Study of Correlation between LC Display Quality and Degree of Crystallinity at Surface of Alignment Film

The market for liquid crystal (LC) displays has been growing with the strong global demand for flat-panel displays such as those used in televisions. Rubbed polyimide films called alignment films are widely used in LC displays to uniformly align LC molecules. Therefore, understanding the mechanism of the alignment of LC on rubbed polyimide surfaces is one of the most important issues from both fundamental and industrial viewpoints. However, no clear-cut explanation of the mechanism has yet been given. We found that the capability of aligning LC molecules is correlated with the crystallinity of the polyimide film at the surface [1].

Figure 1 shows the typical structure of LC displays. The LC molecules are sandwiched between two glass substrates that are coated with a polyimide alignment film that has been unidirectionally rubbed with a cotton or rayon cloth. The LC molecules are aligned in a direction by this rubbing process. The brightness of LC displays is controlled by the direction of LC molecules, which are switched by the electric field. Therefore, the alignment of LC molecules is important for insuring the quality of LC displays, as shown in Fig. 2.

Up to now, we have developed many types of alignment films using many kinds of polyimides in order to control the alignment of LC molecules. Our studies have indicated that the alignment of LC was strongly affected by the molecular structure of the polyimide. Additionally, we have found that there is a correlation between the LC alignment capability and the degree of crystallinity of the polyimide. Grazing incidence X-ray diffraction (GIXD) is a unique technique for separately detecting the crystallinity at the surface and in the bulk. Thus, we investigated the relationship between the degree of crystallinity of the polyimide and the LC alignment capability using GIXD.

We prepared three types of polyimide films that have different LC alignment capabilities. PI-A, PI-B and PI-C polyimides have excellent (○), good (△) and poor (×) LC alignment capabilities, respectively. Thin polyimide films were prepared by curing spin-coated polyamic acid on a Si substrate. The thickness of the films obtained after curing was about 100 nm. GIXD experiments were performed using a multiaxis diffractometer installed in the 2nd hutch of the beamline **BL19B2**. The incident X-ray energy was set at 10 keV.

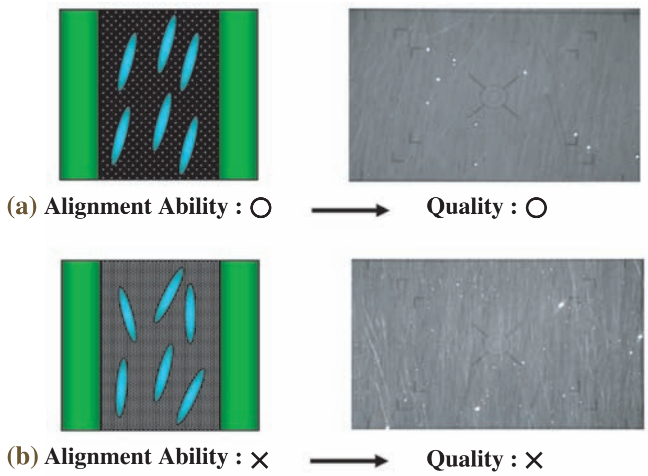

Fig. 2. Relationship between the capability of aligning LC molecules and the quality of LCD. **(a)** When all LC molecules are unidirectionally aligned, the LC quality is high. **(b)** If each LC molecule has a different direction, the brightness varies from area to area. That results in poor LC quality.

Figure 3 shows plots of the observed in-plane θ-2θ profiles of the rubbed films when the scattering vector is parallel to the rubbing direction with an incident angle of 0.16° (over the critical angle of the films). In this condition, we were able to obtain bulk-sensitive information on the films, since the incident X-ray penetrated deep into the polyimide films. For all films, we observed one sharp diffraction peak at around 4° and one broad diffraction peak around at 15°, as shown in the figure. These observed profiles suggest that there was no significant difference in the degree of crystallinity between the bulk films. That is, there is no relationship between the crystallinity of the bulk and the LC alignment capability.

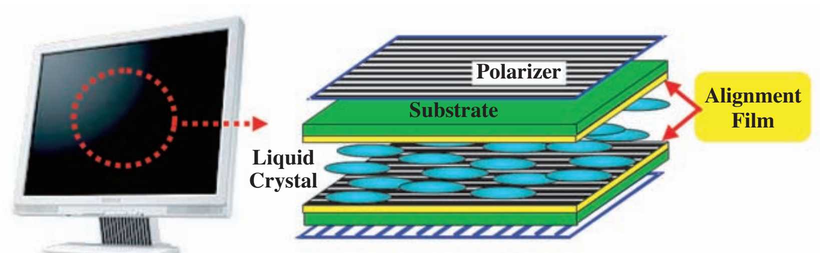

Fig. 1. Typical structure of LCD.

