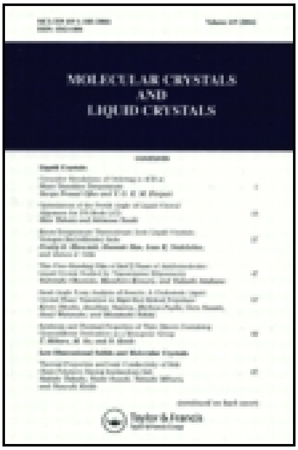

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Musun Kwak [a], Hanrok Chung [a], Jaeha Choi [a], Hyukmin Kwon [a], Jehyun Kim [a], Daekyung Han [a], Chulho Park [a], Sangmun Lee [a], Chulgu Lee [a] & Sooyeol Cha [a]

[a] Panel Technology Department, LG Display Company Ltd., Gyeonggi-do, Korea

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Panel Technology Department, LG Display Company Ltd., Gyeonggi-do, Korea

The surface characteristics of hybrid type twisted nematic (TN) mode alignment film (AF) were studied with atomic force microscopy (AFM) and frictional force microscopy (FFM). As a result, the contrast of friction on FFM image had changed when the probe was scanned in rubbing directions. In the friction loop, the frictional asymmetry was detected differently according to the drying temperature conditions. The difference was explained by pretilt uniformity of side chain molecules arrangement on polyimide (PI) layer surface. The measured data of surface energy and pretilt angle after liquid crystal (LC) injection couldn't represent realistic layer frictional characteristics of AF surface.

Keywords: alignment film; FFM; frictional asymmetry; frictional force microscopy; TN mode

1. INTRODUCTION

Forming AF in LC display (LCD) industry is one of the important factors on demanding products with high quality and resolution. The control of LC alignment has been recognized as fundamental technology in LCD industry. For example, MURA, the representative defect caused by instability of pretilt uniformity of AF surface, greatly affects on yield ratio in manufacturing LCD products. Evaluating surface

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Address correspondence to Musun Kwak, Panel Technology Department, LG Display Company Ltd., 1007 Deogeun-ri, Wollong-myeon, Paju-si, Gyeonggi-do, Korea. E-mail: musunkwak@lgdisplay.com

characteristics of AF was necessary to satisfy a product with high specification [1], but the devices to measure them in manufacturing LCD product process were little. To make up for these weak points, the hybrid AF was newly designed. The hybrid AF which is composed of double layer AF (PI and polyamic acid: PAA) was developed in order to ensure high voltage holding ratio (VHR) and low residual dipolar coupling (RDC) characteristics [2], but it has been understood abstractly whether the double layers in two different liquid phase polymers were formed. Thus, we started to research on directly measuring the formation of hybrid AF (PI+PAA) that was mentioned in the previous report on materializing the double layer formation condition and surface characteristics (Fig. 2a). In the report [3], the change of characteristics of AF was understood as drying conditions change in in plane switching (IPS) LC driving mode. In case of twisted nematic (TN) mode, AF has different pretilt angle of $4 \sim 6^{\circ}$ unlike AF surface structure of IPS mode [4]. Especially, forming the pretilt angle of side chains on PI layer is more critical because LC molecule is guided by the side chain in TN mode. The discovery of the pretilt angle mechanism in AF has been explained as interaction between LC and surface energy [5] and shape of AF [6]. LC molecule is aligned by micro-groups formed in the rubbing process [7]. An experiment to compare mechanism quantitatively is performed [8], but the mechanism of the pretilt angle is not explained enough. Then, how can we identify the surface alignment tilting status after rubbing? The direct measuring method is demanded.

FFM which is the newly devised from AFM is based on this concept. The friction study at the atomic level has been developed rapidly by the invention of FFM in the fields of the experiment. FFM was previous suggested as deciding the tilt direction of the molecule on film [9]. Friction of atom scale was firstly observed by Mate *et al.* [10] through scanning the cleavage of graphite in 1987. FFM allows the practical application to detect surface uniformity of material as well as the friction anisotropy [11] on atomic flat surface. When the probe scans in one direction, the asymmetry of friction strength is reported even if scanning forward and backward [12,13]. FFM can be used in determining tilting directions of molecular species [14].

In this paper, the studies of the AFM/FFM measurement for the structure characteristic of the film by the drying conditions for TN mode with hybrid AF. First, we confirmed the possibility of PI layer formation by SEM and so as to identify the formation of the PI layer surface. By using FFM, the differences of frictional asymmetry in rubbing directions were measured. The pretilt angle and surface energy were measured in the same condition. In addition, it is necessary to understand the basic properties in friction by using FFM.

