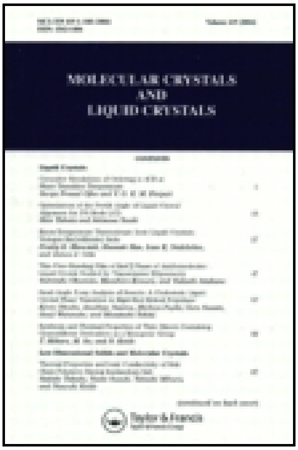

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A New Polyimide with Multifunction of Alignment and Planarization

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A NEW POLYIMIDE WITH MULTIFUNCTION OF ALIGNMENT AND PLANARIZATION

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We developed new material, modified polyimide (MPI) that functions as both an alignment layer for the liquid crystal (LC) and a planarization layer (called overcoat (OC) layer) covering color filter layer. This functioning organic layer is very important to reduce process step and a cost when manufacturing in-plane switching (IPS) and fringe-field switching (FFS) devices since on top substrate of both devices, the alignment layer is coated over the OC layer. The MPI showed excellent aligning capability and high transparency with moderate degree of planarization. In addition, the fabricated twisted nematic LC cell showed similar electro-optic characteristics to those with conventional polyimide.

Keywords: alignment layer; fringe-field switching; modified polyimide; planarization layer; transparency

INTRODUCTION

Recently, the image quality of the active matrix liquid crystal display (AMLCD) is greatly improved and this accelerates replacing of cathode ray tube (CRT) to LCDs. High image quality of the LCDs was obtained with introduction of in-plane switching (IPS) concept of the LC director [1]. At present, the IPS mode is commercialized although they have low transmittance problem. Later on, the fringe-field switching (FFS) [2,3] mode

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that shows high light efficiency with wide viewing angle is introduced and also commercialized. The main characteristic of both modes is that the electrodes exist only on one substrate, generally bottom in AMLCD. On top substrate, only the color filter layer with planarization layer called overcoat (OC) made of epoxy or acrylic or combinations of them exists. Therefore, to align the LC in a specific direction, alignment (AL) layer, generally polyimide (PI) is coated over the OC layer, and then the PI surface is rubbed. However, the coating of PI above the OC layer with thickness of about 1000 Å caused some defects like imperfect coating which lowers yielding ratio and also increase in process time [4].

In order to solve such a problem, we developed a new material, modified polyimide (MPI) which can act as OC layer as well as AL layer simultaneously. In this paper, we report the MPI's characteristics such as aligning capability, transparency, and degree of planarization. In addition, electro-optic characteristics were also investigated and discussed after fabricating the twisted nematic LC cell.

EXPERIMENTAL

The modified polyimide used in this paper was as reported previously [5]. MPIs having different degree of chloromethylation (MPI-20, MPI-50, MPI-100, MPI-150, and MPI-180, respectively) were obtained and abbreviated as MPI-n where n denotes for the degree of chloromethylation. The detailed chemical structures and their characterizations were reported in a previous paper.

The adhesion test of MPI films on a glass substrate was performed following the ASTM D3359-B. The transparency of MPI were examined by measuring the light transmittance of 1.1 μm thick film at 400 nm. Planarizability was tested for 1 μm thick MPI films on a color filter substrate by examining the surface roughness with surface profiling instrument (alpha-step) as described in the text book [6]. Preparation of TN cells for testing the alignment properties were described in the results and discussion section.

RESULTS AND DISCUSSION

In general, the AL layer does a role of only aligning the LCs. The OC layer does a role of planarizing the depth difference between color filter and black matrix made of resin. The film thickness of the AL layer is below 1000 Å but it is over 1 μm for the OC layer to planarize effectively the depth difference in color filter. Therefore, the transparency of the OC layer is also very important not to decrease light transmittance of the device by this layer. Consequently, new material MPI should show following characteristics: good aligning capability, high transparency in visible wavelength range and planarizing capability to replace conventional two layers into one layer. This can be achieved by modifying a soluble fluorinated aromatic polyimide with chemical reagents so as to introduce chloromethyl functional groups in the side chain.

