Print ISSN: 1738-3110 / Online ISSN 2093-7717
http://dx.doi.org/10.15722/jds.17.04.201904.51

The Development of New Cost-Effective Optimization Technology for OLED Market Entry

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Received: March 15, 2019. Revised: April 05, 2019. Accepted: April 05, 2019.

Abstract

Purpose - This study aims to improve the distribution structure of the OLED market and develop cost-effective optimization techniques. Specifically, it is a study on the optimization of ferric chloride to improve the etch of SUS MASK for OLED.

Research design, data, and methodology - Applying the optimal conditions of the experiment, the final confirmation was evaluated for improvement by the Process Capability Index (Cpk). It is possible to derive social performance such as improvement of precision of SUS MASK manufacturing, economic performance such as defect rate, reduction of waste generation and treatment cost, technological achievement such as SUS MASK production technology, improvement of profit structure of technology development and process improvement do.

Results - The improvement of the Cpk before the improvement was made was confirmed to be 0.57% with a defect estimate of 25.07% with a failure estimate of 0.57% after the improvement, and 8.84% with a failure estimate of 0.57% level after the improvement.

Conclusions - If the conclusions obtained from the specimen experiment are applied to the manufacturing process of SUS MASK, it will be possible to expect excellent cost-effective competitiveness due to the improvement of precision and reduction of defect rate to enhance the OLED market penetration.

Keywords: SUS MASK, OLED Market Penetration, Cost-effective Optimization Technology Development, ORP, Process Capability Index.

JEL Classifications: M3, H8, I11.

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1. Introduction and theoretical background

1.1. Introduction

New technological developments or innovations tend to replace traditional markets and create new markets. The replacement of older generation technological products with the newer generation ones is common in the high-technology sector(Tseng et al., 2009).

As the performance level of electronic devices such as TV and smart phones is continuously increasing by the demand of consumers, device components should also be developed to be compatible with the high-performance electronic products(Heo et. al., 2015).

The current international economic trend can be characterized as that of pursuing globalization(Zhang & Lee, 2017).

In the flat panel displays (FPDS), the organic light-emitting diode (OLED) display is attracting considerable interest, because it is much thinner, lighter, and more flexible than liquid crystal display (LCD)(Chen et al., 2013). The OLED display market is analyzed based on key applications such as mobile phones, TVs, notebooks, tablets, digital cameras and automobiles.

As a result, the demand for SUS MASK, which is used for electrostatic Chuck of Semiconductor Wafer (ESC), is also expected to increase(Elp et al., 2004).

SUS MASK is a MASK that designs circuits on glass substrates for OLEDs that require high resolution, and

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requires electrostatic precipitations that produce static electricity to maintain a constant gap between the substrate and the lower electrode in the naming process. It is a mask for deposition of the dielectric film that requires ultra-precision and uniformity(Kim & Brugger, 2004).

Photosynthesis technology is applied to various types of industrial parts, including electronic parts and automotive parts, where photos are taken using photomasks made of glass or polyester film and applied to various industrial parts such as electronic parts and automotive parts(Ahn & Lee, 2011). These naming techniques are used to etch the materials of copper alloys ($CuCl_2$) and to etch the materials of stainless steel alloys ($FeCl_3$)(Lee & Lee, 2019).

Copper(Ⅱ) Chloride is a pet manufacturing technology for PCB printed circuit boards, and while photo-adaptation technology using $FeCl_3$ has advantages of alloying materials such as SUS and Nickel (Ni), which are difficult to corrode(Xu et al., 2016).

The conventional SUS MASK production method using ferric chloride is a method in which ferric chloride is continuously supplied in a countercurrent manner and adjusted according to pH and oxidation-reduction potential (ORP).

Also, SiO_2 is used in fabricating optical wave guides and it is employed as an etching mask for optical gratings(Lee et al., 2009).

Although this method provides excellent product maintenance for the precision and uniformity of the etching hall, the unit cost of the component is very high due to the rise in manufacturing cost(Heravi et al., 2009).

Since it is difficult to apply an automatic liquid management system due to the increase in impurities caused by the various ingredients contained in the material for petting purposes (Ni, Cr, C, etc.), there are limitations in managing precision and uniformity of processed products in South Korea as it is not easy to apply the automatic liquid management system once used.