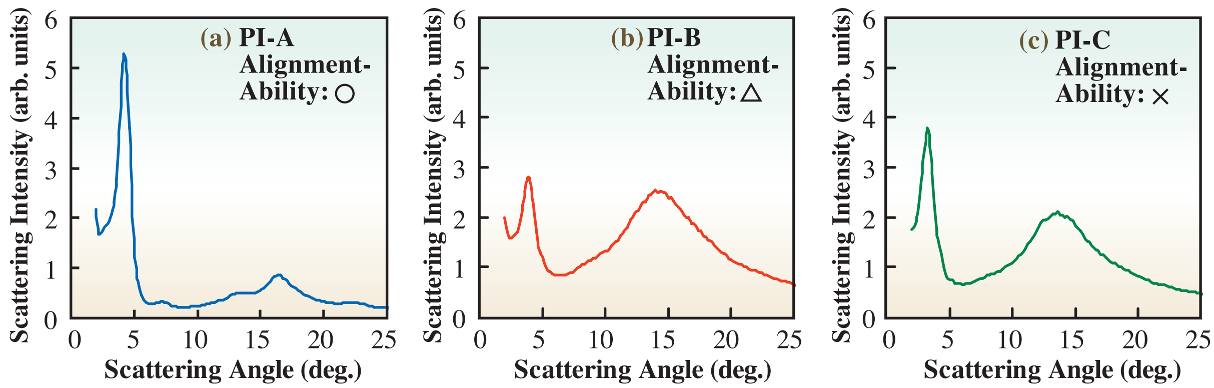

Fig. 3. Observed diffraction profiles obtained from **bulk**-sensitive measurements.

On the other hand, surface-sensitive profiles were obtained from in-plane θ-2θ scans by setting the incident angle at 0.12° (below the critical angle). In this condition, the X-ray penetration depth was estimated to be about 8 nm. The surface-sensitive profiles show important differences in the intensities of the diffraction peak at around 4° among the three films, as shown in Fig. 4. A sharp and intense peak was observed in the case of PI-A, which has excellent alignment capability (○). However, the surface-sensitive peak of PI-B (alignment capability: △) is weak. Furthermore, there appears to be no surface-sensitive peak in the case of PI-C (alignment capability: ×) despite the fact that the bulk-sensitive peak of PI-C was clearly observed. These facts indicate that there is a clear correlation between the LC alignment capability and the degree of crystallinity at the surface of the polyimide films.

In conclusion, we investigated the crystallinity of polyimide films having different alignment capabilities using GIXD and found a correlation between the LC alignment capability and the crystallinity at the surface. As mentioned above, the LC alignment capability is directly related to the LCD quality. Thus, we have obtained a result that can act as a guide for the development of films with excellent alignment that have the capability of realizing excellent LCD quality.

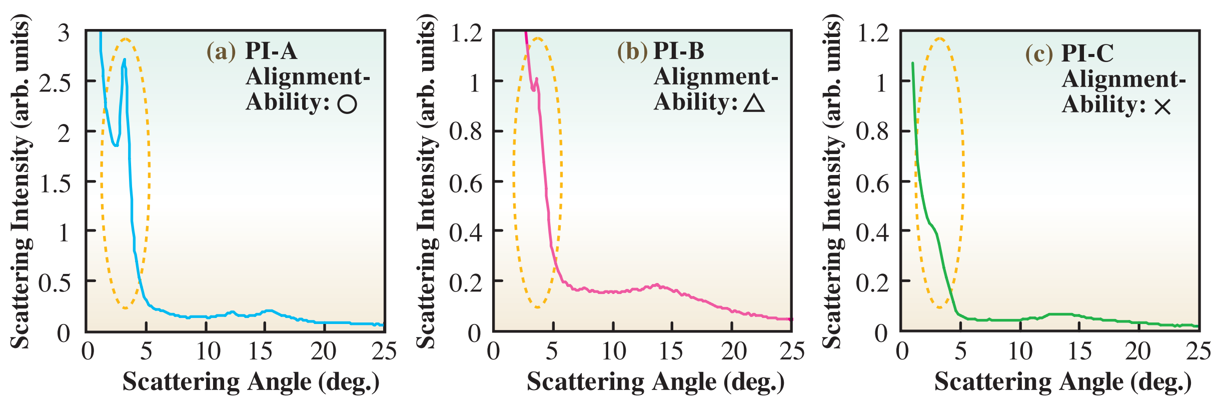

Fig. 4. Observed diffraction profiles obtained from **surface**-sensitive measurements.

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References

[1] *T. Sakai: Kinou Zairyou (Function & Materials)* ***27*** *(2007) 69 (in Japanese).*