The Optimization of Indium Zinc Oxide Thin Film Process in Color Filter on Array structure

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Abstract

For obtaining the best panel quality of color filter on array(COA) architecture in TFT LCD, we investigated the influence of deposition temperature, O_2 flow, thickness on the optical transmittance, wet etching and adhesion properties of IZO deposited onto each color photo resist(red, green, blue). Average transmittance of the pixel single layer in the visible range(between 380 and 780nm) was mainly affected by thickness and showed maximum at 1250 Å while the thickness showing peak transparency in each R, G, B wavelength was different. The relation was calculated by using bi-layer transmission and reflectance model, which corresponded to experimental data very well. The adhesion of IZO deposited on each color PR was found to have enhanced value except red PR case, compared to that of IZO which was deposited on SiN_x. Wet etching pattern linearity was decreased as the thickness increased. The thickness of IZO was one of vital factors in order to optimize overall pixel process for fabricating COA structure.

1. Introduction

Transparent conductive oxide (TCO) films have been widely used as transparent electrodes for various applications, such as liquid-crystal displays (LCDs) or solar cells. Among these, especially, indium zinc oxide (IZO) are known to have several advantages of good conductivity[1], high optical transparency[2], and low deposition temperature[3]. Moreover, excellent surface smoothness[4] and high etching rate[3] for amorphous IZO[5] thin films have been discussed by researchers.

Color filter on array(COA) architecture in TFT LCD, which have color filters directly patterned on TFT structure, have benefits compared to normally patterned on upper panel: These are larger aperture ratio(;higher transmittance), more simple process , and thus lower production cost than normal TFT-LCD structure. However, optimum optical condition, interface problems between IZO pixel and color PR are not clear.

In this paper, we investigated the effect of deposition temperature, O_2 flow, thickness on the optical transmittance, wet etching and adhesion properties of IZO deposited onto color PR array, which is typical COA architecture.

2. Experimental

The IZO thin films were sputter-deposited on bare glass or color photo resist patterned glass substrates using an indium zinc oxide target (ZnO: 10wt%,Idemitsu Kosan Co., Ltd)in an DC magnetron sputter deposition system. The deposition temperature was 50-130℃, O_2 flow was 0-2.0 sccm, Ar 50-150 sccm, and IZO thickness varied from 550 to 1300Å.

Optical transmittance was measured in the wavelength range of 380-780nm by UV-visible(HP). The indices of refraction as well as extinction coefficients of the film were determined in the visible region of 380-780nm by using a spectroscopic ellipsometer and especially those at the specific wavelength which represent red, green, blue visible ray were listed in Table 1. As Fig.1 shows, after patterning IZO pixel which was deposited onto each color photo resist coated glass, we measured the adhesion strength between IZO and color photo resist by using taping test method. For quantifying the value, the number of undetached or undefected IZO film out of 100 pixels, which were patterned onto each color PR, was counted and divided by that of undefected IZO pattern deposited onto SiN_x as a reference and the relative % values was obtained. The equation can be written as follows, showing that increasing this value means increasing the adhesion strength between two layers.

Adhesion Strength(%)
= {(100-number of defected pixel on CF)
/(100- number of defected pixel on SiN_x)}*100

Wet etching pattern linearity made on the each color PR was observed by optical microscopy. For analyzing the experimental result, we used DOE(Design of Experiment) method.