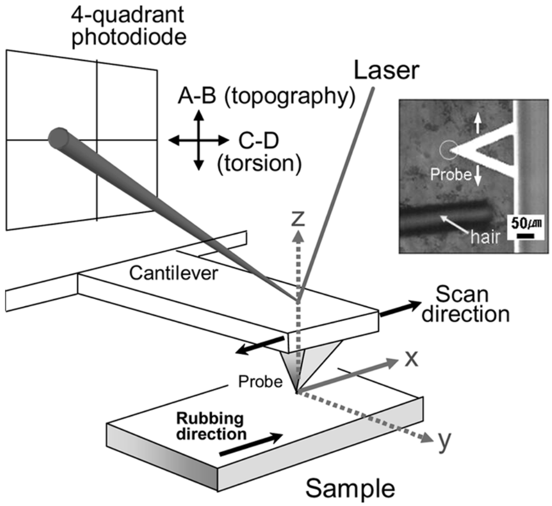

FIGURE 1 AFM/FFM principle. The FFM probe along the rubbing direction can be detected strength friction.

2. EXPERIMENTAL

The hybrid AF samples were cured on ITO substrate in higher than 220°C that coated with a temperature condition of prebaking from 60°C to 90°C. The samples were scribed in liquid N_2 for preserving the status. The characteristics of hybrid AF structure were analyzed with SEM and AFM/FFM. Figure 1 shows the AFM/FFM principle. NanoScope IV AFM of Digital Instruments was used in FFM mode. The probe was triangular silicon cantilever (force constant 0.12 N/m) with a square pyramidal stylus of silicon nitride. The normal load was set at 12.57 nN. The FFM probe was scanned on the rubbing direction. The friction loop showing the torsion (friction signal) of the cantilever was also recorded. The direction of tilt on the surface of AF was measured by detecting frictional asymmetry through FFM.

3. RESULTS AND DISCUSSION

3.1. Double Layer at Hybrid AF in TN mode with SEM

The results are shown in Figure 2(b). The double layer formation for the hybrid AF was verified with the experiment. Unlike hybrid AF in IPS mode, the double layer structure of hybrid AF in TN mode was formed independently with temperature [3]. From the results, the surface of PI layer was confirmed. In TN mode, surface energy

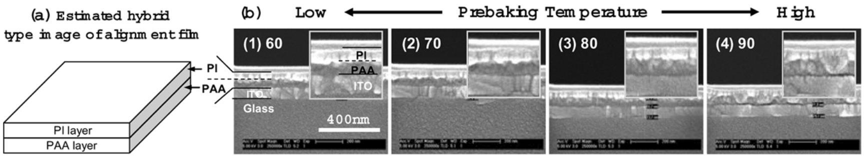

FIGURE 2 SEM images of prebake temperature conditions of hybrid AF TN (postbaking condition over 220°C). (a) Estimated image of hybrid type image AF and (b) AF double layer formation dependence by the prebake temperature. Double layer structure is detected.

of PI is 42 mN/m and that of PAA is 53 mN/m. (Ref.: In IPS mode, surface energy of PI is 56 mN/m and that of PAA is 58 mN/m.) The contain of side chain molecular makes difference in surface energy.

