Development of Splicing-Coated Polarizers for TFT-LCDs

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Abstract
Polarizers are one of the essential components for TFT-LCDs, which directly determines the image quality of panels. Large-size TFT-LCDs have become a new trend in the market in recent years while the size of conventional polarizers limits the growth of ultra-large size LCDs. The technology of coated polarizers can realize this demand and has the potential to be directly fabricated on glass substrates. In this study, we focused on optimizing the coated process on glass to prepare a large-size polarizer. Considering the relatively high cost and low yield of a whole-surface coated polarizer, we proposed a new approach to create a splicing-coated polarizer by combining conventional polarizer films and coated polarizer. The splicing-coated polarizer was successfully fabricated at a 32-inch real panel, proving its high feasibility. This technology demonstrates great potential for integrating next-generation polarizer films into LCDs.

Author Keywords
Polarizer; Coated; TFT-LCD; Ultra large size; Splicing

1. Introduction
Large-sized thin-film transistor liquid crystal displays (TFT-LCDs) are increasingly favored by more and more customers due to their superior viewing experience.[1] However, the current maximum size that can be mass-produced is limited to 110 inches (16:9) due to the width limitation of the polarizer films.[2-3] Typical polarizers comprise various components, including polyvinyl alcohol (PVA) layers, triacetyl cellulose (TAC) layers, pressure-sensitive adhesives, protection layers, release layers, and other functional layers. Among them, the PVA layer is central in generating and filtering polarized light. The wet stretching process, which includes dissolving PVA, casting it into films, dyeing the PVA film and stretching, is commonly employed to prepare PVA films. Among these steps, the composition of the dyeing solution for PVA and the stretching orientation are critical factors that directly influence the polarization characteristics and stability of the polarizers.[4] Due to limitations in the stretching process, the maximum width of the polarizer for TFT-LCDs is restricted to 2500 mm.[5]

As shown in Figure 1, both component films and stretching equipment for polarizer films currently have a maximum width of only 2500 mm, which is just sufficient for a down polarizer utilized in 130-inch panels (2435*2800 mm). This limitation restricts the development of larger commercial TFT-LCDs. Different from the highly stretching-oriented PVA chains with iodine dyeing methods in traditional polarizers, the process of making coated polarizers involves applying polymers onto substrates and then orienting them through rubbing, photo alignment or shear force. The polarization function is realized by the sequential coating of dichroic dyes, which is inserted into the polymer layer and combined with oriented polymer chains by the intermolecular force. The coated method allows for the fabrication of polarizers on TFT-LCD glass directly in the production line, eliminating the size restriction of the traditional polarizers and enabling the commercialization of ultra-large-size TFT-LCDs. In this study, we optimized the preparation process of coated polarizers on the glass surface and proposed a new splicing method for generating large-size polarizers. The obtained coated polarizer exhibited a polarization degree of 99.77 % and was applied to 32-inch panels.

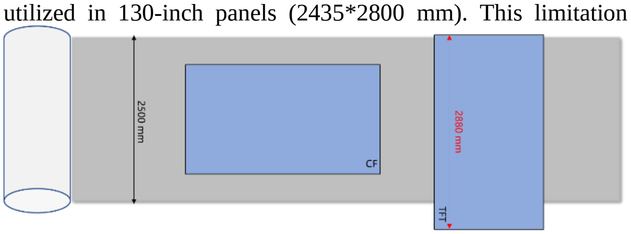

Figure 1. The comparison of the width of conventional polarizer films and the size of a 130-inch panel (16:9).

