Fabrication of TFTs for LCD using 3-Mask Process

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Abstract

A new technology for reducing photolithography process from a four step to a three step process in the fabrication of TFT LCD is introduced. The core technology for 3-mask-TFT processes is the lift-off process [1], by which the PAS and PXL layers can be formed simultaneously. A different method of the lift-off process was developed in order to enhance the performance of efficiency with conventional positive and not negative PR which is the generally used in other lift-off process. In addition, the removal capacity of the ITO/PR in lift-off process was evaluated. The evaluation results showed that the new process can be run in conventional TFT production condition. In order to apply this new process in existing TFT process, several tests were conducted to ensure stability of the TFT process. It was found that the outgases from PR on the substrate in ITO sputtering chamber do not raise any problem, and the deposited ITO film beside the PR has conventional ITO qualities. Furthemore, the particles that were produced due to the ITO chips in PR strip bath could be reduced by the existing filtering system of stripper. With the development of total process and design of the structure for TFT using this technology, 3-mask-panels were achieved in TN and IPS modes, which showed the same display performances as those with the conventional 4-mask process. The applicability and usefulness of the 3-mask process has already verified in the mass production line and in fact it currently being used for the production of some products.

Keywords : TFT LCD, 3-mask, lift-off, TN, IPS

1. Objectives and Background

A mask reduction technology is very effective for the improving the productivity of LCD panels because TFT LCD is fabricated by repeated processes.

Mask reduction technology has many advantages such as reducing the number of process steps and tact time as well as requires lesser materials and equipment compared with conventional. All, these merits contribute enhances productivity in existing factories and is expected not to incur as much investment cost in future factories.

Currently some leading companies in the LCD industry are using the 4-mask process technology as the standard process [2-3] but still trying to further improve the 3-mask process in order to further increase productivity.

2. Basic Idea

The TFT process in general is the repetition of cleaning, deposition, photolithography, etching and PR removing. To make two kinds of patterns of different layers, it takes a total of ten steps. But through the lift-off process, the same patterns can be made through only six steps.

The following is the comparison of the proposed method to the conventional one. First, the deposition, photolithography and etching for one layer are the same in the conventional, whereas in the new one, the deposition of the other layer is performed before the PR stripping after which the PR and film are removed simultaneously. Fig. 1 shows that the processes of PR removing, cleaning, photolithography and etching can be reduced.

Actually, the 3-mask process was achieved by using this lift-off process in PAS and PXL layers.

