of the substrate and prevents the movement of the substrate to perform the alignment process of the substrate. However, it has a limitation to some degree in correcting the bending of the substrate to the flat shape. On the contrary, the stretching method is a method of applying tension to both directions in the state of clamping the both ends of the substrate. This method can make the substrate flat as the original shape of the substrate, while the chamber should be provided with a system capable of applying the tension so that this method has limitations of the increase in the volume rate of the chamber and the addition of control sequence. The article will be described based on the results of the method of applying only the clamping to the substrate loader port in order to optimize the implementation of the OLED producing system technique by reducing the process time and minimizing the alignment error. It can be appreciated that the substrate loader applied to develop the alignment system minimally maintains the bending of the substrate when clamping the long side (920mm direction) and the short side (730mm direction) of the substrate by 6 point and 4 point, respectively without performing the operation of the stretching through the simulation [FIG. 2] and [Table. 1].



[No. 1] [No. 2] [No. 3]

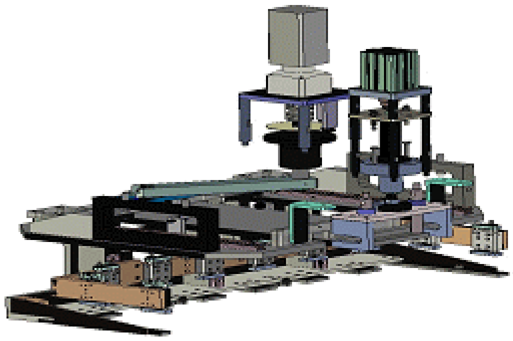


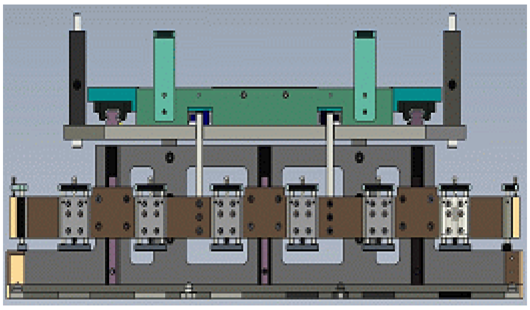
[No. 4] [No. 5]

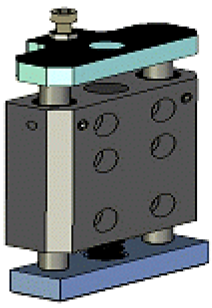
No.	Clamping Point		Bending degree of the substrate (central portion, mm)
	Long Side	Short Side	
1	2	4	2.161
2	4	4	1.739
3	3	4	1.715
4	1	1	2.681
5	6	4	1.473

[FIG.2] & [Table 1] A Result of a substrate drooping simulation from No.1 to No.5

The substrate loader is constituted by performing the conditions showing the bending phenomenon of the substrate as small as possible as in [FIG. 2] according to the design as shown in [FIG. 3].





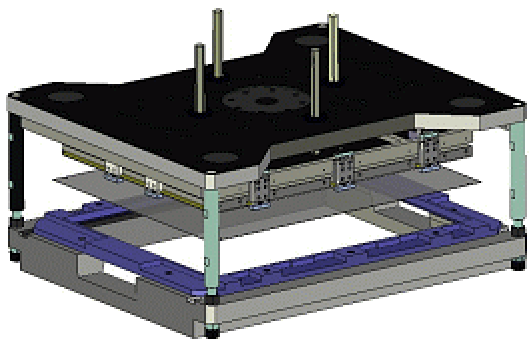


[FIG. 3] A substrate loader unit (top), a long side (920mm direction, middle), and a clamp (bottom)

The fine areas of each point corresponding to the clamping are produced in 5mm (width) × 60mm (length). The bending phenomenon of the substrate mounted to the actually produced substrate loader droops by about 1.5mm as compared to the end of the restricted substrate. This is well conformed to the result(1.473mm) of the simulation in shown in [FIG. 2].