2. The structures of polarizers
As shown in Figure 2a, conventional polarizers consist of several layers including hard coater, adhesive layers, PVA, TAC and release films. [6] The sophisticated structure indicates its complex manufacturing process. Compared with the complicated structure of conventional polarizers, coated polarizers contain only one PVA layer for the conversion of circular-polarized light to linear-polarized light (Figure 2a). The preparation process of the coated polarizer in this work is shown in Figure 3. Firstly, the glass substrate was pre-treated with acetone, detergents, base and plasma, respectively. This procedure was to remove potential pollutants on its surface and increase the dyne value of the substrate, which can improve the distribution of the primer on the substrate. Secondly, the primer was coated on the glass and cured by heat to enhance the adhesion ability between the sequential alignment layer and the glass, and thus improve the orientation of the alignment layer. Thirdly, the alignment layer was coated by shear force and cured by baking. The orientation uniformity of the alignment layer determines the optical properties of the polarizer. Finally, the substrate was soaked in the iodine solution to achieve the polarization function. The excess iodine solution was cleaned with ethanol and dried with an air knife. The coated polarizer was then successfully prepared.

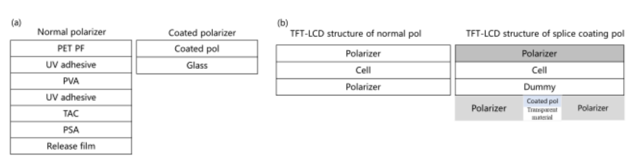

Figure 2. (a) The film construction of conventional polarizer and coated polarizer in this work. (b) The TFT-LCD structure of conventional polarizer and the splicing coated polarizer in this work.

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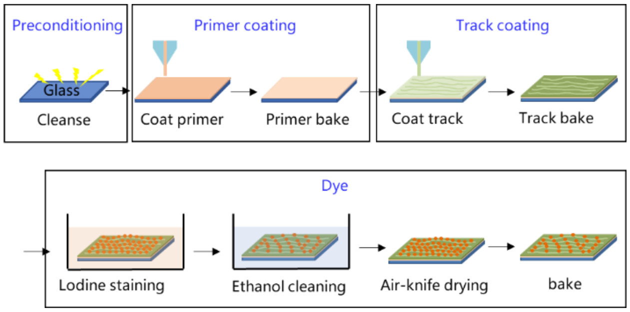


Figure 3. The preparation process of the coated polarizer.

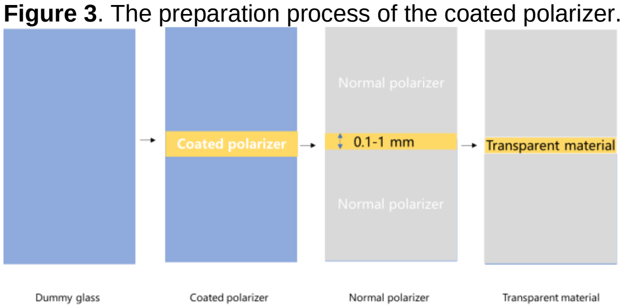


Figure 4. The preparation process of splicing-coated polarizer.

Encouraged by the successful preparation of coated polarizers, we proposed a new splicing approach, named splicing-coated polarizers, combining conventional polarizers and coated polarizers (Figure 4). The coated polarizer was utilized to fulfill the splicing seam between two conventional polarizers on the substrate to overcome the size limitation of conventional polarizers for ultra-large-size panels. Compared with the whole-surface coated polarizer, the splicing-coated polarizer was much more feasible and possessed the advantages of lower cost and higher yields. Figure 4 implied the preparation process of a splicing-coated polarizer. First, the coated polarizer was prepared in the middle of the dummy glass, with a width of approximately 3 mm. Then, the conventional polarizers were attached to the glass, with the note that both conventional polarizers needed to cover part of the coated polarizer. The splicing seam between two conventional polarizers should be between 0.1-1 mm. Finally, transparent adhesive with a certain refractive index was filled into the splicing seam, eliminating the dark lines of the splicing part and protecting the coated polarizer. The splicing-coated polarizer could realize the preparation of an ultra-large-size polarizer with no splicing seam without affecting the overall optical properties of the panel.