3. Experiments and Results

In order to efficiently remove the film on the PR in the

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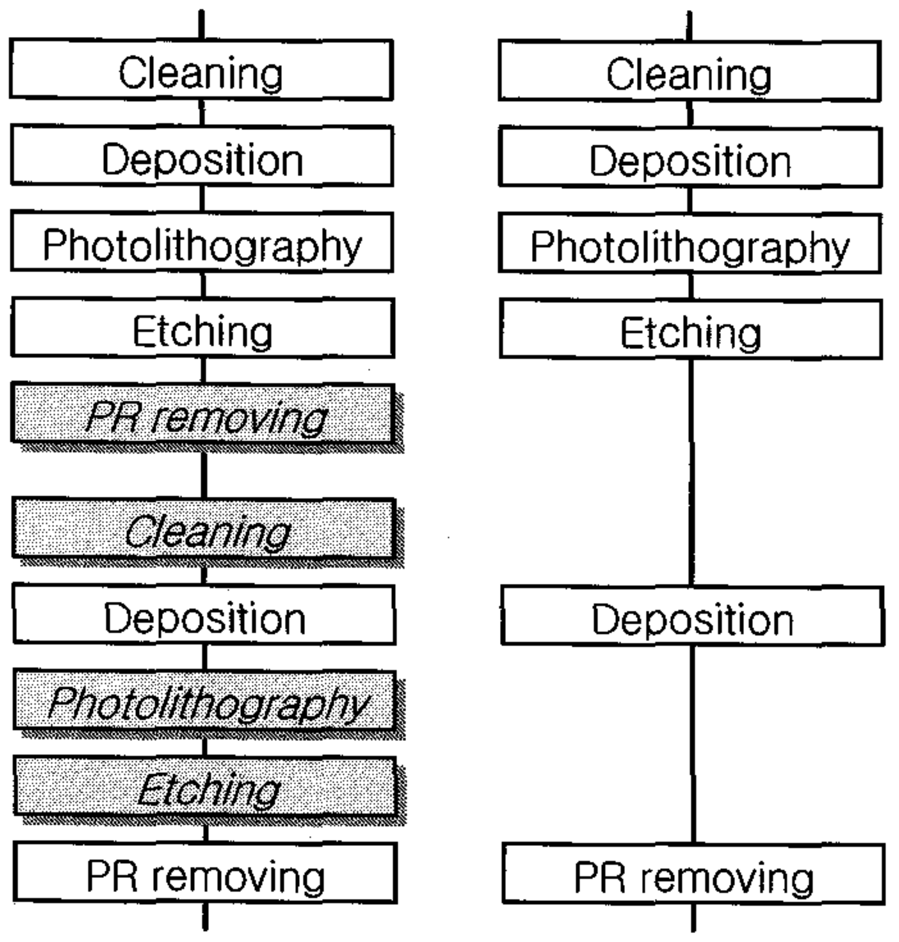
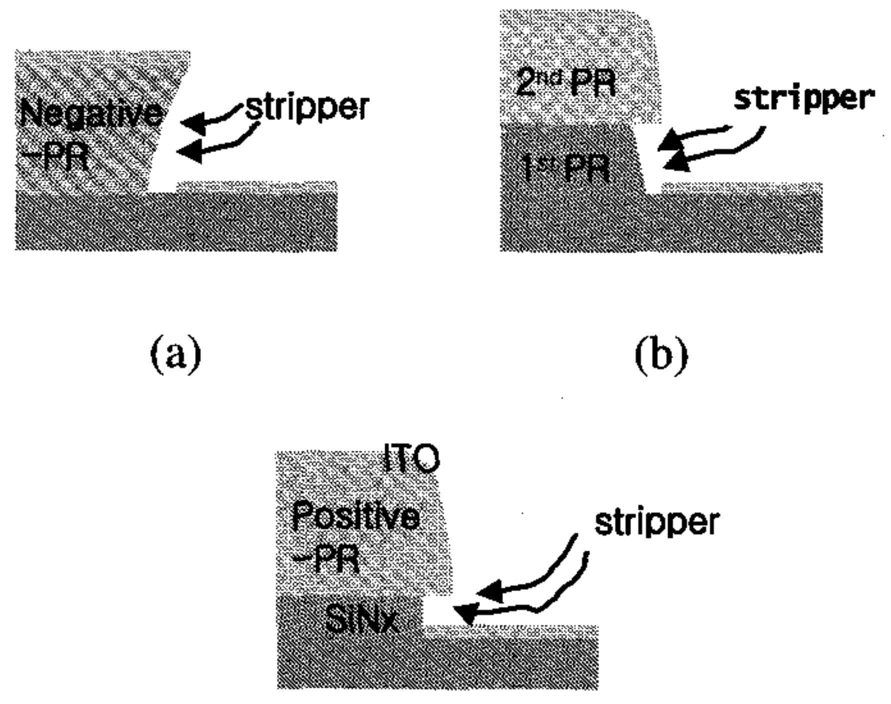
lift-off process, it is important to have a gap form under the film. As the stripper penetrates through this gap, the film on the PR is removed clearly. This lift-off technique is currently used in some industries to make patterns of noble metals, where a negative PR or stacked two kinds of PR is used to make this gap.



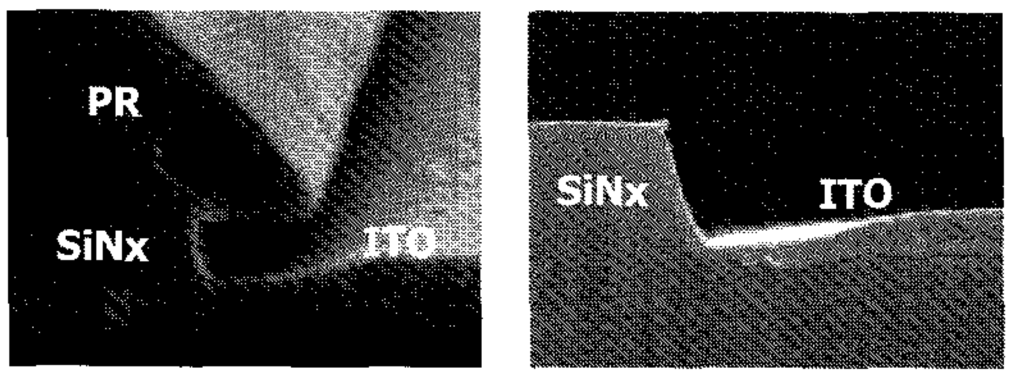
(a) (b)

Fig. 1. Process steps for making two kinds of patterns of different layers (a) Normal and (b) New idea.