The modification of fluoropolyimide resulted in the improved physical properties such as optical transparency, adhesion, planarization, and aligning capability. MPIs were soluble in most of organic solvents including chloroform, tetrahydrofuran (THF), and cyclohexanone as well as polar aprotic solvents such as N-methylpyrrolidinone (NMP), N,N-dimethylformamide (DMF) and dimethylsuloxide (DMSO). The glass transition temperature of MPI was in the range of 258–297°C. The thermogravimetric analysis (TGA) of MPI showed 2-step thermal decompositions, which are corresponding to the decomposition of side functional groups at near 285°C, and the decomposition of the main chain at above 480°C, respectively. MPI films with thickness of about 1000 Å was prepared on a glass substrate with or without adhesion promoter pre-treatment (1% aminopropylsilane), and the adhesion of sample was compared before and after the thermal treatment at at 230°C for 30 min. MPI showed adhesion grade of 2B–3B depending on the degree of chloromethylation. Pre-treatment of adhesion promoter slightly increased the adhesion. After thermal treatment, however, it was increased to 5B. Compared to this, the polyimide before the modification showed adhesion grade 1B even after the thermal treatment. All the MPI was optically clear and showed transmittance higher than 96.9%. Interestingly, even after heating at 230°C for 240 min in air, the transmittance changed less than 1.5% (95.5%). That of the conventional polyacrylate-based OC (OCE-10 from ADMS Tech. Co.) decreased from 97.1% to 83.8% after the heating. Planarizability was tested by spin-coating NMP solution of MPI on a color filter substrate and examining the surface roughness after solvent removal. Depending on the solid content (SC) of MPI solution, the degree of planarization (DOP) varied from 0.2 to 0.48 (SC = 5 and 15%, respectively). From the preliminary experiment, it was found that DOP could be increased more with optimum solid content and molecular weight of MPI. To confirm aligning capability of the MPI, we fabricated homogeneously aligned LC cell with cell gap of 60 μm and film thickness of about 1000 Å, and then observed it under optical polarizing microscope. To compare aligning capability with conventional PI (SE-7492 from Nissan Chemicals), we made two cells, as shown in Figure 1. The first one has conventional PI layers on both top and bottom substrate and the second one has PI on one side and MPI on the other side. As clearly seen, both cells exhibited a good dark state without alignment defect. We also measured pretilt angle of the MPI as a function of the pile

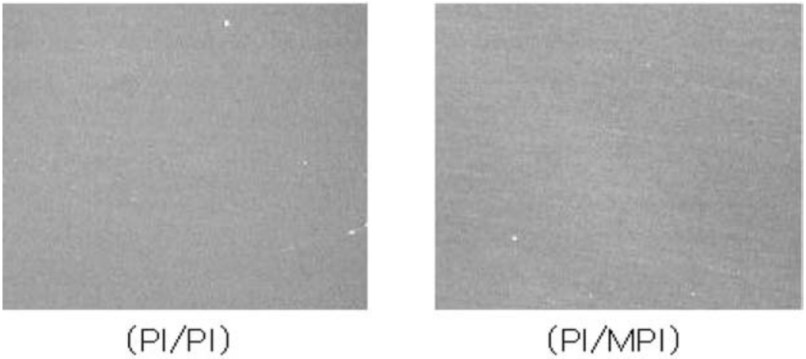

FIGURE 1 Photos that show excellent aligning characteristics for the cells with PI/PI and PI/MPI on top and bottom substrate.

depth using the crystal rotation method (see Figure 2). In the cells, the super fluorinated LC ($\Delta n = 0.1$ at 589 nm, $\Delta\varepsilon = 8.0$) was used. For rubbing conditions, the roll speed was 40 mm/s, the revolution per minute was 800 and the roll diameter was 10 cm. As a rubbing cloth, the cotton was used. At low pile depth, the pretilt angle was 1.6° which is suitable for the IPS and the FFS device and although the pile depth was increased to 1 mm

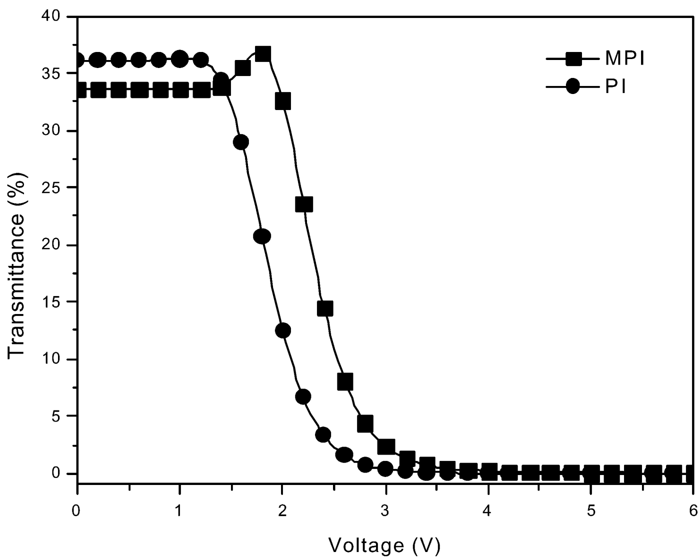

FIGURE 2 The pretilt angle of the MPI as a function of the pile depth.

