A Study on Black-Matrix CMP Technology for Automotive On-Cell Louver Micro Structure

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Abstract

In this study, we have investigated the charcteristics of organic black matrix(BM) chemical mechanical plarnarization(CMP). Starting from simulation based on the several parameters, we have successfully obtained process capabilities at 6G-half glass. Experimental results suggest that the mechanism of BM CMP is more dependent upon physical effects rather than chemical reactions and the dynamics of slurry flow. Using CMP technology we developed, on-cell-louver(OCL) micro structure was prepared has shown the 75 % of front transmittance luminance and 3 % at the 45 cut-off angle.

Author Keywords

Organic BM CMP; automotive display; OCL; Cut-off; front luminance

1. Introduction

Active-Matrix Organic Light-emitting-diode (AMOLED) panel development that mounted along the front surface shape of the vehicle has increased so that it mounted easily on the front area. Therefore, recently, due to problems such as increased cost and inability to internalize technology, the development of panels for vehicles, such as deploying functional optical systems that replace the light control films (LCFs) on AMOLED panels [1, 2].

In order to implement SPM using selective light control structure of AMOLED panels, the light going left, right, up, and down controlled through a column-shaped optical system, which called OCL as an optical system that attached above onto the AMOLED panels [3, 4].

Direction of light must be controlled through a columnar optical system with several tens of ㎛ thickness, and a light path is made using a black material to block the light, and an organic planarization process is used to remove overflowing black organic material as shown in fig. 1.

In this paper, by the large organic film planarization process [5-7] after filling the black resin into the column structure at a large glass substrate we could uniformly remove the overflowing black resin materials. There were several report to ensure uniformity and polishing amount, a large area planarization process for display application was firstly introduced in SID 2024 [8, 9].

At first, we understood a large area of Oscar-type polishing machine and performed trajectory density simulation according to parameters of the equiments to reduce attempts and errors for the polishing uniformity. As the demand for flattening large-area substrate of the display has recently increased, various type of equipments are studied.

2. Experimental

The planarization method used in this study is similar to the rotary CMP facility commercialized in conventional semiconductors as shown in fig. 2, and the entire square shape substrate placed on a rotating lower plate one by one. When the lower plate rotate, pressure applied by the weight of the upper plate, which left and right oscillaton perform for large-scale polishing. The size of the glass is half Gen 6 (size of half generation 6, 1500×925 mm^2).

Since the thickness of the glass are less than 0.5 mm and the size is half Gen 6, the facility configured by loading it on the lower rotating plate of the body, and it called face up method, meaning that the polishing surface is facing up. To make the OCL micro structures on a large area substrate, columnar structures made by deep dry etching method. After the process of filling resin in the deep OCL hole the overflowing black resin removed by a rotary CMP equipment as shown in fig 1. An acrylic black matrix (BM) was used as an opaque black resin to block the light.

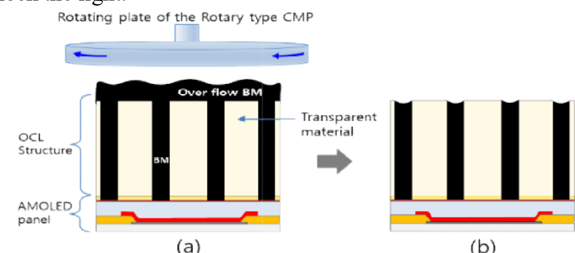

Fig. 1. Schematic diagram of micro structure of OCL in automotive display ; before CMP (a) and after CMP (b).

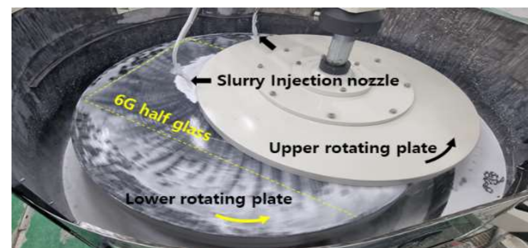

Fig. 2. Operation image of the rotary type CMP equipment capable of processing 6G half glass substrate.

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3. Results and Discussion

3.1 Trajectory density simulation:

Before the polishing evaluation, we check the exact dimensions of the large-area rotary equipment and trajectory simulations performed to reduce the trials before actual large area CMP tests shown in fig. 3.

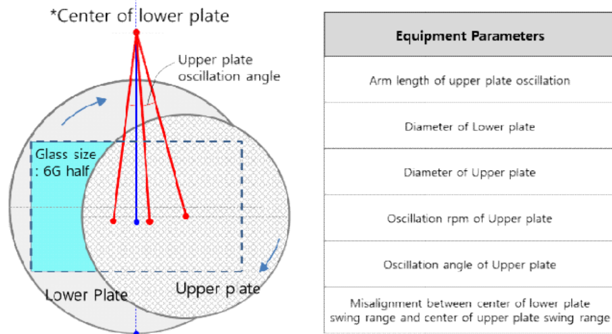


Fig. 3. Schematic diagram of the rotary type CMP and its parameters.