(a) (b) (c)

Fig. 2. Structures of lift-off patterns : (a) Inverse tapered type using negative PR, (b) Multi-step type staking two kinds of PR, and (c) Undercut type using positive PR – New idea.



(a) (b)

Fig. 3. SEM image for cross section of PAS and PXL patterns (a) after ITO deposition and (b) after the lift-off.

In this study, the new structure was set up to match existing TFT process. As mentioned above, the lift-off process was applied to the PAS and PXL layers in TFT process. This causes, the slightly over etching of SiNx to form a gap through which the stripper can penetrate into PR under the ITO on that.

Fig. 2 shows the structures of lift-off patterns. This new method is important to make path of stripper in real production because it uses the positive PR used in conventional TFT process. Fig. 3 is a photograph of the lift-off process, after ITO deposition and after removing.

Fig. 4 shows the removing capability for ITO/PR. It depends on the running time of removing in spray and dip mode each other. Considering the mass production in existing facilities, if the PR strip process time is 100sec, it will be able to be removed for about 300㎛ pattern. This result can be used to design the TFT panel, especially in the

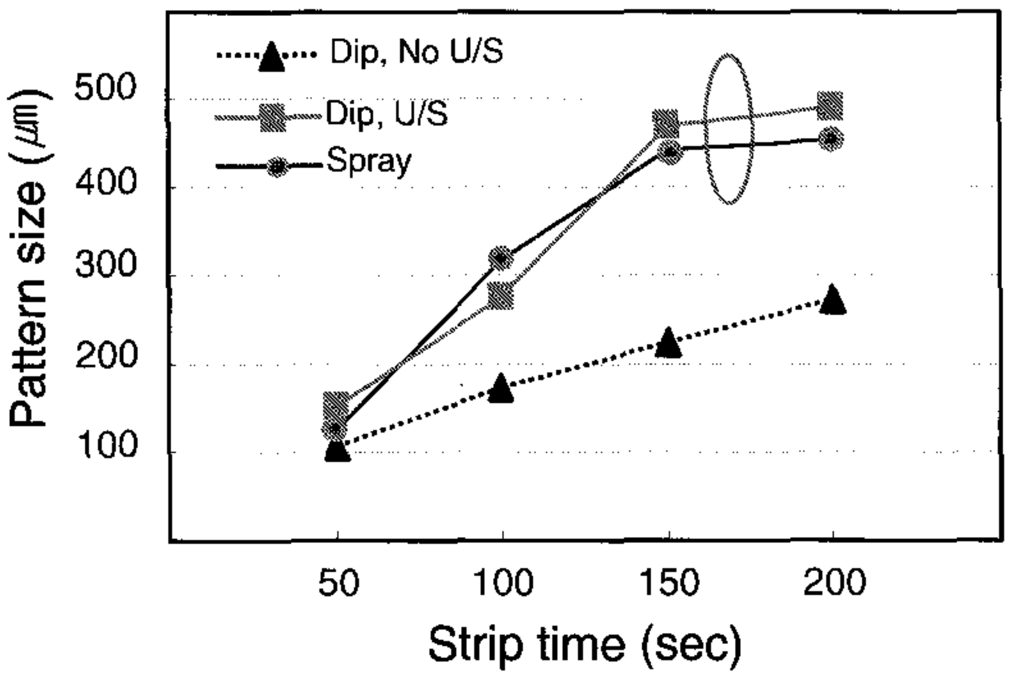


Fig. 4. Removed pattern sizes as a function of strip time.