2.2 Magnet Unit

A mechanism is constituted to often include a permanent magnet on the upper portion of the substrate, as a method of closely attaching the mask to the substrate as maximally as possible. So we could prevent a shadow effect by angle and size of mask and the organic materials through the mask can be accurately evaporated on the patterned substrate. In order to minimize the shadow effect, the mask includes magnetic component to be influenced by magnetic force and is mainly formed of a material of invar that has the minimum thermal expansion. In the meantime, a method of using an electrostatic adsorption system[3-6] may be used, however, when being constituted by means of this method, the high definition mask may be seriously damaged due to the expansion of the mask by the generated heat and the complication of the inner and outer portions of the chamber. Therefore, the system is currently constituted to closely attach the substrate to the mask by mainly using the permanent magnet in order to minimize the shadow effect. As the permanent magnet used up to now, there are neodymium magnet, rubber magnet (chlorinated poly ethylene), or the like. The neodymium magnet has a constant shape such as a bar shape or a circular shape, or the like. However, there is a need for considerable effort to arrange this. The reason is that when the mask pattern is a Grille type, the twist or wrench phenomenon of the mask pattern caused upon closely attaching the substrate to the mask can be removed by well considering the direction of magnetic force lines. On the contrary, the sheet type of rubber magnet frequently used has an advantage that the magnet is easily arranged without having great limitations of the sizes of the substrate and the mask and the direction of the mask pattern. However, since the sheet type of rubber magnet has weak magnetic force as compared to the neodymium magnet, it is specifically required to maintain an optimum distance from the magnet to the mask upon constituting the system.



[FIG. 4] A schematic view of a magnet unit

As shown in [FIG. 4], the sheet type of rubber magnet with the thickness of 5mm is arranged on a thin SUS plate to vary a total distance up to the mask when the align is completed so that magnetic flux formed between the lower portion of the substrate and the upper portion of the mask is optimized.

2.3 CCD Camera Unit

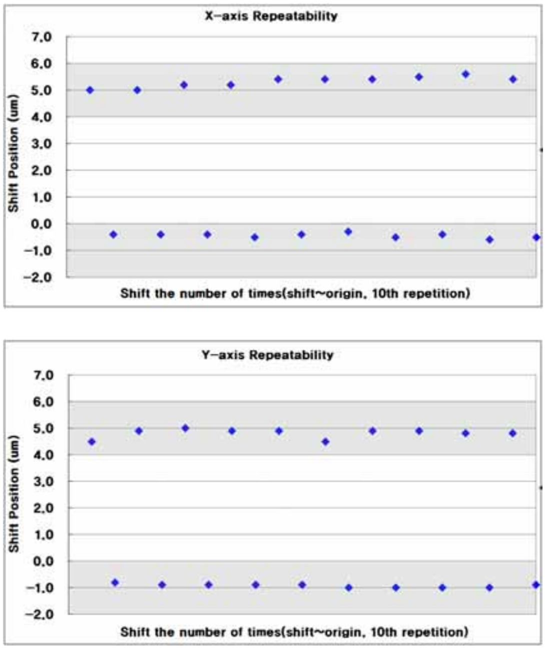
In order to obtain a precision align, obtaining a clear image of an align mark of the substrate and the mask is also a core component of the system. The selection of the camera suitable for a system specification such as a working distance that is a distance from the lens of the camera to the align mark, a field of view (FOV), a depth of focus (DOF), a camera lens, and a coaxial lighting and an outside lighting, etc. is an important point. In order to avoid the interference with the structure within the chamber, a CV-A1 model with the depth of focus of 2.6mm and the working distance of 476mm is selected as the detailed specifications of the camera. This shows FOV 3.3×2.5mm^2 with the resolution of 1392 pixel (h)×1040 pixel (v). One pixel within the FOV corresponds to 2.3㎛×2.4㎛. This is again subdivided with the sub-pixel of 0.23㎛×0.24㎛ corresponding to 1/10 by a soft program. Therefore, it is judged to be sufficient as the vision performance for the present development. In the meantime, in order to obtain clearer image, this is supplemented with the LED outside lightning with a function of controlling lighting sensitivity in addition to the coaxial lightning and in order to reduce the error of the same image caused due to the outside vibration, the CCD camera is supported by means of a bracket.

3. Characteristic Evaluation of Alignment System

3. 1 Stage Characteristic

The UVW type of stage driven with a servo motor requires the very precision repeatability and position accuracy between X and Y axes. When implementing the alignment within ±3 ㎛, the process TACT and the off-set (movement of x and y axes) between the substrate and the mask are a reference capable of judging the performance of the alignment system. In the stage system, the measurement results through the repetition ten times from the starting point (0 ㎛) to 5 ㎛ for each of X and Y axes are shown in [FIG. 5]. [FIG. 5] shows a result of repeating ten times with the pattern moving the X-axis of the stage from the starting point (0 ㎛) to 5 ㎛ in a + direction and then back returning it to the starting point (0 ㎛), since all the points are positioned within the space with thin color, the repeatability with ±1 ㎛ or less is shown. Likewise, as a result of evaluating the characteristic of the repeatability in the aforementioned scheme for the Y-axis, the same results as the X-axis are shown.