Tabel. 1 Simulation results of the several paramers: trajectory density map and uniformity value of the map: uniformity value is arbitrary number.

Diameter of Upper Plate (mm)	a mm	b mm	c mm
Map & Uniformity value (arb. unit)	1.00	0.91	0.77
Oscillation speed of Upper plate (rpm)	d	e	f
Map & Uniformity value (arb. unit)	0.77	0.75	0.75
Oscillation angle of Upper plate (degree)	g °	h °	i °
Map & Uniformity value (arb. unit)	0.86	0.77	0.72

Table 1 shows the trajectory density simulation results according to the facility parameter, confirmed that a circular map with a high density in the center and a low density in the outer part of the large area rotary facility occurred. In order to improve the uniformity of the residual layer after polishing and to reduce the times of the tests, the trend of trajectory density due to parameter change was pre-confirmed.

As increasing the diameter and swing angle of the upper rotation plate the uniformity value of the trajectory density decreased. The uniformity of the trajectory density saturated at the value of 0.75 as increasing the oscillation speed of the upper plate. Low uniformity value is arbitrary unit and it means the better uniformity.

3.2 Removal amount and uniformity:

The initial thickness before polishing was the level of average 5.47 ㎛ and its initial film uniformity to 10 %, and after polishing, the residual film thickness was 4 ㎛ or less, there by securing a condition in which the polishing amount was above 1.5 ㎛ as shown in fig. 4 and fig. 5.

Map images in fig. 5 shows the uniformity of the residual film thickness increased from 10% to about 32.9% after polishing, but by changing the parameters to improve the uniformity. We obtained level of 10.5 % after polishing, which is similar to uniformity of the initial thickness.

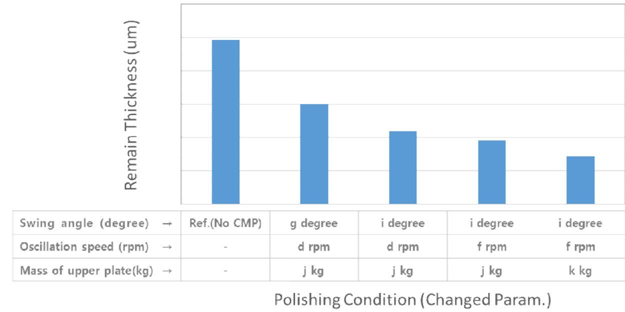
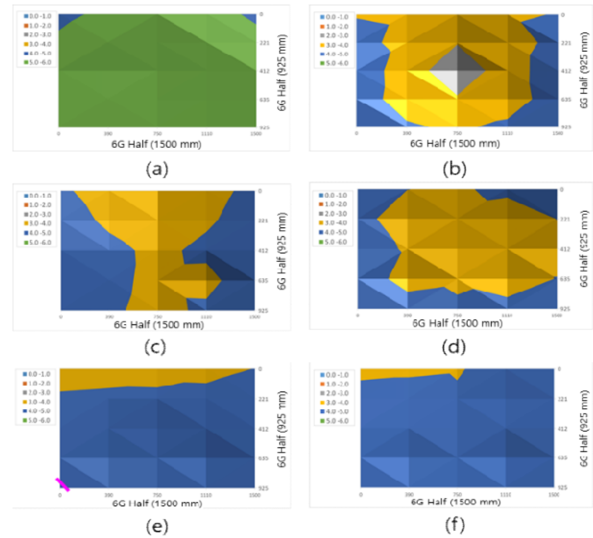


Fig. 4. Remain thickness of the organic BM layer after CMP process according to the polishing parameter.