In addition, the value of ORP also changed due to decreased reproducibility due to changes in drug concentration, increased metal content, and impurities, and changed the value of ORP not only hinders the processing and productivity of the etching parts requiring ultra-precision, but also excessive waste caused by the increase in drug usage, which has resulted in many problems in environmental pollution as well as disposal costs(Mijangos et al., 2018).

Therefore, in this study, we developed a laboratory scale automatic liquid management system to derive the nicking factors such as specific gravity, injection pressure, and ORP using ferric chloride ($FeCl_3$) as the nicking solution, and used SUS MASK precision for OLED, we will seek to improve the distribution structure of the efficient organic light emitting diode market and optimize the cost-effective process by suggesting optimized conditions that improve the quality and reduce the defect rate of the product.

1.2. Theoretical background

OLED displays are supposed to enjoy high market penetration due to their biodegradable advantages. In addition, as demand and supply gaps around the world increase, OLED displays are creating a new energy-efficient way to consume power. Because of very thin active layers (several 10–100 nm), the low material amount used for the production of OLED results in cheap and lightweight products(Eritt et al., 2009).

OLED displays are said to save up to 40% of power for mobile phones and TVs depending on brightness and content. OLED display displays a wide range of colors, increased number of times of display repaints data, improved 3D adaptability, thinner dimensions, improved flexibility and transparency. During the past few years, LED-based lighting products have achieved significant market acceptance while OLED-based lighting products are poised for tremendous market growth in the near future(Williams, 2015).

In recent years, there has been a drastic reduction of patents related to LCD technologies, which suggests that next-generation OLED technology is penetrating the TV market, and a high level of maturity is expected by 2026(Cho & Daim, 2016). Guedes et al.(2014) have studied that the thin film obtained by the deposition of PANI, prepared in perchloric acid solution, was identified through PANI-X1.

Zyczkowska and Konarzewska(2016) explore to show technical aspects of new materiality - intelligent materials, allowing transmission of changeable visual content (like powerglass, GKD mediamesh, IMAGIC WEAVE, TEXLON lexipix, ETTLIN lux, OLED technology) and interaction between a user and space, so as spatial aspects of this new materiality. Taydakov et al.(2016) studied effective electroluminescent materials for OLED applications based on lanthanide 1.3-diketonates bearing pyrazole moiety. And, blue fluorescent OLED materials and their application for high-performance devices were studied by Kuma and Hosokawa(2014). Khaoula and Azzedine (2014) compared difference modeling of single layer organic light emitting diode “OLED” with DP-PPv. And Xiong et al(2017) explored Performance analysis of multi-primary color display based on OLEDs/PLEDs.

In the last year, Bizzarri et al.(2018) studied Sustainable metal complexes for organic light-emitting diodes (OLEDs). Recently, Wang et al.(2019) analysed high-performance red organic light-emitting diodes with ultrathin Cu film as anodes.

It is predicted that global markets for OLED TVs will grow rapidly in South Korea and abroad due to increased demands for OLED TVs, smart phones and etc.

Table 1: Differences and similarities feature of the precedent study

Studies	Differences	Similarities
Bizzarri et al. (2018)	Sustainable metal complexes for organic light-emitting diodes (OLEDs)	cost-efficiency, lightening, new technology, thin
Cho & Daim (2016)	technology forecasting, energy consumption, oled, led, pdp, lcd	
Eritt et al. (2009)	OLED; indium–tin oxide (ITO); vacuum thermal evaporation	
Guedes et al. (2014)	develop optoelectronic technology	
Khaoula & Azzedine (2014)	difference modeling of single layer organic light emitting diode “OLED” and DP-PPV	
Kuma & Hosokawa(2014)	blue fluorescent OLED materials and their application for high-performance devices	
Taydakov et al. (2016)	developing effective electroluminescent materials	
Wang et al. (2019)	studying high-performance red organic light-emitting diodes with ultrathin Cu film	
Williams(2015)	developing pixelligent technologies	
Xiong et al. (2017)	multi-primary color display based on organic/polymer light-emitting diodes	

2. Research method

2.1. Experimental device for optimizing the affinity of SUS MASK

For the purpose of this experiment, the automatic liquid management system was manufactured from main & sensor controller, flow sensor, ORP, hydrometer, pH, injection pressure device, and quantitative pump, and transmitted data collected from the sensor to the PC in real time, and applied to the manufacture of the SUS MASK specimen.