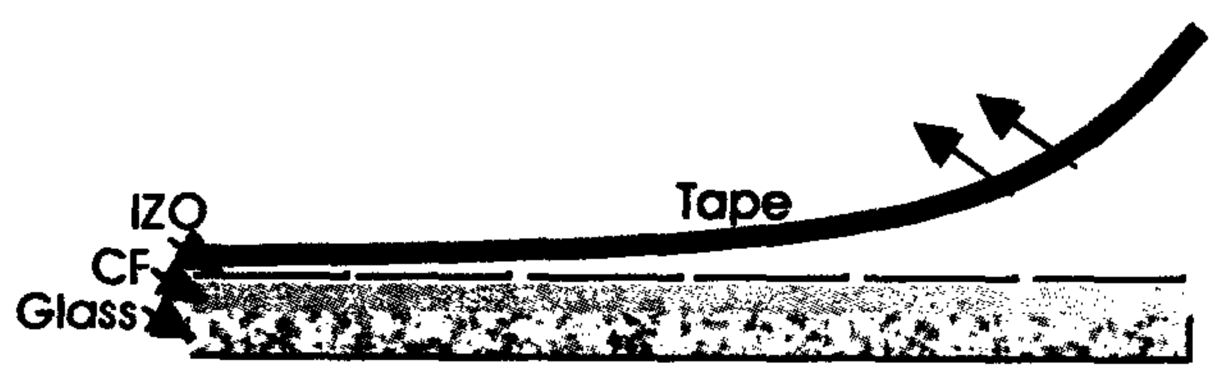

Fig. 1 Schematic illustration of tape test method for measuring adhesion strength between IZO pattern and each color filter blanket film.

Optical data of IZO at each wavelength	Blue (460nm)	Green (540nm)	Red (620nm)
Refractive index (n_1)	2.0944	2.0241	1.9769
Absorption coeffient(k)	~ 0	~ 0	~ 0
Air(n_0)	1		
Glass(n_2)	1.2~1.5		

Table1. Refractive index and absorption coefficient of IZO and glass with respect to air measured by ellipsometer at each wavelength representing blue, green, and red color.

3. Results and discussion

Fig.2 shows the effect of deposition temperature, film thickness, and O_2 flow, during IZO deposition, on the average optical transmittance between 380 and 780nm. The transmittance decreased as temperature and O_2 flow were increased and, on the contrary, thickness was decreased down to 550Å. However, statistical analysis, using ANOVA(Analysis of Variations) tools, showed that only the thickness was meaningful parameter effective to control the optical transmittance of IZO within 5% significance level in our experimental range of above three parameters. The reason why increasing the film thickness of IZO induced decrease of optical transmittance can be explained by bi-layer transmittance and reflectance model as shown in Fig.3.