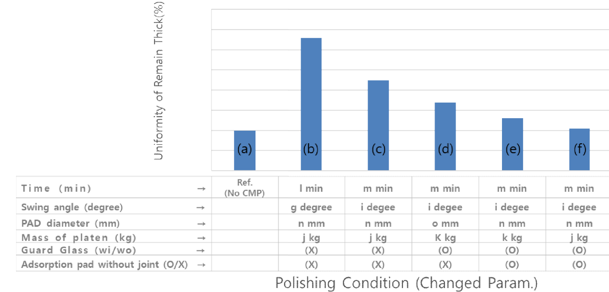


Fig. 5. Maps of the remained thickness of BM layer and uniformity (%) after CMP process according to the polishing condition. Uniformity of remain thickness (%) ; (max-min)/(max+min)*100

As increasing the swing angle and polishing pad diameter of the upper rotating plate the uniformity (%) of the remain thickness decrease. As increasin the polishing time and mass of the rotating plate, the uniformity (%) decreased but the removal amount increased. We used the guard glass to develop the uniformity (%) of the remianed thickness by preventing the rotating plate tilting. The glass substrate should be attached on

the adsorption pad onto the lower rotating plating. The adsorption pad is an elastic pad made of rubber material, and the elasticity of the adsorption pad during polishing plays an important role in polishing quality. These glass adsorption pads should be made of one piece without joints, and when there are joints, elasticity decreases due to wetting caused by the slurry penetration into the joints, and uniformity (%) decreases as shown in fig.5 (b), (c), (d).

The upper plate performs an oscillating motion from left to right while circularly moving, and as the oscillating swing cycle increased and the density of the trajectory decreased, the uniformity of abrasive trajectory density decreased as shwon in fig. 5. The weight of the plate decreased as the rotational speed of the plate decreased, and the uniformity and trajectory density decreased in the simulation results as in fig. 5. Therefore, the level of residual film uniformity after actual polishing improved according to the above conditions.

3.3 Mechanism of Organic BM CMP

To compare the polishing mechanism between organic BM CMP and conventional non-organic CMP, an inter layer deposition(ILD) thin film and an organic BM film were prepared in 2G (Gen 2 size: 370×470 mm^2)substrate.

Gen 2 size of rotary equipment was evaluated using face down type [10]. Face down type means that the method of inverting and attaching the glass substrate onto the upper plate and attaching the polishing pad to the lower plate as shown in fig 6 (b).The face down method is a structure in which slurry inflow into the center of the substrate easily through the pad grooves compared to the face up method [11], and the face down method of all conventional semiconductor processes generally adopted. However, when using a large-area glass substrate, face up method used due to the advantage of the glass handling as shown in fig.6 (a).

In case of conventional ILD CMP, despite the fact that the slurry inflow into the center area of the substrate easily through the pad grooves compared to the face-up method. The polishing amount of the ILD film is lower than that of the BM film, so the map of the center low, where is less polished as shown in fig. 7 (a).The wt.% of wet ceria abrasive is low and viscosity is close to 1 cP in deionized (DI) water, so even if slurry inflow is easy, the abrasive amount in the center is low. This is because slurry circulation is essential to help chemical reactions on the ILD surface, and slurry circulation, which is still valid, is insufficient due to the large substrate [12-14]. Even though the open pore structure of the suede pad that can hold the slurry and a rotary facility designed to have a high density of the trajectory at the center area, it seems that additional slurry flow improvement needed to increase the polishing amount into the center in ILD CMP.

However, in case of organic BM film, a center high polishing amount map obtained as shown in fig. 7(b). Therefore, in case of BM CMP, the flow rate of slurry abrasive is not important than that of conventional ILD CMP.

Fig. 8 (a) shows the polishing mechanism of the inorganic conventional ILD CMP and acrylic organic BM CMP. The lower part of fig. 8 shows the polishing schematic diagram and chemical reaction formula with Ceria abrasive, which mediates actual polishing between the target material and the Suede PAD.

When the ILD surface becomes Si-OH on the surface by hydration reaction, and the Ceria abrasives form Si-O-Ce on the surface polished by combining and removing on the surface. Ceria abrasives in the slurry react with the ILD surface, continuous inflow and discharge of Ceria abrasives to polish the ILD layer effectively. Fig. 8(b) also shows an abrasive polishing mechanism on acrylic organic BM CMP. A Ceria and Zirconia abrasives intervene between the target film on the lower substrate and Suede pad pores on the upper plate.

In case of the organic films, a mechanism in which the abrasive pressure and time increase proportionally depending on the physical factors of the abrasives. Zirconia abrasive with a particle size of 10 to 20 times larger than the ceria abrasives, showing a schematic diagram in which the abrasive amount does not change significantly due to chemical reaction. These are major factors, which affect the amount of polishing, and it shows that mechanism in which the amount of polishing increases due to physical parameters rather than chemical ones is the main polishing mechanism of organic BM CMP [15-16].

Mechanism of BM CMP is more dependent upon physical effects rather than chemical reactions and the dynamics of slurry flow.