2.2. Changes in velocity due to the increase in the specific gravity of the affectionate fluid

In order to investigate the effect of the specific gravity of the nicking solution on the nicking properties, the variation of the nicking rate by the specific gravity 1.43~1.49 was examined by mixing hydrochloric acid (38%) and water at the ratio of 6 to 4.

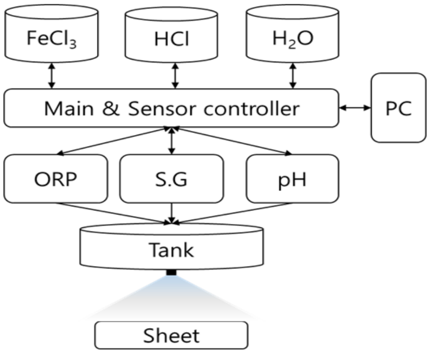


Figure 1: Automatic liquid management system for etching optimization

2.3. Injection pressure on affinity

In order to confirm the optimal spraying pressure, we measured 0.5kg/㎠ increments with 2.0~3.5kg/㎠ interval, and the deviation and cross section of SUS MASK hole position were verified by using a vision meter.

2.4. Deriving optimal ORP values

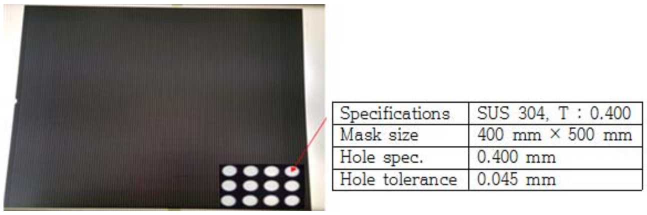
In order to fix the specific gravity value obtained from the optimal ORP value extraction experiment, the specific value of the new ORP was adjusted to 628 to 608 mV in order to derive the optimal ORP, and 200 sheets were prepared and recorded in units of 10.

2.5. SUS Mask multiple hall analysis

The SUS mask used to verify the accuracy and accuracy of the etching used was a stainless steel material (0.4T x 400mm x 500mm) with multiple holes Ø 0.400mm (tolerance: ±0.045mm).

Analysis of the characteristic hole deviation by weight uses 20 sheets, and sampling divided the nominal fluid section into 7 sections, analyzed the hole dimensions on a total of 1 sheet, and then determined the range of work (maximum to peak value). The Process Capability Index (Cheong, 2015) used for the capability evaluation was compared before and after improvement by measuring 25 points per sheet of 200 sheets in units. While the balanced scorecard is simply an indicator of the company's business diagnosis(Kim & Hyun, 2017), process capability indices (PCIs), Cp, Ca, Cpk, Cpm, and Cpmk have been developed in certain manufacturing industry as capability measures based on various criteria, including process consistency, process departure from a target, process yield, and process loss(Wu et al., 2009).

The dimensions of these SUS Masks, the hole diameter is Fig. 2. As shown in Fig. 2, the final verification of multiple hole deviations was conducted with a contactless three-dimensional meter at the request of the Korea Chemical Convergence Testing Institute (KTR).



Specifications	SUS 304, T : 0.400
Mask size	400 mm × 500 mm
Hole spec.	0.400 mm
Hole tolerance	0.045 mm

Figure 2: SUS MASK multiple holes

3. Research result

3.1. The change in the petticoat speed by weight

Observing the change in the petticoat according to the weight, the speed of the petticoat was reduced from 0.54 m/min to 0.53m/min as shown in Table 2. This can be said to be the result of the decrease in the moving speed of the affectionate solution in the petticoat as the portion of the affectionate liquid increases depending on the nominal speed.