3. Optical properties of coated polarizers

Transmittance is one of the most essential properties of a polarizer. Therefore, the optical behavior of coated polarizers was evaluated and compared with conventional polarizers. K1 and k2 represent the transmittance of linear-polarized light on the transmission and absorption axes, respectively. Compared with the conventional polarizer, the transmittance of the coated polarizer on the transmission axis was slightly lower than that of the conventional polarizer during the range of 450-750 nm (Figure 5). Moreover, the transmittance between 380-420 nm of the conventional polarizer was lower than the coated polarizer, which was due to the doping of UV absorbers in the TAC film, while the substrate of the coated polarizer was glass without

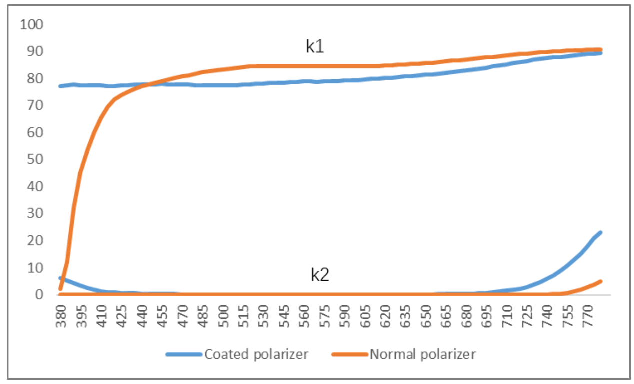


Figure 5. The transmittance of linear polarized light in two directions of conventional and coated polarizers.

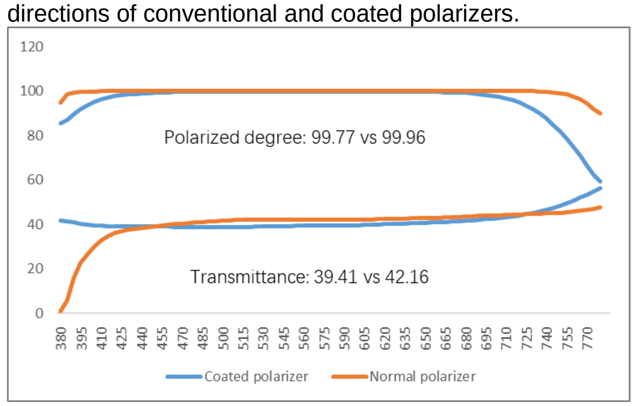


Figure 6. The polarized degree and optical transmittance of conventional and coated polarizers at visible light region.

similar additives. Other than transmittance, polarization degree was another significant parameter, which was usually estimated by equation (1),

$$\mathrm{PE}\% = \frac{k1-k2}{k1+k2} \tag{1}$$

, where PE represented the degree of polarization. In the visible region, the PE% of the coated polarizer was 99.77 %, which was very similar to that of the conventional polarizer (99.96 %). The low polarization degree of the two types of polarizers at the long wavelength range was caused by the inherent characteristics of iodine molecules, whose absorption spectrum could not cover the wavelength range of 700 - 780 nm. In addition, the transmittance of two perpendicularly coated polarizer films was 39.4 %, which was 6.6 % lower than the conventional polarizer films. In general, the orientation of the polymer chains of coated polarizers was not as good as that of the traditional tensile-oriented PVA chains, leading to a slightly poorer arrangement of dichroic dyes. For further advancement of coated polarizer technology, it is critical to develop new polymer alignment materials with higher orientation ability.