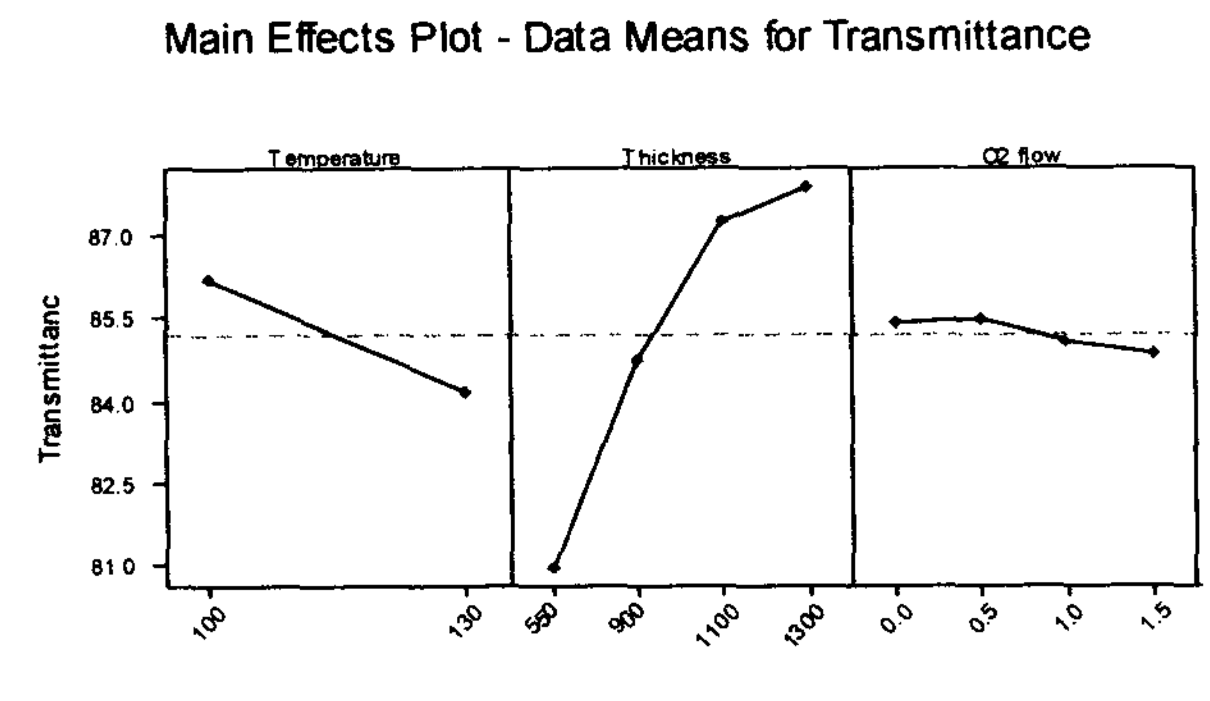

Fig. 2 Variations of average optical transmittance of IZO depending upon deposition temperature, film thickness and O_2 flow rate.

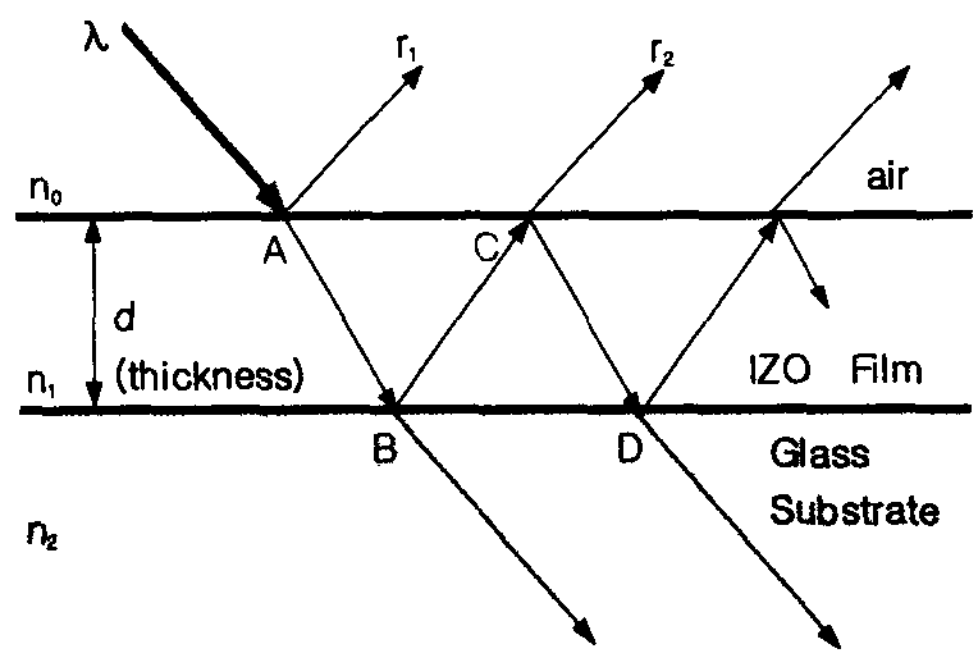

Fig.3 Schematic illustration for obtaining theoretical optical transmittance of IZO thin film deposited on bare glass where the transmittance and reflectance were considered.

When we assume a incident light with single wavelength, construction interference from B, D,... point cause maximum transmittance while destruction one cause minimum transmittances at certain IZO thicknesses. Using the experimental data as shown in Table 1, we calculated the theoretical transmittance of each fixed red(R),green(G),blue(B)wavelength in the visible range and the results showed good agreement with experimental data as shown in Fig.4. Although each wavelength had different peak value, average