Table 2: Specific gravity according to etching rate

S.G.	1.43	1.44	1.45	1.46	1.47	1.48	1.49
Etchant Velocity. (m/min)	0.54	0.54	0.53	0.53	0.52	0.51	0.49

3.1.1 Center hall deviation by weight

The SUS MASK sheet was divided into 20 areas, measured by location, and the center hole deviation was analyzed as shown in Fig. 3. The average value is 0.414 mm, with a peak value of 0.352mm and a maximum value of 0.467mm, the range of work being 0.115mm is found to be within the range of ±0.0575mm.

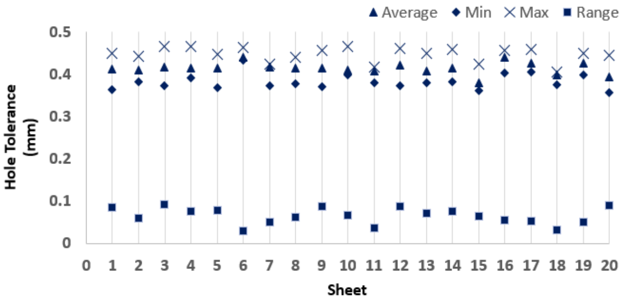


Figure 3: Specific gravity according to etching hole deviation

3.1.2 Analysis of SUS MASK section with variation of weight

The SUS MASK section is Fig. 4 according to the weight of the sections 1.43 to 1.49. It turned out like Fig. 4. It has been confirmed that the processing cross section of the affectionate penetration will be uniformed as the weight increases to 1.46, but from the beginning of section 1.47, the etching will disappear due to the collapse of the etching side, which can be attributed to the high concentration of the etching. Etch factors are initially high at small depths of etch or etch deltas and gradually decrease, becoming constant as etching progresses(Moscony et al., 1996). Based on the results of the experiment, it is believed that additional experiments will be needed by dividing the specific gravity range into a more detailed section.

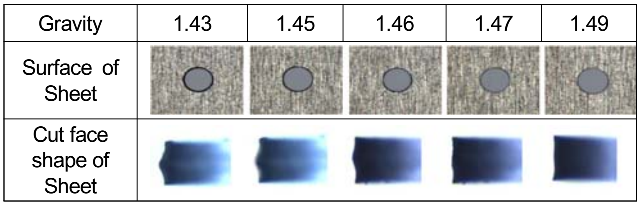


Figure 4: Specific gravity according to etching section and shape

3.2. Changes in injection pressure on the affinity

The nominal injection pressure is shown as a deviation for each hole position as shown in Table 3. As a result, the average pressure indicates that the deviation value by average location is reduced to improve precision. In the case of working range, the nominal pressure of 3.0kg/㎠ is reduced to 3.5kg/㎠, and 3.0kg/㎠ is considered optimal when compared to other injection pressures to secure the naming and working process.

Table 3: Etching injection pressure change according to hole position deviation value

Division	Average	Min.	Max	Range
2.0kg/cm^2	0.414	0.358	0.459	0.101
2.5kg/cm^2	0.402	0.356	0.455	0.099
3.0kg/cm^2	0.396	0.352	0.447	0.095
3.5kg/cm^2	0.392	0.351	0.448	0.097

3.3. Optimal ORP change rate analysis

The new fluid ORP value is measured at 628 mV and the results of continuous measurements up to 608 mV are expressed as frequency. It is shown as Fig. 5. The results showed a sharp decrease in frequency at 4 times, 609 mV and 610 mV respectively at 608 mV and above 610 mV.

Therefore, it was confirmed that 610 mV is optimal for securing process stability based on frequency.

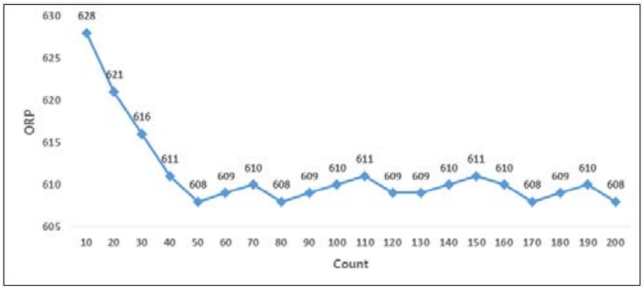


Figure 5: ORP value according to frequency change

3.4. Final evaluation and results

For final evaluation of SUS mask for deposition of dielectric membranes for OLED, the concentration of gravity, injection pressure, 3.0kg/㎥, ORP 610 mV, and factors derived from the above experiment were applied to compare the value of Cpk before and after introduction of the automated liquid management system. As shown in Fig. 6, the improvement of the Cpk before the improvement was made was confirmed to be 0.31% with a defect estimate of 25.07% with a failure estimate of 0.57% after the improvement, and 8.84% with a failure estimate of 0.57 level after the improvement.