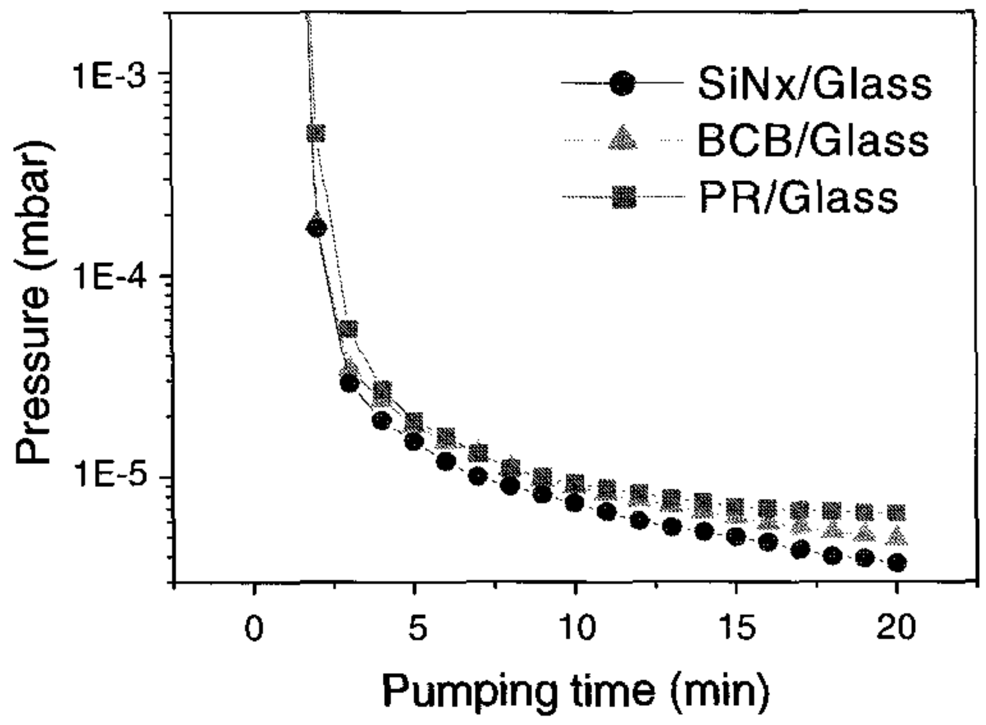


Fig. 5. Pumping speeds of ITO sputtering chamber for SiNx/Glass, BCB/Glass and PR/Glass substrates.

case where the ITO/PR pattern size is so much large that it would be impossible to be remove.

In order to apply this new technology to the TFT process, it is important to ensure that there are not potential problems that might occur.

Fig. 5 shows the pumping speed and Fig. 6 the vacuum after discontinuing the pumping for ITO sputtering chamber with several types of substrates. Compared with the case of general SiNx/Glass and organic BCB/Glass, the pumping speed is slightly slower and there are more outgases in the case of PR/Glass. The results of the analysis on these outgases by QMS is shown in Fig. 7.

There is no contaminable substance, such as carbon chain, from PR. Those are all guessed to component of at an atomic mass of 1, 17 and 18. It is an optimistic result because the H_2O is used as the carrier gas for ITO sputtering in recent.

It is ultimately important to confirm whether it possible to change the ITO film qualities during this process.

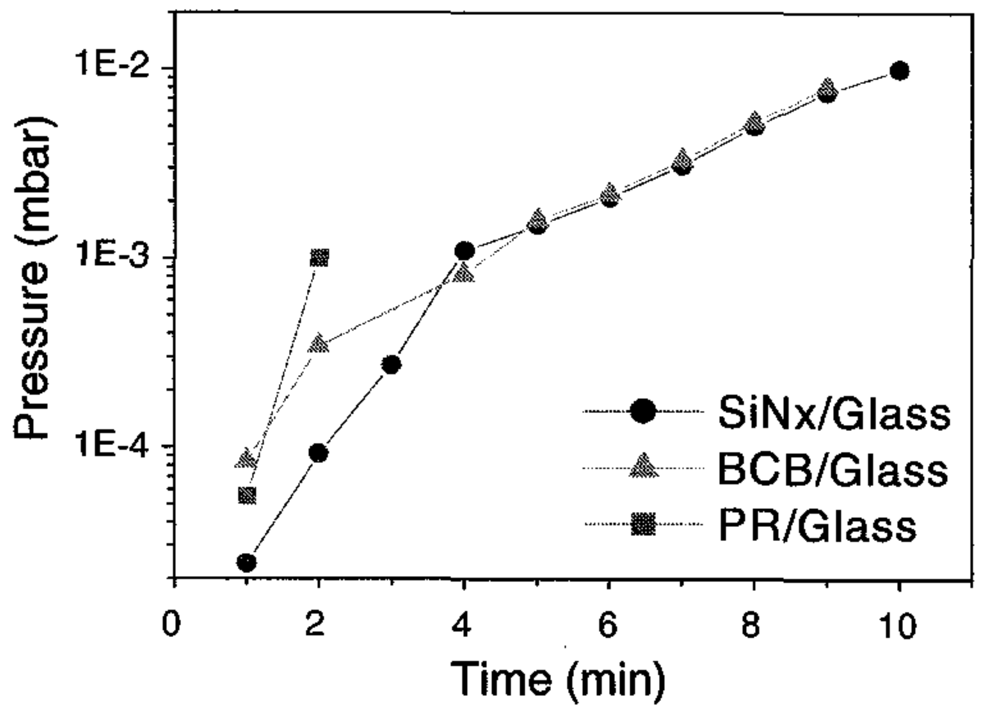


Fig. 6. Vacuum of ITO sputtering chamber after pumping for SiNx/Glass, BCB/Glass and PR/Glass substrates.

