The fabrication of TFTs for LCD using the 3mask process

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Abstract

New technology that reduces photolithography process steps from 4 to 3 in fabrication of TFT LCD is introduced.

The core technology for 3mask-TFTs is the lift-off process [1], by which the PAS and PXL layer are formed simultaneously. To evaluate the stability of this lift-off process, outgases from photo resist on a substrate during ITO deposition and the quality of ITO film were analyzed and the conventional photo resist stripper machine which operates lift-off process was examined to see its ability to reduce particle problems of the machine.

Through the development of total process and design for TFTs using this 3mask technology, panels in TN and IPS modes which exhibit same performances of a display using a conventional process were achieved. In addition, this process was already verified in the mass production line and now some products are being produced by the 3mask technology.

1. Objectives and Background

The technology for reducing mask steps in TFT process is very effective to improve the productivity because TFT LCD is fabricated by repeated processes.

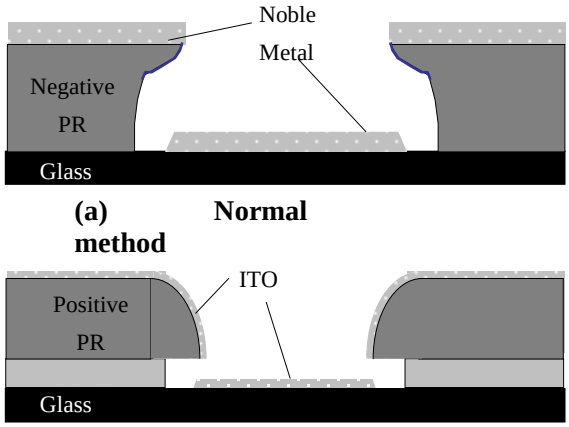
Mask reduction technology has lots of advantages such as decrease in process steps, tact time as well as less materials and equipments. Therefore, these merits contribute to improvement of productivity in existing factories and less investment cost in future factories.

Currently some leading companies in the LCD industry are using the 4mask process technology as the standard process [2-3] and making an effort continuously to develop the 3mask process to improve their productivity.

2. Results

2.1. Basic experiments

Lift-off technology was used in this 3mask process, and it has never been applied in TFT-LCD part, also in other industries the technology is seldom used to make patterns of noble material. In most lift-off processes, negative PR is generally used to peel the object material easily because it is an inverted taper shape. But to use conventional positive PR a different technique was developed in this paper. Figure 1 shows the lift-off patterns of normal and developed.



(a) Normal method

(b) Developed method

Figure 1. Lift-off pattern shape

The object material is ITO film and the sequence is as follows; First, PR pattern for contact hole is made followed by basic etching of SiNx and 2nd etching slightly under the PR to make the lift-off path. The next step is to deposit the ITO film and finally the ITO/PR patterns are removed simultaneously in stripper except those necessary ITO patterns on a substrate.

To confirm the stability of this new process in existing system, feasibility tests were performed for sputter and strip machines. Firstly, contaminations in the chamber of ITO sputtering in which PR substrate resides were examined. Figure 2 shows increasing pressure of the vacuum chamber for several types of

glass substrates individually. In case of PR, the subject of this paper, there is much more outgases than in other cases. By measuring the substances of these outgases by QMS(Quadruple Mass Spectroscopy), most of substances were found to be H_2O (Figure 3).

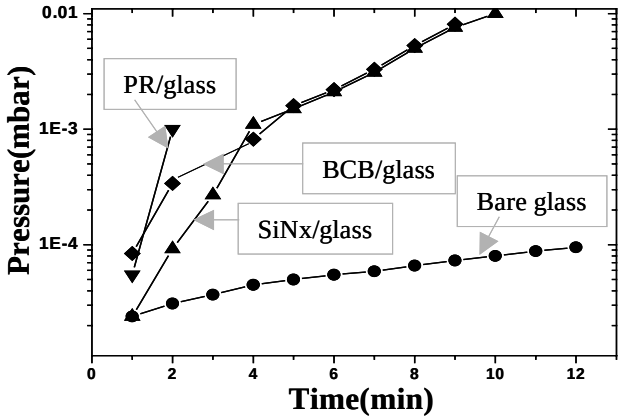


Figure 2. Increasing pressure of vacuum Chamber as a function of substrate

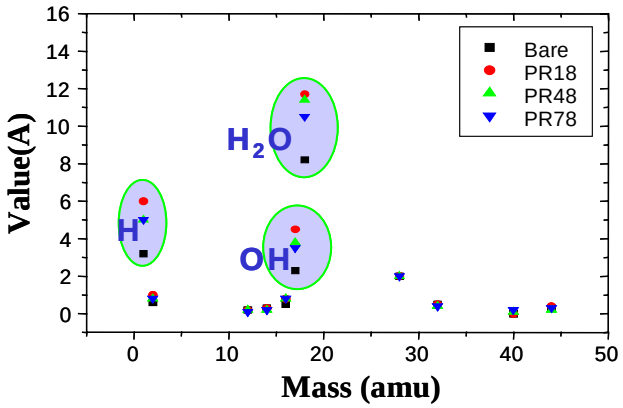


Figure 3. QMS analysis for the substance of outgases from substrates as a function of number of running glass