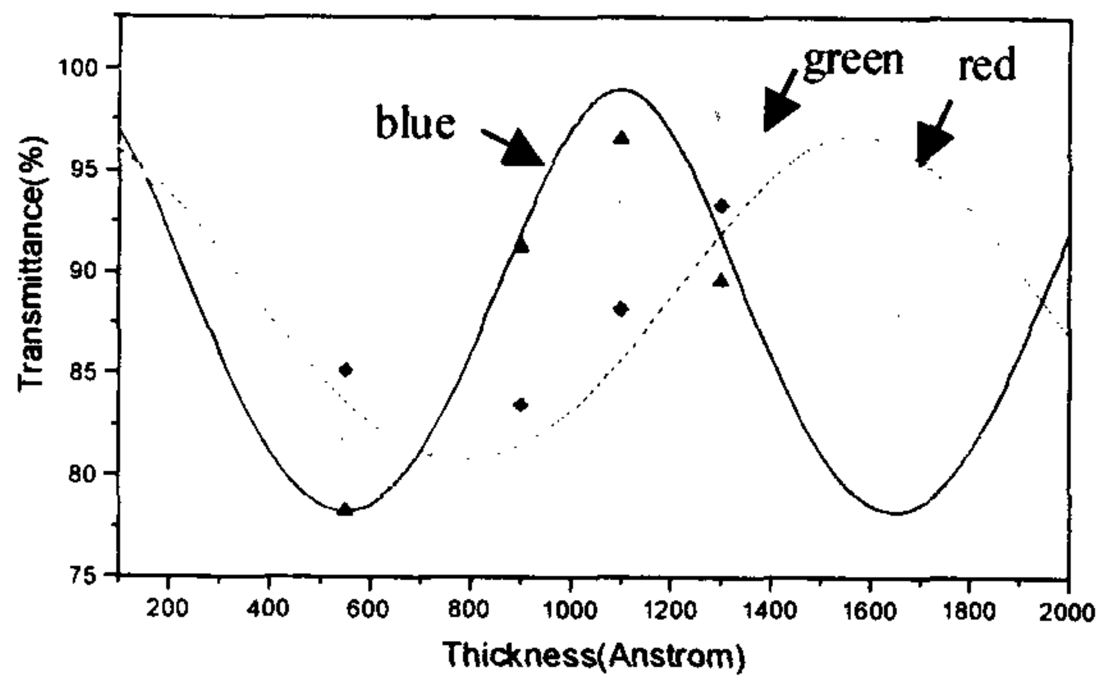

Fig.4 Optical transmittance measured with UV-visible at each fixed R,G,B wavelength plotted with calculated results; solid lines show theoretical result at blue (460nm), green(540nm), red (620nm) wavelength and symbol shows experimental results ; ♦: red, ▲: blue, ■ : green.

