Fabrication of an All-Layer-Printed TFT-LCD Device via Large-Area UV Imprinting Lithography

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Abstract

Nanoimprint lithography (NIL) using ultraviolet (UV) rays is a technique in which unconventional lithographic patterns are formed on a substrate by curing a suitable liquid resist in contact with a transparent patterned mold, then releasing the freshly patterned material. Here, various solutions are introduced to achieve sufficient overlay accuracy and to overcome the technical challenges in resist patterning via UV imprinting. Moreover, resist patterning of all the layers in TFT and of the BM layer in CF was carried out using UV imprinting lithography to come up with a 12.1-inch TFT-LCD panel with a resolution of 1280x800 lines (125 ppi).

Keywords: Imprinting, TFT-LCD, overlay, CD

1. Introduction

The display industry has developed various patterning technologies for a low-cost and high-volume production process. Moreover, the enormous investment cost of increasing the glass size underscores the necessity of new-patterning-technology development. Inkjet printing, roll printing, and imprinting are the breakthrough candidates that can replace the photolithography used in the current TFT-LCD manufacturing.

Display R&D Center (LCD Business., Samsung Electronics Co.) is working towards new-patterning-technology development, and imprinting is one of the new patterning technologies that the center is developing. Imprinting has been known to replicate the use of a high-resolution pattern with a high-fidelity and low-cost equipment. Moreover, imprinting using ultraviolet (UV) rays is a technique in which unconventional lithographic patterns are formed on a substrate using a low-viscosity, UV-curable material on top of a traditional resist in contact with a transparent patterned mold, after which a freshly patterned material is released [1-3].

In detail, a mold is pressed into the UV-curable resist on the substrate, and then the sample is exposed to UV irradiation to cure the resist layer. The mold is then detached from the substrate, leaving the reverse pattern in the polymer layer. The advantage of imprinting is its ability to pattern structures from the micron to nanometer scale at a low cost. As the feature size diminishes rapidly, however, a grand challenge that remains to be overcome is the fabrication of dense and complex nanostructures with high aspect ratios, and, in this process, completely releasing the mold from the patterned substrate becomes essential [4-6]. For this reason, a repetition test was successfully carried out over two thousand times, and a new method using high-durability molds with chemically treated surfaces was developed. Further, these authors' research center developed and exhibited a 2.46" QVGA transflective TFT-LCD panel with an imprinted organic-lens array layer for increasing the reflectance [7].

Based on the one-layer imprinting technology, these authors' research has been extended to resist patterning for

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all the layers in TFT and for the BM layer in CF. The fabrication of a 12.1” WXGA (1280´800) TN mode TFT-LCD panel was achieved as a result of the development of imprinting resist patterning.

2. Results and Discussion

Conventional photolithography has been replaced with imprinting for patterning the resist material, as shown in Fig. 1. Resists for five layers (from the gate to the pixel) in TFT and for the BM layer in CF were patterned via imprinting.

The process for patterning each layer consists of six steps, as follows: layer deposition, resist coating, imprinting, ashing to remove the residual layer, etching, and resist strip. The process steps for patterning the layer using imprinting, which replaced photolithography, are described in Fig. 2. During the imprinting process development, overlay accuracy, CD (critical dimension) uniformity, resolution, and yield were achieved, and through these technical accomplishments, a high-quality TFT-LCD panel was obtained.

To allow sufficient overlay accuracy, these authors’ efforts were focused not only on the improvement of the tool’s performance but also on the development of the process. As shown in Fig. 3, less than 1 um alignment accuracy with the gate layer was obtained in the succeeding four layers.

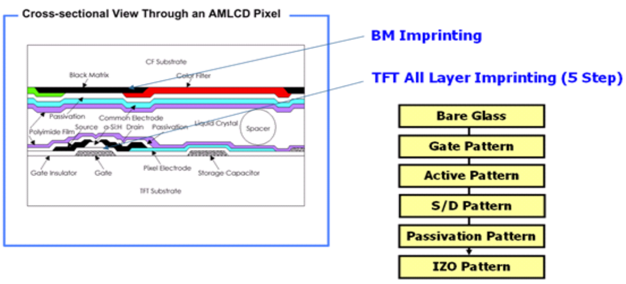


Fig. 1. Cross-sectional view through an AMLCD pixel. Imprinting was applied to resist patterning for five layers in the TFT and one layer in CF.

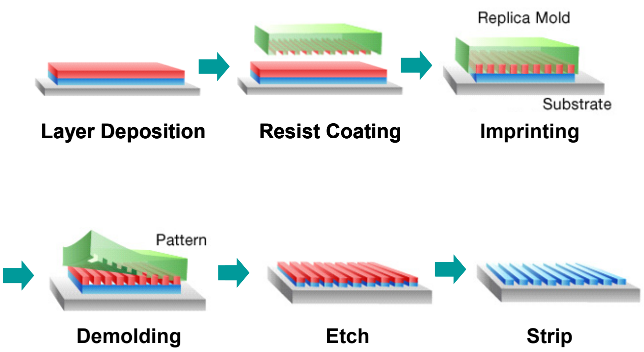


Fig. 2. Schematic diagram of the process steps for patterning the layer via imprinting.