And H_2O is not expected to cause contamination in ITO film because it is actually used in deposit. Figure 4 shows the result of SIMS for normal and tested ITO films, and no differences were found. Actually, ITO film qualities such as resistance and transmittance during the test were not different than normal qualities.

Secondly, it is necessary to exam the number of particles after lift-off process because it is very important factor in process yield and ITO lifted with PR is not soluble in stripper that is the solution of lift-off process. Figure 5 indicates that the particles over 1.0 ㎛ in size were reduced by under 5 ㎛ size filter. As a result, it is found that ITO particles caused by lift-off process can be removed by the existing filtering system in the strip equipment.

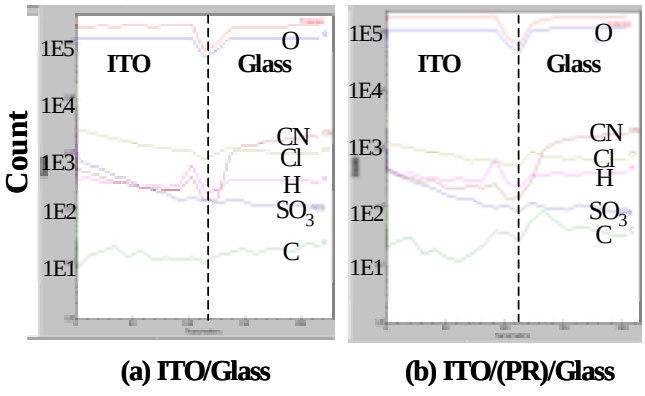


Figure 4. SIMS depth profile

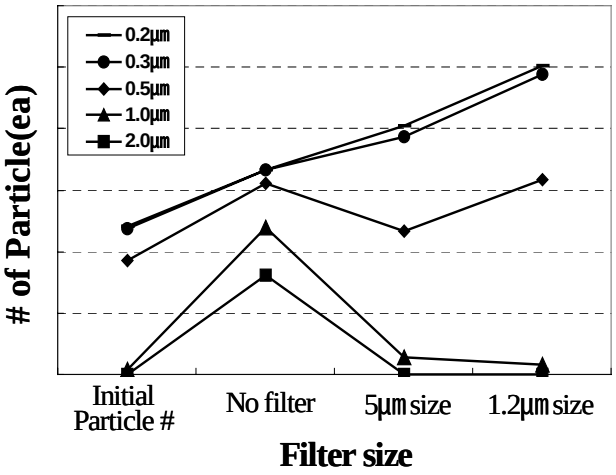


Figure 5. The number of particle as a function of filter size

The lift-off methods were tested by two different strip modes - the spray mode using nozzles and the dip mode using US. Figure 6 is the result of main effects plot analyzed statistically. It indicates that main factors of the lift-off effect are the time of spray and dip, pressure of spray and US power.

In addition, the design of appropriate pattern size is necessary for tact time in existing strip process. Figure 7 shows the pattern size in function of spay time. In around 60sec, under 300 ㎛×300 ㎛ size pattern can be removed. It means that design of lift-

off patterns should be limited in size for ability of machine.