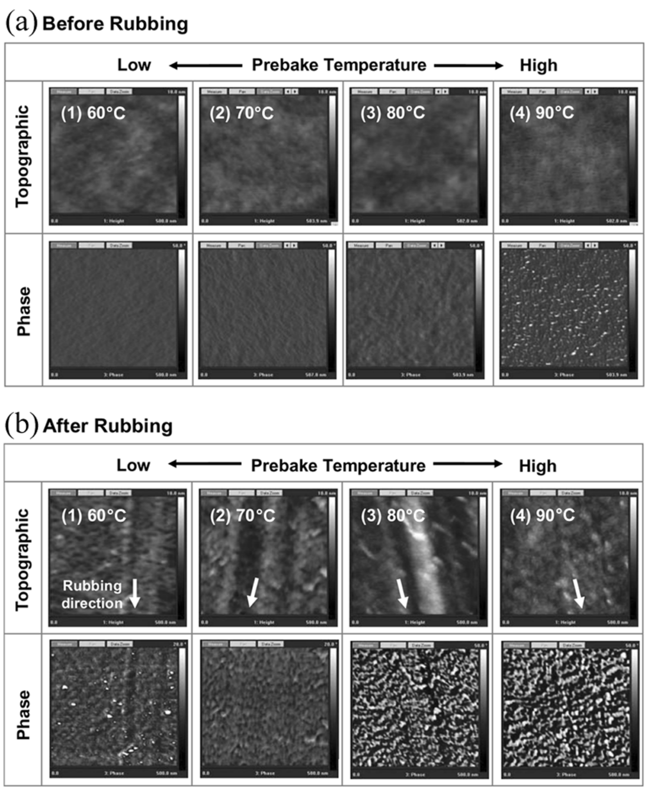

FIGURE 3 The AFM topographic and phase images with prebake temperature conditions (scan size: 500 nm sq.). The phase images in (b3) and (b4) show unstable contrast as the prebake temperature increased.

The image-sticking phenomenon in IPS mode was examined by an electric double layer of the RDC voltage formed between LC and AF interface. The adsorption of LC molecules having strong polarity and of ionic impurities existing in the layer of LC was explained in the paper. Therefore, to reduce the image-sticking, the stable process conditions are required to reduce the adsorption on the surface of AF.

3.2. AFM on PI Layer Surface

Figure 3 shows the AFM analysis for the same sample. Topographic image of the surface of PI layer before rubbing is relatively stable. But that of the surface of PI layer after rubbing is unstable on temperature conditions. The phase images in (b1) and (b2) show stable contrast because the regular shape of micro groove on the surface by rubbing was seen in case of (b2). But the phase images in (b3) and (b4) show unstable contrast as the prebake temperature increased. The alignment of the surface shape is affected by the prebake temperature. The analysis of the characteristic changes by prebake temperature as well as rubbing condition is necessary to increase uniformity on the surface of PI layer. Finally, we decided to analyze frictional characteristics with the samples of (b2) and (b4) which were expected to show the differences on frictional asymmetry.

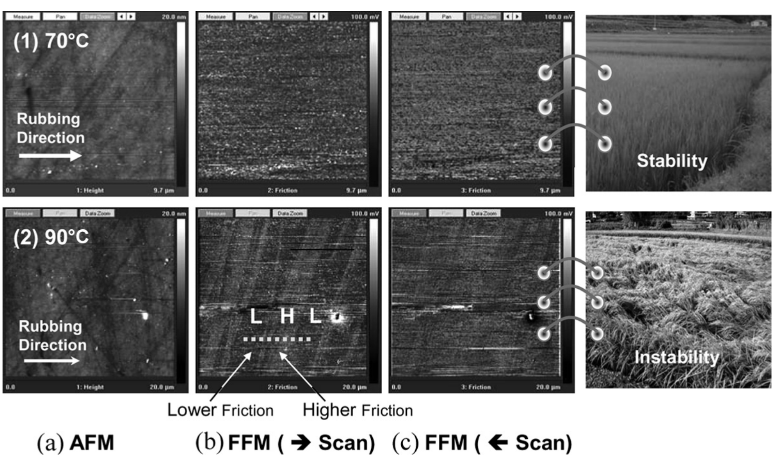

FIGURE 4 AFM (a) and FFM images (b,c) on PI layer surface. (1) FFM images show stable contrast (scan size: 9.7 μm sq.). (2) FFM image contrast was detected when the probe was scanned in rubbing direction (scan size: 20 μm sq.).

3.3. Frictional Properties of PI Layer Surface

Figure 4 shows the scanning images of AFM and FFM along the rubbing direction on the surface of the PI layer. The frictional contrast images of (b) and (c) were detected, so the frictional asymmetry was expected. When scanning the dotted line in Figure 4. b2, the friction loop in Figure 5(a) clearly shows the frictional asymmetry caused by the tilt direction of side chains. Figure 5(b) shows scheme of the unstable side chains on the surface of PI layer. Figure 5(c) shows the direction of inclined side chains according to the scanning direction. The frictional force may normally increase when the stylus scans in