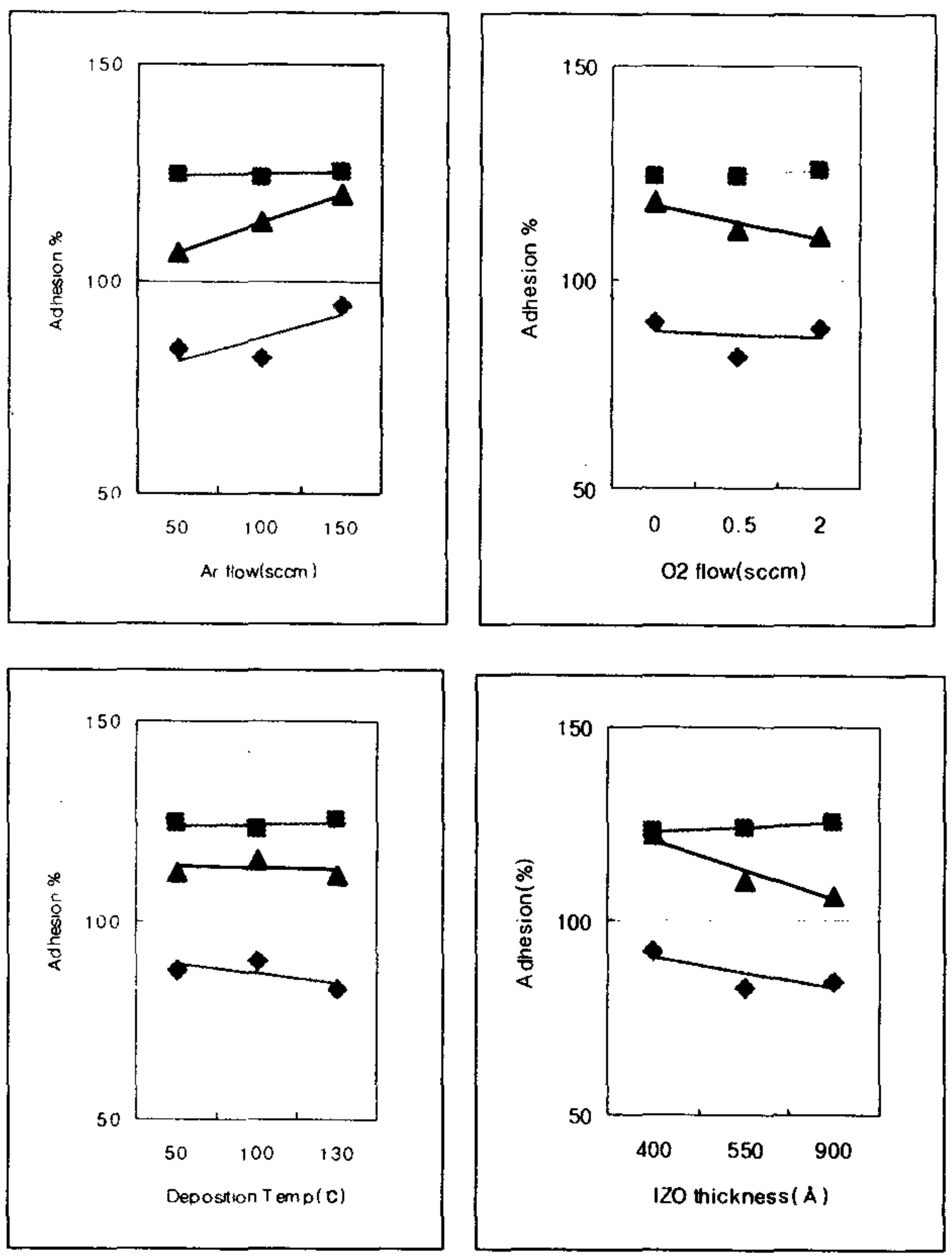

Fig. 5 Adhesion parmeter between IZO pattern and each color photo resist; ♦: IZO/red CF, ■: IZO/green CF, ▲ : IZO/blue CF.

optical transmittance showed maximum at 1250Å. However, this model, we did not include the absorption coefficient term, might be inaccurate above 2000Å.

Fig.5 shows the adhesion strength between IZO pattern and color photoresist(CPR) or color filter(CF). Green PR was least influenced by above 4 process variables and had the highest adhesion strength. For blue PR case, as O_2 flow and thickness were increased and Ar flow was decreased, the adhesion strength decreased. And red PR showed also similar tendency to blue PR. When average property was considered from PR to PR, blue and green PR were superior to SiN_x while red PR was poorer than SiN_x, which was used as a reference, in adhesion strength.