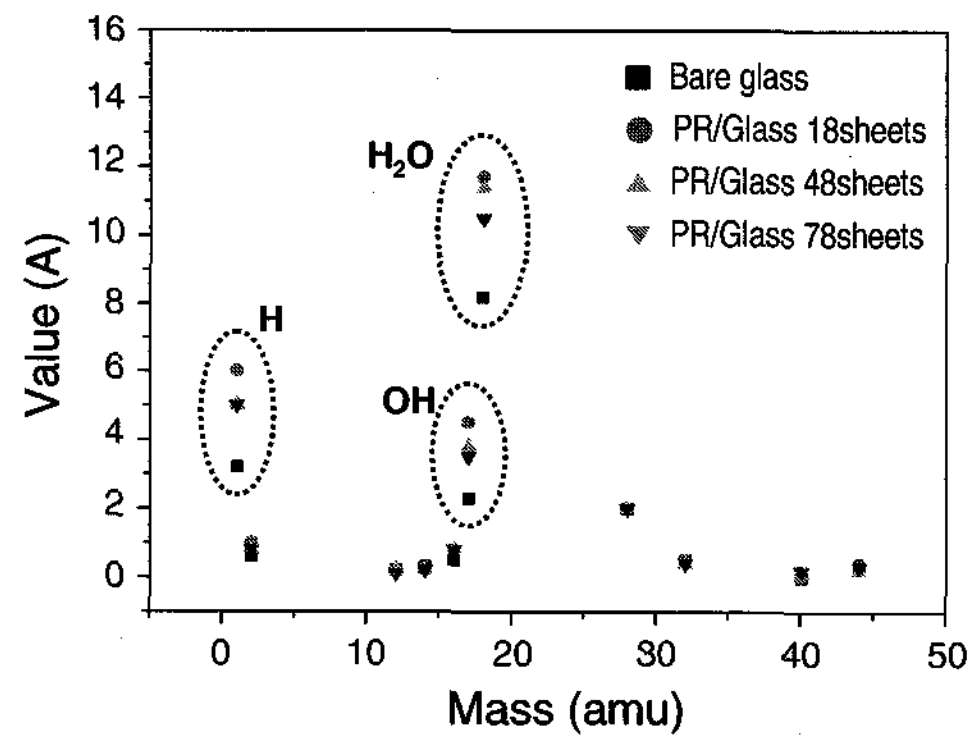


Fig. 7. QMS(Quadruple Mass Spectrometer) analysis of outgases from PR/Glass substrates.

Fig. 8 shows the analysis of SIMS for ITO films deposited by normal and with PR. There is not observable difference. It shows that this new process do not release contaminations to ITO film in sputtering chamber. In fact, the resistance and trans-mittance of tested ITO film are measured as 20.4Ω /□ and 95%.

Fig. 9 shows the trends of particles in PR strip bath. The particles can cause defects to LCD panels. Thus, in the TFT LCD process, it is important to reduce the particles. In this lift-off process, however, the ITO film removed with PR is not solved in PR stripper and the fractured ITO chips become particles. To see the graph, the number of particle was increased after running the tested substrates without a filter being used. By using these filters in the circulation pipe, the number of larger sized particle could be seen to be reduced significantly.