4. Reliability performance of coated polarizers

The reliability of conventional polarizers, coated polarizers and splicing-coated polarizers and adhesive-protected coated polarizers were evaluated. The samples were stored at 60 ℃ and 90 % humidity for 168 h. To maintain the consistency of the substrate, the conventional polarizer was attached to the glass for the experiment. The conventional polarizer maintained its polarization ability after the aging test. Its light transmittance and polarization degree changed only by 1.37 % and 0.028 %, respectively (Table 1 and Table 2). The coated polarizer was completely depolarized and changed its color. In addition, the splicing-coated polarizer was partially depolarized (white line at the splicing seam). In the case of the adhesive-protected coated polarizer, the changes in transmittance and polarization degree were 9.43 % and 6.59 %, respectively (Table 1 and Table 2). The difference between conventional polarizers and coated polarizers was mainly related to the PVA layer protection. In the conventional polarizer, the PVA layer was well protected by the COP or TAC films, effectively avoiding oxygen and moisture invasion. For the coated polarizer, the PVA layer was only loosely attached to the glass by adhesives without further protection, resulting in the loss of iodine molecules at a high temperature. The addition of a layer of UV adhesive to the coated polarizer could significantly reduce the iodine loss and improve the polarization degree. However, the fluidity of adhesives was relatively poor and the splicing seam could not be perfectly fulfilled at the splicing area. Therefore, for the splicing-coated polarizer, there was still a risk of losing the polarization degree because of the fluctuation during manufacturing. In the further advancement of splicing-coated polarizers, it is crucial to develop protective materials resistant to high temperature and high humidity.

Table 1. The changes of polarizers before and after the HTHHS test.

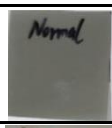
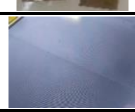
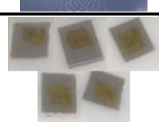
Sample	T0	T168
Conventional polarizer		
Coated polarizer		
Splicing-coated polarizer		
Adhesive-protected coated polarizer		

Table 2. The transmittance and polarization degree change of conventional and adhesive-protected coated polarizers before and after the HTHHS test.

	Transmittance (%)		Polarization degree (%)	
	T0	T168	T0	T168
Conventional polarizer	36.5	37.0 (+1.37 %)	99.985	99.957 (-0.028 %)
Adhesive-protected coated polarizer	42.4	46.4 (+9.43 %)	98.7	92.2 (-6.59 %)

5. Application of a splicing-coated polarizer in real panels

The performance of the splicing-coated polarizer was finally evaluated on a 32-inch VA-type panel. The lower polarizer was a conventional one and the upper polarizer was replaced by a splicing-coated polarizer (Figure 7). The splicing seam between two conventional polarizers was perfectly covered by the coated polarizer. The color and brightness difference between the normal region and the splicing seam could be barely identified through the naked eye, demonstrating the excellent applicability of the splicing-coated polarizer in the large-size TFT-LCDs.

Figure 7. The demo of a 32-inch panel with a splicing-coated polarizer as the upper polarizer.

6. Summary

In summary, this work proposed a new type of polarizer, named splicing-coated polarizer, and introduced its construction and manufacturing processes. The optical behavior and reliability performance of the coated polarizer were slightly weaker than the conventional polarizers, which is due to the difference in the construction and preparation procedures. The addition of a protective layer on the surface of coated polarizers could significantly improve its reliability. Finally, the splicing-coated polarizer was successfully applied to a 32-inch VA-type demo as an upper polarizer, exhibiting great optical performance. The demo proves the great application potential of the splicing-coated to ultra-large-size TFT-LCDs.

7. Reference

1. Fan Z. Polarizer Knowledge Lecture Sixth Lecture on the development and current situation of Polarizer manufacturing. Modern Shows, 2012, 7, 5-12. (Chinese)
2. Yang P. Super wide polaroid line in September will try and put into operation in fuzhou. China Electronics News, 2022-08-23 (006). (Chinese)
3. Guo J., Zhao R., Li J., Zhang M., Xie Z. P-12.6: The application study of coated polarizer for TFT-LCD panels. SID Symposium Digest of Technical Papers. 2023, 54, 874-875.
4. Lai Y., Jiang L., Tian Z., et al. Polarizer for liquid crystal display. Laser & Optoelectronics Progress, 2007, 7, 46-51. (Chinese)
5. Diao R., Luo L., Wu X., Jia H., Cui X., Huang Z., et al. 2.5m ultra-wide, ultra-thin PMMA polarizer base film. Sichuan Province, Sichuan Longhua Photoelectric Film Co., LTD.,2022-06-17. (Chinese)
6. Ma J., Ye X., Jin B. Structure and application of polarizer film for thin-film-transistor liquid crystal displays. Displays, 2011, 32, 2, 49-57