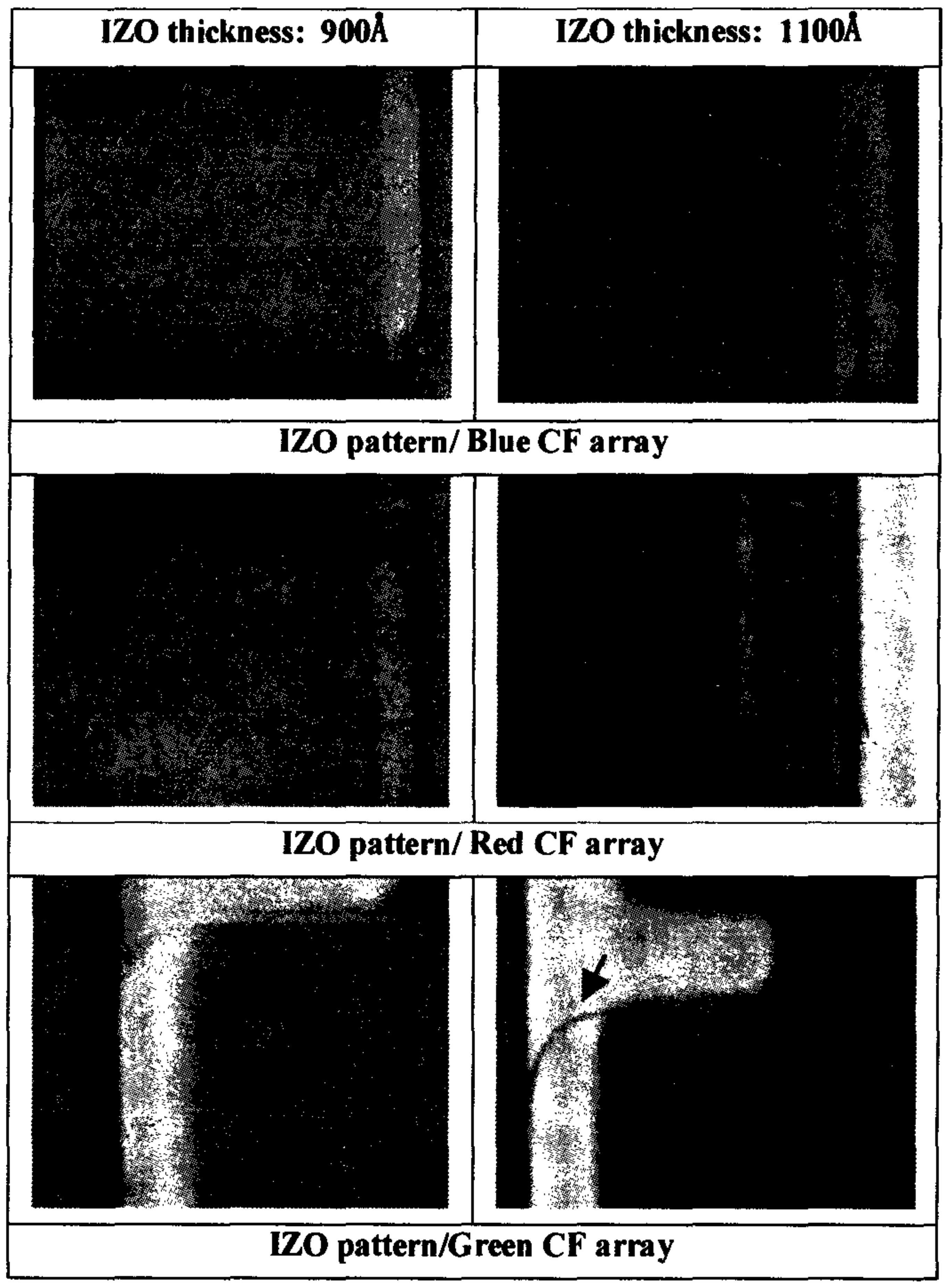

Fig. 6 Wet etching pattern of IZO film deposited on color PR array showing that zigzag edge shape emerges as thickness increases; IZO deposition temperature was 130℃.

Moreover, after IZO deposition on the color PRs, some swelling occurs in the red PR, although not shown here. Different additive contents for making suitable color in each CF might be one reason for decreasing the adhesion strength between two layers. Because surface energy of PR could be changed with addition of additives, IZO contact property with PR or adhesion strength might be affected.

As shown in Fig.6, IZO pattern linearity, processed with acid based etchant, on red PR was most poor showing zigzag shape at 1100Å and green PR showed best pattern linearity with increasing thickness. We can see that this tendency corresponded with the adhesion strength, which is shown in Fig.5, quite well. Therefore, IZO thickness optimization is necessary to get the best panel quality in COA structure.

4. Conclusion

Average transmittance of the IZO single layer in the visible range was mainly affected by thickness and showed maximum optical transmittance at 1250Å. The adhesion of IZO deposited on green and blue PR was found to have enhanced value while that of red PR was poor, compared to the adhesion strength of IZO which was deposited on SiN_x. Wet etching pattern linearity was decreased as the thickness increased. The optimizing IZO thickness was one of major factors for fabricating COA structure.

5. References

[1] T. Minami, T. Kakumu, S. Takata, J. Vac. Sci. Technol. A 14, 1704(1996)

[2] N. Naghavi, A. Rougier, C. Marcel, C. Guery, J. B. Leriche, j.M. Tarascon, Thin Solid Films 360, 233(2000)

[3] A. Kaijo, Display Imaging 4, 143 (1996)

[4] W.J. Lee, Y.-K. Fang, J.-J. Ho, C.-Y. Chen, L.-H. Chiou, S.-J.Wang, F. Dai, T. Hsieh, R.-Y. Tsai, D. Huang, F.C. Ho, Solid State Electron. 46, 477(2002)

[5] Y.-S. Jeong, J.-Y.Seo, D.-W. Lee, D.-Y. Jeon, Thin Solid Films 445, 63(2003)