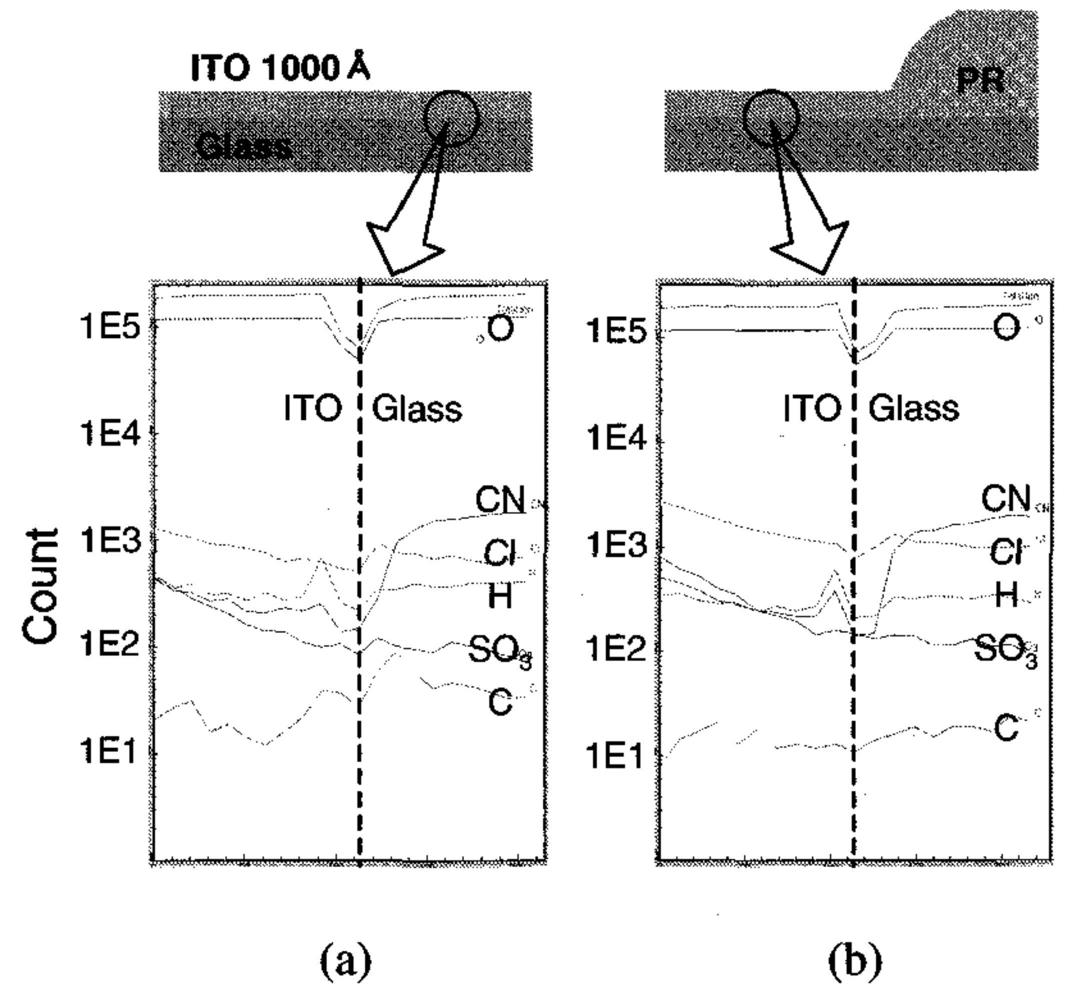


Fig. 8. SIMS profiles for ITO films deposited (a) by normal and (b) with PR.

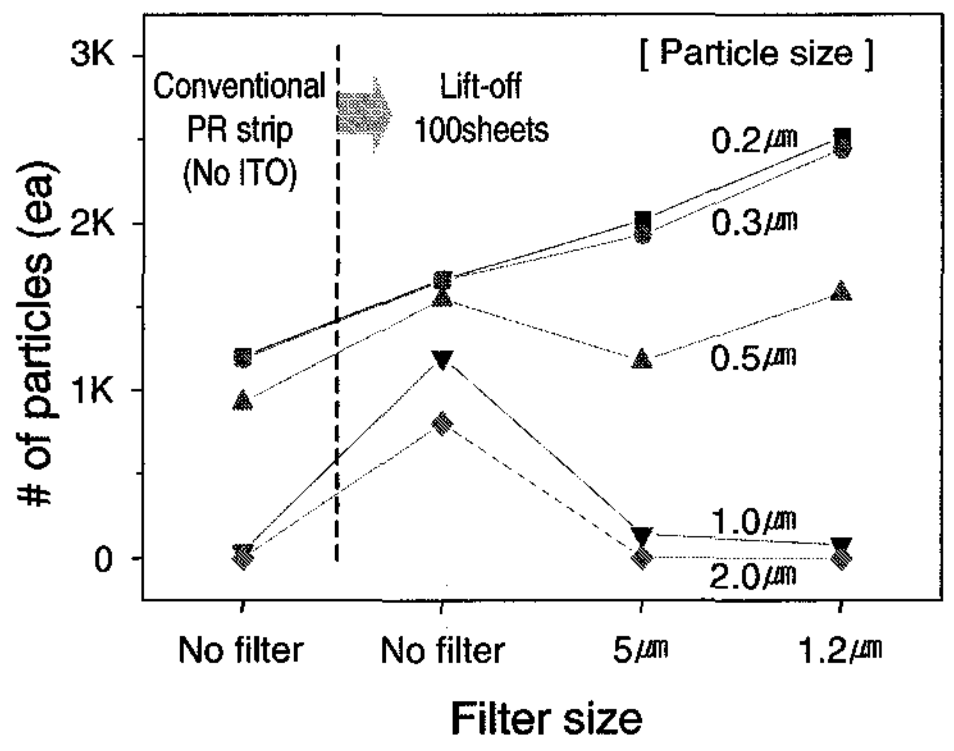


Fig. 9. Number of particles in PR strip bath as a function of filter sizes.