0 ~ 5um		1		2		3		4		5		6		7		8		9		10	
		shift	origin	shift	origin	shift	origin	shift	origin	shift	origin	shift	origin	shift	origin	shift	origin	shift	origin	shift	origin
X-axis	X1	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
	X2	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
Measurement (um)	X	5.0	-0.4	5.0	-0.4	5.2	-0.4	5.2	-0.5	5.4	-0.4	5.4	-0.3	5.4	-0.5	5.5	-0.4	5.6	-0.6	5.4	-0.5
Y-axis	Y	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
Measurement (um)	Y	4.5	-0.8	4.9	-0.9	5.0	-0.9	4.9	-0.9	4.9	-0.9	4.5	-1.0	4.9	-1.0	4.9	-1.0	4.8	-1.0	4.8	-0.9



[FIG. 5] A result of X-axis & Y-axis stage repeatability

As another characteristic evaluating item of the present state, the position accuracy is referred to as the performance judging how accurately the axes are moved within the range of the minimum error when moving a constant section from the current position. For each of the X and Y axes, the characteristic of the position accuracy is shown [Table 2] by moving a constant section in order of [0 ㎛ → 5 ㎛ → 10 ㎛ → 20 ㎛ → 30 ㎛ → 50 ㎛(from a + direction to back a starting point that is a – direction) → 30 ㎛ → 20 ㎛ → 10 ㎛ → 5 ㎛ → 0 ㎛]. All the X and Y axes are positioned in the area within ±1 ㎛ in the referenced section. As a result, it can be appreciated that the stage used in the present development has reliability as the large area alignment system.

(Unit um)

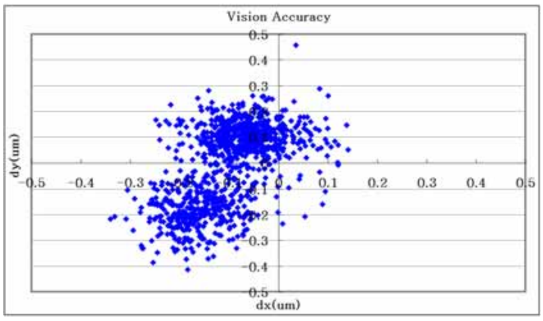
X-axis	0	5	10	20	30	50
(+ direction)	0.0	4.3	9.3	19.4	29.3	49.3
(- direction)	0.1	4.6	9.9	19.9	29.1	
(+ direction)	0.0	4.5	9.6	19.6	29.5	49.4
(- direction)	-0.1	4.5	9.7	19.5	28.8	
(+ direction)	0.0	4.3	9.6	19.7	29.6	49.6
(- direction)	-0.1	4.9	10.0	20.0	29.2	
(+ direction)	0.0	4.5	9.6	19.6	29.6	49.5
(- direction)	-0.1	4.9	9.9	19.9	29.1	
(+ direction)	0.0	4.4	9.6	19.6	29.6	49.5
(- direction)	-0.1	4.8	9.7	19.9	29.0	

Y-axis	0	5	10	20	30	50
(+ direction)	0.0	5.0	9.9	19.8	29.9	49.8
(- direction)	0.2	4.9	10.4	20.5	29.4	
(+ direction)	0.0	5.0	9.9	20.2	30.2	50.2
(- direction)	0.3	4.9	10.5	20.6	29.2	
(+ direction)	0.0	5.1	10.2	20.2	30.3	50.5
(- direction)	0.3	5.0	10.5	20.7	29.3	
(+ direction)	0.0	4.9	10.0	20.4	30.4	50.5
(- direction)	0.3	5.0	10.5	20.7	29.5	
(+ direction)	0.0	4.9	9.9	20.1	30.4	50.3
(- direction)	0.1	4.9	10.4	20.7	29.7	

[Table 2] A result of X-axis & Y-axis stage position accuracy

3.2 Characteristic of Vision Accuracy

If the precision align is not achieved by make the small pitch between pixels in order to produce the OLED display with high resolution, the misalignment such as the infiltration of other colors, etc., occurs so that it is difficult to produce the panel. The image of the align mark, which is repetitively extracted several hundreds times, should have little errors at the same position as the extraction of the clear image of each mark in the alignment process of the substrate and the mask. In the article, the results of measuring each mark 1000 times in the state where the alignment of the substrate and the mask is completed is shown in [FIG. 6].