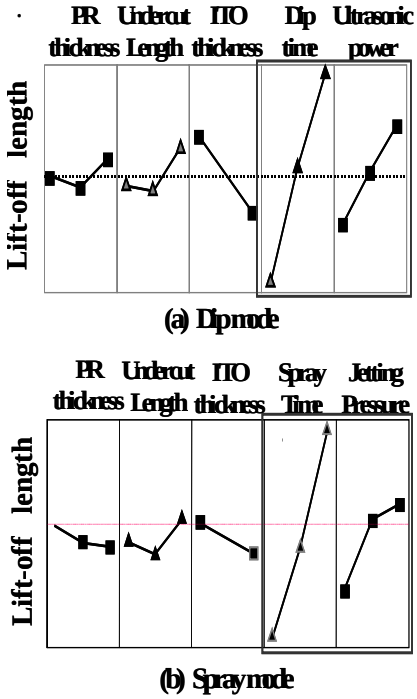


Figure 6. Main effects plot for dip and spray mode respectively

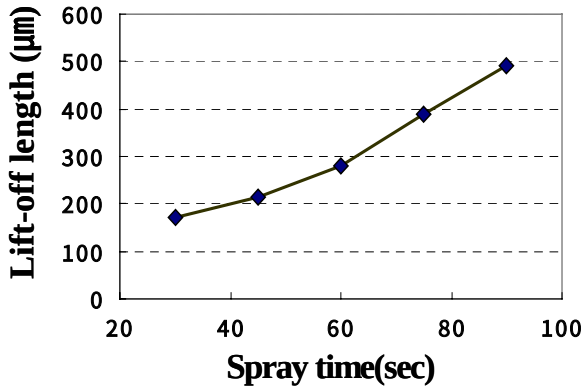


Figure 7. Pattern size for lift-off as a function of spray time

2.2. 3mask TFT structure

Structure of the 3mask TFT is BCE(Back Channel Etch) as usual, and the process flow is also same as 4mask process using diffraction technology except PAS and PXL layer. Through the lift-off technology mentioned earlier, the patterns of PAS and PXL layer are formed simultaneously. Figure 8 shows the process flows for 5mask, 4mask and 3mask and the main technology of each other.

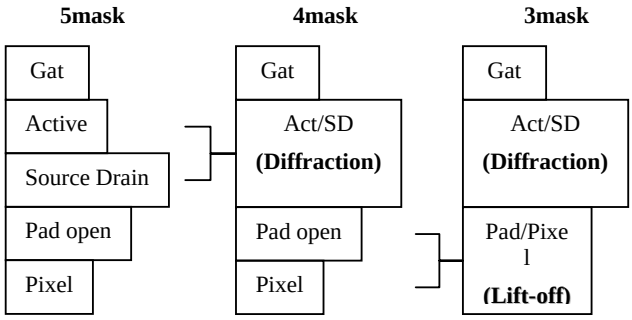


Figure 8. The process flows and mask reduction technologies

2.3. The Characteristics of the 3mask panel

Basically, the characteristics of TFT fabricated by 3mask process are all the same as by 4mask process because there is any difference in structure and method on TFT device. Figure 9 is the typical characteristic of 3mask TFT. And all display performances were as same as 4mask panel. It was achieved by making 15”XGA panel for each TN and IPS mode. The main results are as follow: Over 60% of aperture ratio and 0.4nit in black for TN and 40% and 0.8nit for IPS. And these panels passed the reliability test at 50℃ in 90% humidity for 2000hr. Figure 10 is the photograph of 15” IPS panel made by 3mask process.

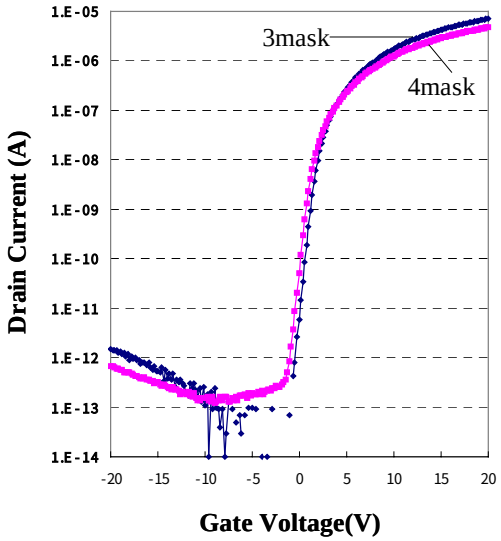


Figure 9. The comparison for transfer characteristics

Figure 10. The photograph of the 3mask panel (IPS, 15.0", XGA)

3. Impact

Through the 3mask process, it is possible to reduce the process steps of photolithography and resist strip process by 25% and also wet etch process by 30% due to special advantages of lift-off process.

This new process can be easily applied to conventional fab. because the 3mask process uses conventional machines and materials. In addition, the reliability of panels fabricated by the 3mask process is equal to the reliability of panels fabricated by a conventional process because there is no physical contact on any part of device structure.

This is the first time that lift-off process is applied to LCD. It is possible that this new process will generate other new ideas to improve processes of TFT fabrication and to increase chances in applying new materials such as noble metal which has never been treated in the past because of its etch process issues. We hope that the 3mask process, innovation in productivity, will contribute to lower LCD cost.

4. References

1. M. Hatzakis et al, IBM J. Res. Develop, Vol 24, No 4 (1980)
2. Chang Wook Han et al, Asia Display 1998, p1109 (1998)
3. Jean H. Song, et al, Conference digest of SID 2002, p1038 (2002)