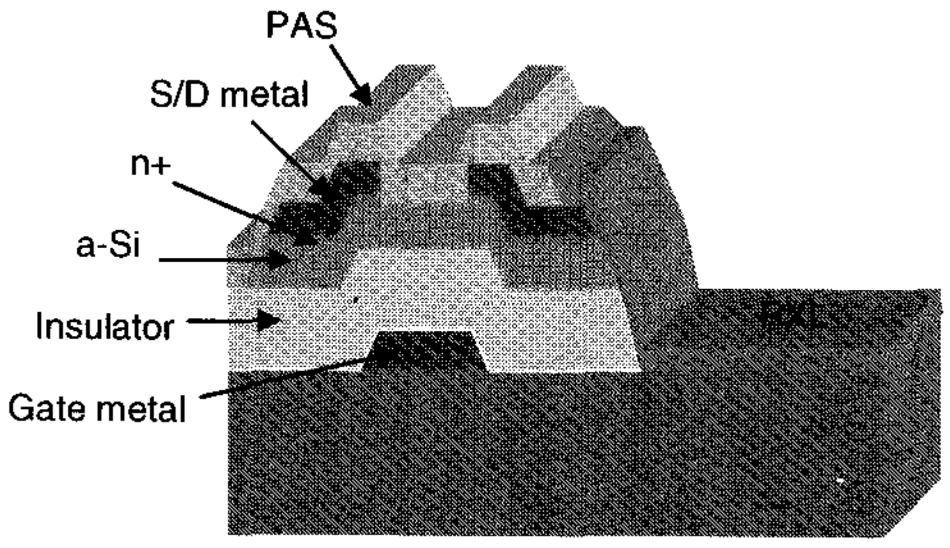


Fig. 10. Structure of 3-mask TFT.