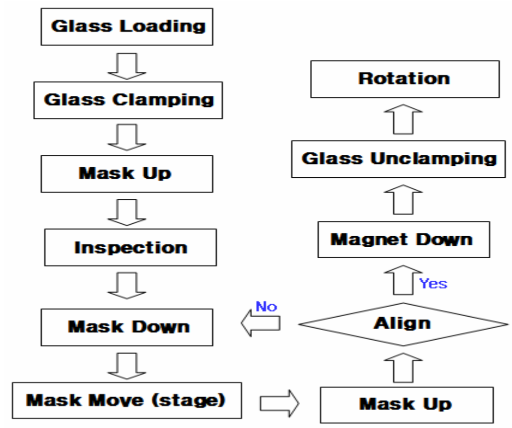


[Fig. 6] Vision Accuracy at an evaporation position and a measurement result 1000 times

This represents the difference of the alignment values measured each time for the alignment values (dx, dy) measured through the vision. It can be appreciated that this difference is within the error range of ±0.5 ㎛ over all the times. It can be judged from the result measured every time that the alignment mark is extracted as the same image in the vision and the degree that the outside vibration having an effect on the vision and the mark, that is, the outside vibration factors such as the cryo pump, etc. have an effect on the image extraction is small enough to be negligible.

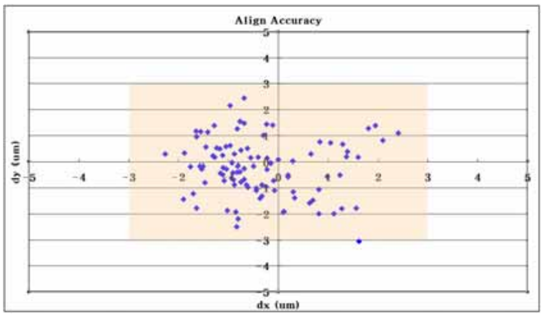
3.3 Characteristic of Align accuracy & Align Process TACT

The flow chart of the alignment process up to the step before the evaporation in the substrate transfer from the outside can be shown as in [Table 3].

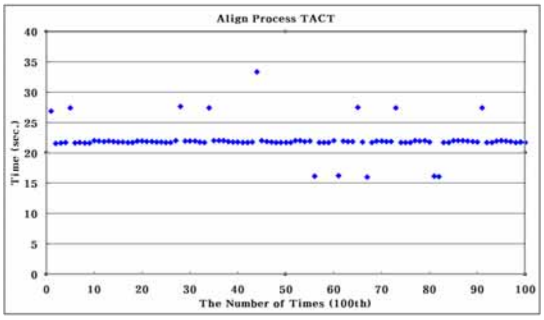


[Table 3] An align flow chart

The alignment process of the substrate and the mask is progressed in the aforementioned order and the alignment within ±3 ㎛ is shown as in [Fig. 7] by inputting 100 different substrates. At this time, the process TACT of the progressed alignment process is shown in [Fig. 8]. The time consumed in the alignment process is completed within 30 sec. and is indicated at 22.1 sec. on an average.



[FIG. 7] A measurement result 100 times



[Fig. 8] A measurement result of an align TACT time 100 times

4. Conclusion

The development process of the alignment system for producing the OLED panel using the large area substrate (fourth-generation) and the characteristic of the produced alignment system will be described. At the point in time where the interest in the large area and high resolution AMOLED TV has been gradually increased, the alignment system between the TFT back plane substrate and the metal mask in the OLED evaporation process is recognized as a core technique required for the midsize and large AMOLED panel by using the large sized substrate. It is expected that the present development advances the technique for producing the midsize and large AMOLED. The system disclosed in the article is the alignment system of the upward evaporation manner using the small molecular organic materials developed by Doosan Mecatec and the development of the evaporation system is simultaneously under developing using the extra-large AMOLED substrate through the vertical type of the alignment system development to be corresponded to the next-generation extra-large glass substrate.

5. References

[1] FPD International 2007
[2] KR Patent, 10-2005-0094149
[3] JP Patent, 2002-0019030
[4] JP Patent, 2002-0062045
[5] JP Patent, 10-2007-0049689