from 0.6 mm, it was almost saturated to 2.2°, implying that by using the MPI we could obtain uniform display quality in terms of the pretilt angle. The degree of chloromethylation did not significantly affect the pretilt angle. Finally, we fabricated the twisted nematic (TN) cells using PI and MPI, separately. The cell gaps for the cell with PI and MPI were 5.3 and 8.2 μm, respectively. The super fluorinated LC ($\Delta n = 0.097$ at 589 nm, $\Delta\varepsilon = 6.2$, chiral pitch = 100 μm) was used. Figure 3 shows voltage-dependent transmittance (V-T) curves for two cells. For the cell with MPI, the V-T curve had a bump at about 1.8 V, resulting from the large retardation value of the cell over first minimum condition of 0.48 μm, and also shifted to the right compared with the cell using PI, due to large cell gap. Except these, the maximum light transmittance was about the same for both cells. We repeated the measurement several times and obtained the same results. This informs that the surface anchoring energy of the MPI is strong enough not to give a hysteresis. Further, we checked the response time of both cells. The rising time for the cell with PI and MPI was 4 ms and 5 ms, respectively, which was about the same, indicating the surface anchoring energy of the MPI is about the same as that of the PI. The decay time for the cell with PI and MPI was 17 ms and 36 ms, respectively. The difference in decaying time was presumably due to the cell gap difference.

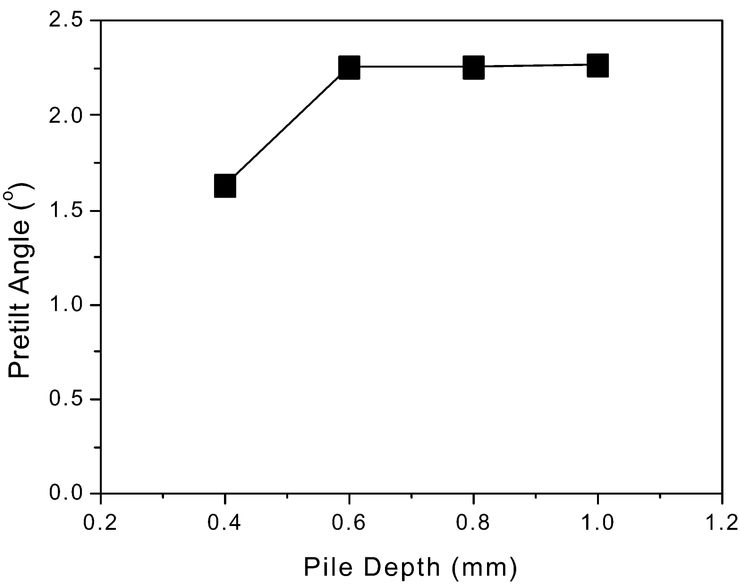

FIGURE 3 The voltage-dependent transmittance curve for the twisted nematic LC cells with the PI and the MPI.

SUMMARY

We developed a new material that does a role of both aligning the LC and planarizing the color filter substrate. Modified polyimide (MPI) synthesized from a soluble fluoropolyimide was used for that purpose. According to the characterization results, the new material showed excellent aligning capability with very low pretilt angle, and good electro-optic characteristics. Along with the good aligning characteristics, it exhibited the improved physical properties as an overcoat material such as high optical transparency, excellent adhesion, and good planarization behavior. The result is very important to reduce process steps and a cost when manufacturing the IPS and the FFS AMLCD.

REFERENCES

[1] Ohta, M., Oh-e, M., & Kondo, K. (1995). *Asia Display'95*, 707.
[2] Lee, S. H., Lee, S. L., & Kim, H. Y. (1998). *Appl. Phys. Lett., 73*(20), 2881.
[3] Lee, S. H., Lee, S. L., Kim, H. Y., & Eom, T. Y. (1999). *SID'99 Digest*, 202
[4] Lee, S. H., Lee, S. M., Kim, H. Y., Kim, J. M., Hong, S. H., Jeong, Y. H., Park, C. H., Choi, Y. J., Lee, J. Y., Koh, J. W., & Park, H. S. (2001). *SID'01 Digest*, 484.
[5] Zhang, A., Li, X., Nah C. W., Hwang, K., & Lee, M.-H. (2003). *J. Polym. Sci.: Part A Polym. Chem., 44*(1), 22.
[6] Wong, C. P. Ed., (1992). *Polymers for Electronic and Photonic Applications*, Academic Press: London, 154.