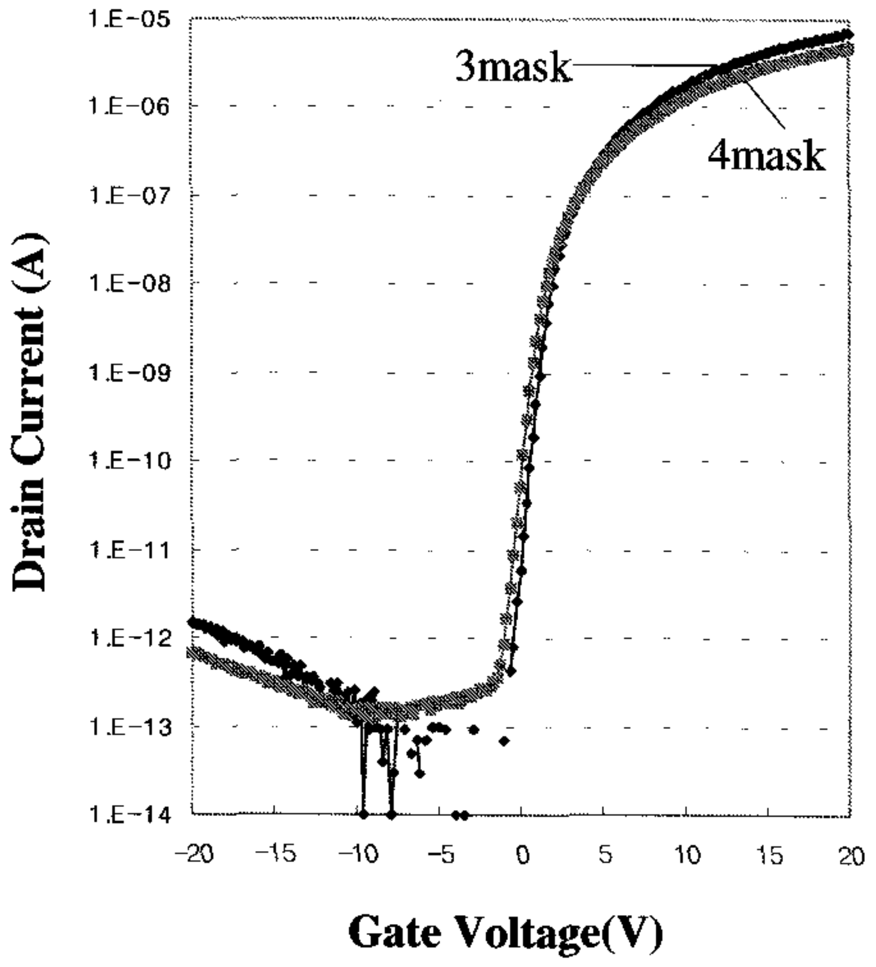


Fig. 11. I-V curves of 4-mask and 3-mask TFTs.

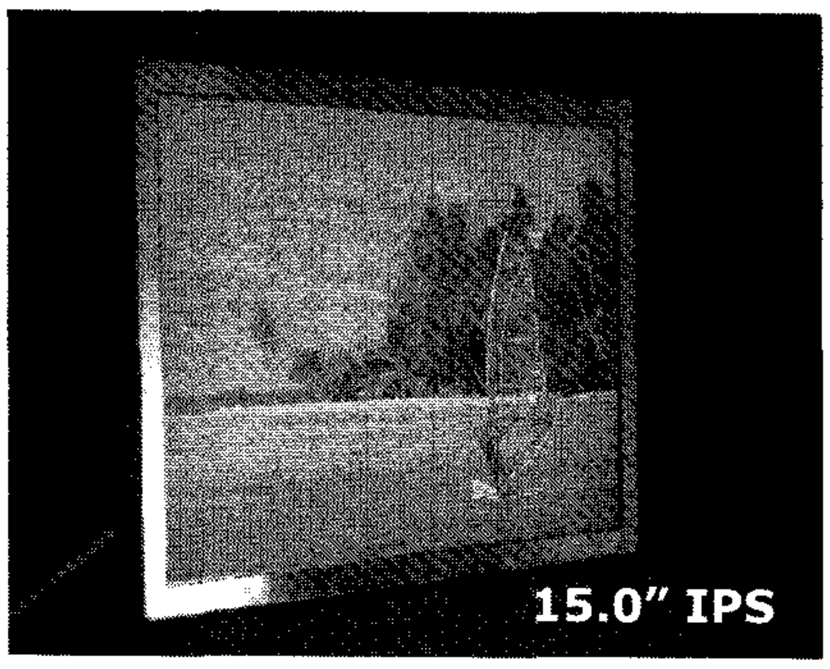


Fig. 12. Demonstration of 3-mask panel.

From these observations, we can conclude that the existing filtering systems in PR strip bath can reduce the particles released from lift-off process because submicron-sized particles could hardly be found in the LCD panels in our study.

The structure of the 3-mask TFT used in this study was the conventional BCE(Back Channel Etch), and the same process flow as that of the 4-mask process, with the exception of PAS and PXL layer, was used.

Basically, the characteristics of TFT fabricated by the 3-mask process were all the same as in the case of the TFT fabricated by the 4-mask process, because there is little difference in structure and method on TFT device. Fig. 10 shows the structure and Fig. 11 shows the typical characteristic of a 3-mask TFT.

Lastly, the display quality of the panel fabricated by this 3-mask technology is the same as that of a 4-mask panel. This could be achieved by developing a 15″ XGA panel for each TN and IPS mode. The main results are as follows: Over 60% of aperture ratio and 0.4nit in black for TN and 40% and 0.8nit for IPS. These panels passed the reliability test at 50℃ in 90% humidity for 2000hr. Fig. 12 is a photograph of a 15″ IPS panel that was made by the 3-mask process.

4. Conclusions

Development of mask reduction technologies have been a continuous effort since the beginning of LCD industry so as to increase the productivity of LCD panels. The latest process in mass production is the 4-mask process. Many ideas have been introduced about the 3-mask process, however there have not been any success in achieving real production. In this study, we introduce our 3-mask process through which such objective was achieved.

Through this 3-mask process, the process steps of photolithography and PR strip process can be reduced by 25% and also wet etch process by 30% due to special advantages of lift-off process. In addition, it is easy to adopt this technology in existing facilities because the 3-mask process still uses the existing machines and materials. Moreover, the 3-mask panels assure as much reliability as the 4-mask panels.

This was the first attempt to apply the lift-off process 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. We hope that the 3-mask process will contribute to lowering costs for LCD.

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