The properties of the imprinting resin and mold were investigated with a process factor. It was found that the low viscosity of the material was a great advantage in terms of high throughput and residual uniformity. The 6 cP material was used as the imprinting resin. The microscopic-level pattern pitch and the high modulus of the mold made it impossible to achieve conformal contact between the mold and the substrate by varying the height due to the previous patterned layer(s), as seen in Fig. 4. This nonconformal contact causes the loss of some resist patterns during the ashing process because ashing should be applied until the residual layer on the lowest part is completely removed. To overcome this problem, compensation should be considered in the master design.

Particle contamination and the bubble defect are the main factors that are relevant to the imprinting process yield. The influences of the particles and bubbles on the pattern were investigated, and it was found that particles are generally the sources of the line short. Bubbles, on the other hand, cause line disconnection. Fig. 5 shows an abnormal pattern caused by particles and bubbles.

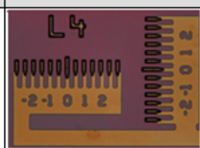
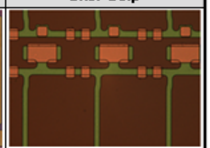
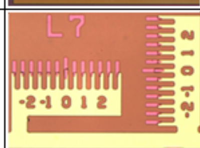
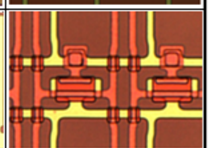
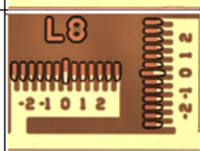
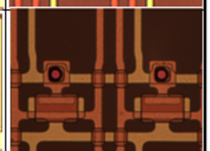
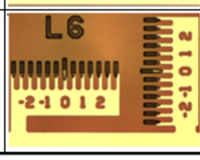
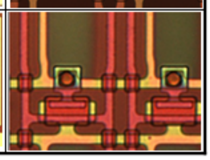
Layer	Misalign form Gate	Vernier Key	Imprinting Pattern after Strip
Active	< 0.5 um		
Source / Drain	< 1.0 um		
Passivation	< 1.0 um		
Pixel	< 1.0 um		

Fig. 3. Alignment accuracy with the gate layer and the pattern scope image of the succeeding four layers (active, S/D, passivation, and pixel).

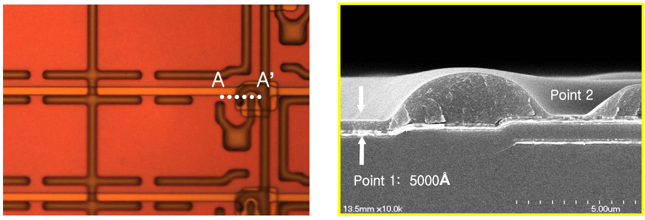


Fig. 4. Pattern scope and SEM image after S/D imprinting. The SEM image shows the different thickness residual layers in two points.

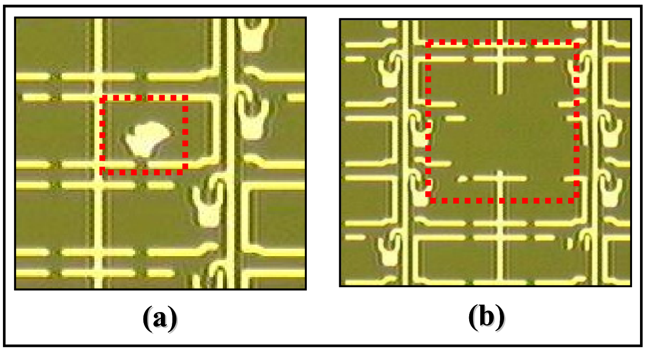


Fig. 5. Abnormal patterns after the imprinting process caused by (a) particles and (b) bubbles.

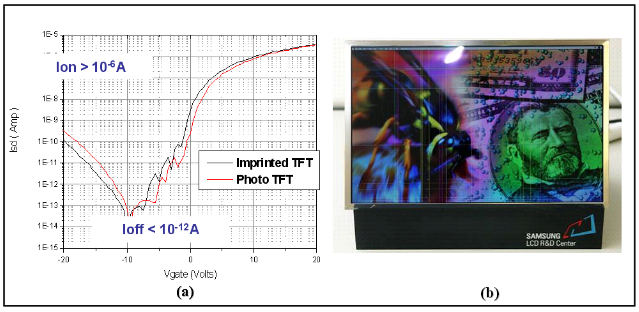


Fig. 6. (a) Comparison of the TFT properties from imprinting and photolithography, and (b) picture of the prototype 12.1” WXGA (1280×800) TN mode TFT-LCD panel.

Through the imprinting technology, it is expected that the display industry will realize a high-resolution pattern that will increase the aperture ratio in the TFT device. To introduce this advantage of imprinting to the industry, it is essential to fabricate the master with a fine pattern. A large master (300x400 mm) with a fine pattern with a 1 um space as channel length was developed. A sufficient-quality TFT was attained through the imprinting process, and a prototype 12.1” WXGA (1280×800) TN mode TFT-LCD panel was achieved, as shown in Fig. 6(a) and (b), respectively.

3. Conclusions

Resists for five layers (from the gate to the pixel) in TFT and for the BM layer in CF were patterned via imprinting. The fabrication of a 12.1” WXGA (1280′800) TN mode TFT-LCD panel was achieved through the development of imprinting resist patterning.

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