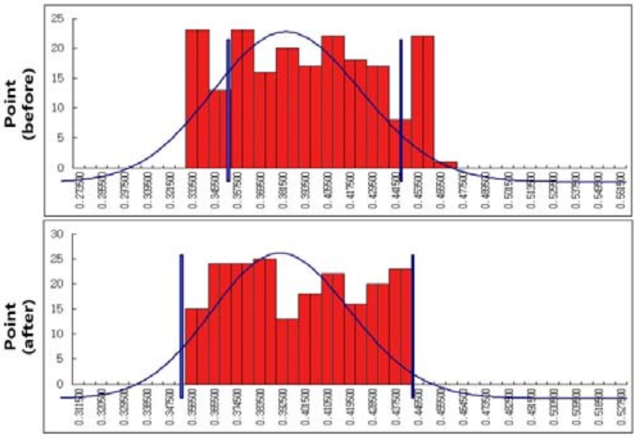


Figure 6: Cpk of automatic liquid management system of introduction before and after

4. Conclusion

Were the first devices based on organic materials produced on a large scale and have revolutionized the display industry by offering hardware that consumes much less power and offers higher quality, in addition to using less physical space(Belyaev et al., 2017).

Display manufacturers are investing heavily into production lines for OLED displays(Mai & Richerzhagen, 2007). In order to fully realize the potential of AMOLEDs(Active-Matrix Organic Light-Emitting Diode), manufacturing methods must be developed for large glass sizes that result in a significant cost advantage compared to the alternate technology of LCD(O'Regan, 2008).

In this study, the automatic liquid management system was constructed and applied to the manufacturing process of SUS MASK for OLED, which requires high precision by using Copper(Ⅱ) Chloride to derive optimized etching conditions.

1) The petticoat speed for the specific gravity was low to 0.53m/min, but the petticoat speed for the 1.47 to 1.49m/min sections was drastically reduced to 0.52m/min to 0.49m/min.

2) Analysis of the deviation dimensions by center hole location by weight revealed that the mean value is 0.414mm, the maximum value is 0.352 mm, and the maximum value is 0.477mm, with a range of 0.115mm, which is within the range of ±0.075 mm.

3) The processing section and shape by the specific gravity section were homogeneous on the processing side of the nominal perforation, but with the addition of and the affection for the section 1.47.

4) Tests of changing the nominal injection pressure from 2.0 to 3.5kg/㎠ show high precision and workability when applied with 3.0kg/㎠.

5) The 200 sheets were used to show the ORP values measured in frequency, indicating that 610 mV was the best.

6) In an experiment to identify before and after the process improvement of the etching property, the Cpk value before the improvement was 0.31, and the poor prediction value was 25.07%. The Cpk value after the improvement was 0.57, which was 8.84%, indicating that the process improvement effect was 16.23%.

If the conclusions obtained from the specimen experiment are applied to the manufacturing process of SUS MASK, it will be possible to expect excellent cost-effective competitiveness due to the improvement of precision and reduction of defect rate. Also, as shown in the Jung et al.'s study(2018), cost-effective technology demand will be very helpful for the future of OLED market. Cost-Effective technology is expected to contribute to improving the production and distribution structure of the OLED market in the Southeast Asian market as well as in the global display market penetration. As a result of the economic ripple effects of the OLED lighting industry through the industry-related analysis in korea, it is estimated that the total output will amount to about KRW 9.2 trillion by 2011-2020, the total value added will be about KRW 2.8 trillion and the total employment inducement will reach about 39,000(Kim & Shim, 2011).

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