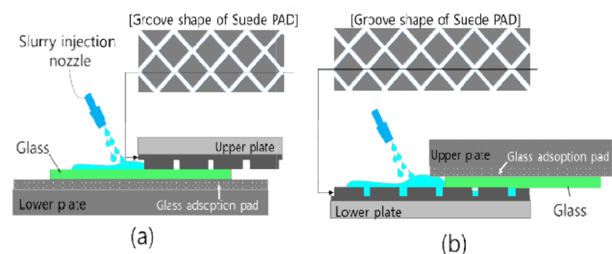


Fig. 6. Face up type CMP (a) and face down type CMP (b) schematic diagram of slurry injection between suede PAD and glass substrate.

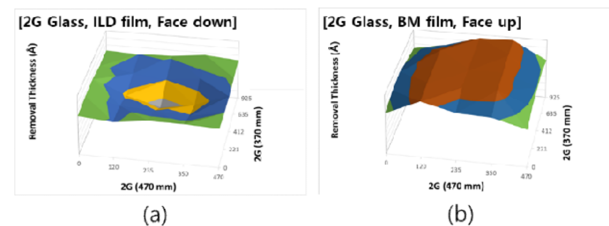


Fig. 7. Maps of the removal thickness after CMP; Conventional ILD CMP(a), organic BM CMP (b) on 2G glass.

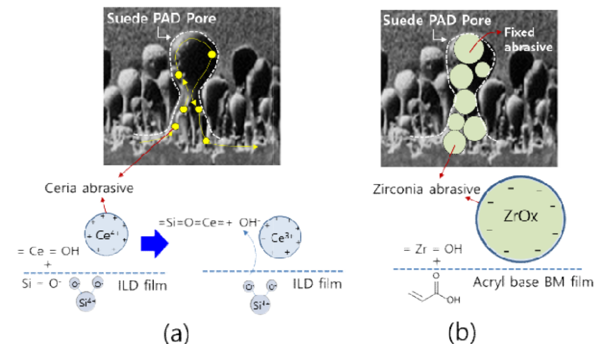


Fig. 8. Normal schematic diagram of abrasive behavior in the inorganic ILD CMP (a) and acrylic organic BM CMP (b)

3.4 OCL structure Formation for automotive:

Fig. 9 shows the cross sectional SEM images of the OCL structures before (a) and after (b) the BM CMP. We check the dishing amount about 0.3 μm as shown in the images (c) in fig 10. The dishing due to the removal amount between BM materials and transparent materials does not significantly affect display quality, but finally dishing should be removed through adjusting the removal rates between materials in the future.

Fig. 10 shows viewing angle differences between top view image (a) and side view image (b) of the OCL on glass substrate, and schematic diagram of visual inspection (c).

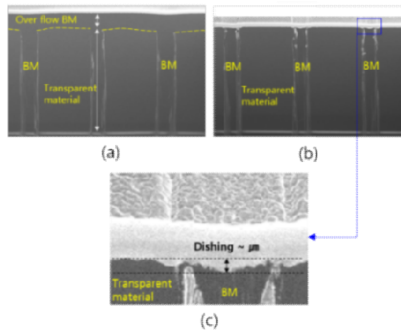


Fig. 9. Cross sectional SEM images of the OCL structures: before the BM CMP (a), after the BM CMP (b) and dishing amount after the CMP (c).

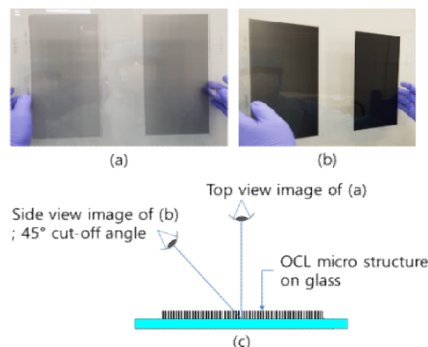


Fig. 10. Top view image (a), side view image (b) of the OCL on glass substrates, and schematic diagram of visual inspection (c).

4. Conclusion

A large-area CMP process with circle-shape rotary head equipment firstly introduced to planarize the level of the BM surface to make the OCL for automotive display. OCL onto the AMOLED panel designed to control the viewing angle of the light from the panel.

The initial thickness before polishing was average 5.47μm and its initial uniformity is about 10 %, and after polishing, the residual film thickness was 4μmor less, thereby securing a condition in which the polishing amount was above 1.5 um.

We compared the polishing mechanism between conventional inorganic ILD CMP and organic BM CMP. In case of BM CMP, it affects physical parameters more than chemical parameters compare to the inorganic ILD CMP. The slurry flow is less important in organic BM CMP.

After polishing the over-flow BM layer onto the OCL, transmittance and cut-off angle were measured to check whether the BM layer on column structure was well removed, the front transmittance luminance level of 75 % and 3 % or less at the 45 cut-off degree, confirming that the upper BM was well removed and flattened.

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