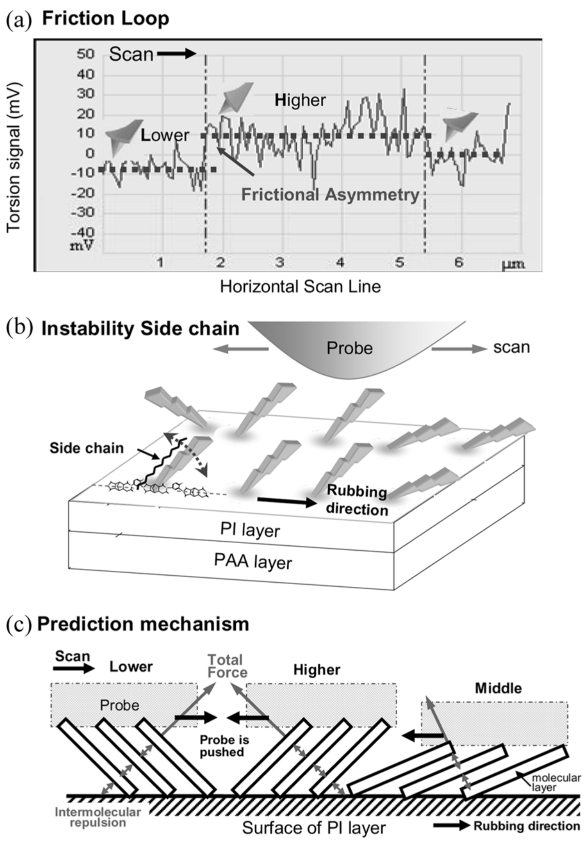

FIGURE 5 (a) Friction loop: Frictional asymmetry was detected as clear difference in grade by the tilt direction of side chain; (b) Interaction between the FFM probe and side chain and (c) The molecular layer will resist against compression in that direction due to intermolecular repulsion.

opposite direction to the molecular direction, but the results were totally against the expectation. According to Liley *et al.* [8], the negative results that the frictional force was increased when scanning to the inclined direction of alkin molecule with monomolecular film of thiolipid on mica were happened. The strength of friction force by the scanning direction was determined by the difference in tilted angle on the united molecule surface [15,16]. It is expected that when the tilted side chain is contacted and pressed by the probe, the repulsive force can be generated perpendicularly by interaction between molecular of side chains as seen in Figure 5(c).

In general, the instability of pretilt angle of side chains causes problems in the process. Stabilized material design for forming pretilt uniformity of side chains and optimized process condition are demanded.

3.4. Surface Energy and Pretilt Angle

Figure 6(a) shows surface energy and the pretilt angle after injecting LC according to temperature condition. The surface energy was increased with the range of 0.3 (mN/m) interval. However, there

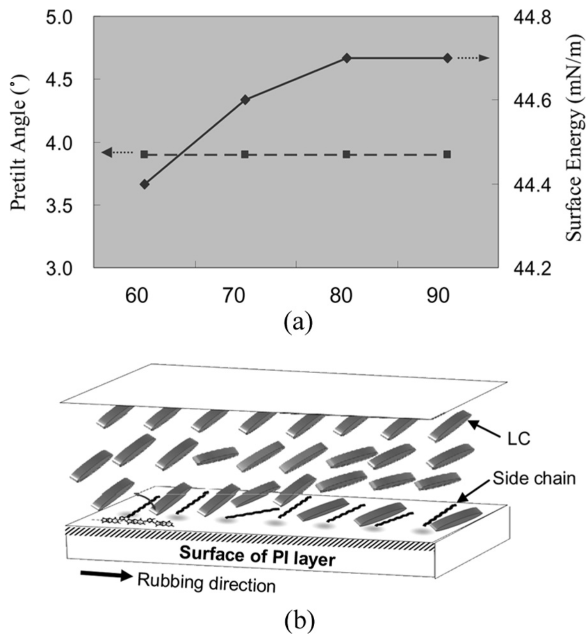

FIGURE 6 Result of surface energy and pretilt angle. There were no obvious interpretable differences in the result of pretilt angle.

was little effect from prebake temperature ranging from 60°C to 90°C in case of pretilt angle. The pretilt angle and the surface energy moved independently except the frictional characteristics over 90°C. Thus, measuring data of pretilt angle of side chains on the surface of AF with LC hardly shows the accurate data (Fig. 6b). This measuring method has been generally used in the industry. If using FFM, measuring top surface AF surface can be possible.

4. CONCLUSION

1. The structure of hybrid double layer in TN mode has been directly observed without prebake temperature range through SEM analysis. Through the observation, the existence of side chains on the layer is confirmed by checking PI layer above PAA.
2. As a result of analyzing the frictional characteristics on the surface of PI layer in TN mode, the friction loop clearly shows the frictional asymmetry. The asymmetry can be explained as the instability of the side chains within prebake temperature condition.
3. Finally, we can suggest the measuring method that detects tilt direction of side chains on PI layer of AF by using FFM.

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