Multidirectional Liquid Crystal Orientation by Using Ion Beam Irradiation

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Abstract

We have investigated the alignment ability of multi-domains by using ion beam irradiation on diamond-like carbon (DLC) thin film layers. The DLC thin films were deposited by plasma enhanced chemical vapor deposition (PECVD) system and the low energy ion beam is irradiated from Kaufman type ion gun. The direction of liquid crystal alignment is varied by the direction of Ar ion beam irradiation.

1. Objective and Background

Because the liquid crystal displays (LCD) are operated by the optical anisotropy of liquid crystal (LC) and a polarizing plate, the variation of effective birefringence with viewing angle is performed unavoidably. This result lowers the quality of the display such as the narrow viewing angles, poor gray scale capability and the low contrast at angles off the normal. And these problems become more serious for large area the LCD. One remedy to modify the LCD externally such as the compensation layer[1)], the multi-domain structure[2)], in-plane switching (IPS) mode[3)]. In these techniques, the multi-domain technique suggested in 1980's where one pixel is divided into two or more domains each having different alignment configurations.

Nevertheless this method is shown good viewing angle effect, the major problem in making multi-domain displays, is the complex preparation process. In the case of conventional rubbing method, it is necessary such as PR coating and

photolithography process for dividing domains. And these factors are result in the poor mass production. But the non-contact method uses only simple masking process for dividing multi-domain such as UV irradiation.

The LC alignment method using this paper is low energy ion beam (IB) irradiation method and this method has lately attracted considerable attention for many advantages than conventional contact method.[4-6] IB irradiation method is non-contact type like UV irradiation method, and it can improve the drawback of rubbing such as the generation of electrostatic charges or the creation of contaminated particles. Moreover there are no surface damages, since ion beam is irradiated by low energy level and this method is evaluated by excellent method than UV irradiation method.

In this study, we investigated the DLC layer by LC alignment material and irradiated multi-directional ion beam for multi-domain structure and analyzed the material property and the LC alignment property. By this multi-directional ion beam irradiation process, it is possible to realize the multi-domain of the LC cell for wide viewing angle

Table 1 Ion beam irradiation condition

Sample	Total Time	Irradiation condition
T0	0min	No IB treatment (as-dep)
T1	20sec	12 o'clock
T2	1min	12 o'clock
T3	2min	12 o'clock
T4	2min	12 o'clock (1min) + 3 o'clock (1min)
T5	2min 20sec	12 o'clock (20sec) + 3 o'clock (2min)
T6	3min	12 o'clock (1min)+ 3 o'clock (1min)+ 6 o'clock (1min)
T7	4min	12 o'clock (1min)+ 3 o'clock (1min)+ 6 o'clock (1min)+ 9 o'clock (1min)
T8	5min	0°

2.1 Surface change of alignment layer after multi-directional IB treatment

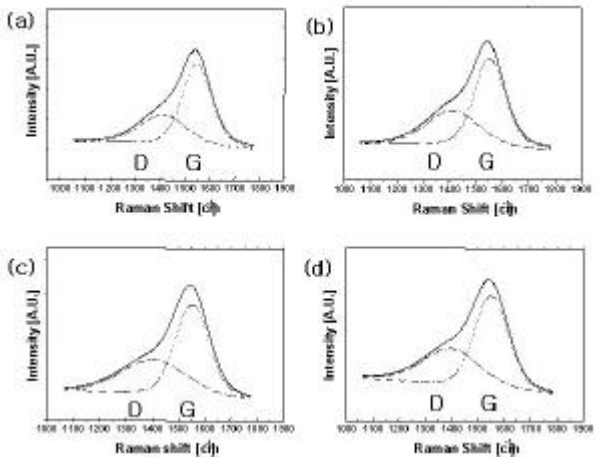

Fig. 1 The Raman spectra of a-C:H thin film (a) T0, (b) T3, (c) T4, and (d) T5

The DLC film has the complex structure between the graphite of sp^2 structure and the diamond of sp^3 structure and the material property is changed various depending on the sp^2/sp^3 ratio[7]. We used Raman spectroscopy in order that we should analyze the property changes of DLC layers before and after IB irradiation. Raman peak from Fig.1 is shown the typical Raman peak of DLC thin films and it is independent on irradiation time and direction. Generally, the sp^2/sp^3 ratio of DLC films is related the I_D/I_G ratio that the area ratio between D peak and G peak. As the I_D/I_G ratio is increased, we can judge that

the sp^2/sp^3 ratio is increased too. In our Raman samples, the I_D/I_G ratios of T0, T3, T4, T5 had the each value of 0.59, 0.70, 0.72, 0.71. Consequently the sp^2/sp^3 ratio is on an increasing tendency when IB is irradiated on DLC layers. Through this result, it is proved that the selective destruction between sp^2 and sp^3 structures. This tendency is not effective by irradiation time and direction.

2.2 Orientation change of liquid crystal molecules after multi-directional IB treatment

In the Table 1, T0~3 are the conditions that evaluate the LC alignment property depending on the irradiation time. All samples are achieved uniform alignment except T0 (non irradiated sample). But the pretilt angle of LC is dependent on the irradiation time, and it is reported that LC

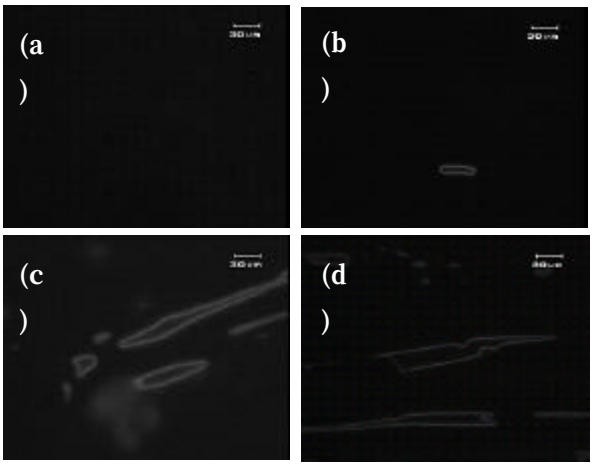

Fig. 2 Micrographs of LC cell with ion beam irradiated a-C:H thin films (a) T4, (b) T5, (c) T6, and (d) T7

present the maximum pretilt angle at 1 min irradiation time, and then, the pretilt angle is lower more or less than 1 min.[6] Fig. 2 is shown the POM data according to multi-directional irradiation. In the case of T4, there are some partial defects in the LC cell in spite of the same irradiation condition with T3. But at T5, when we irradiate second IB (3 o'clock) more than initial direction, we can get more uniform result than T4 Moreover, at T6, triple-directional irradiated sample such as 12, 3, 6 o'clock is shown perfect uniform normal black state. Finally, T7, added 1 more irradiation at 9 o'clock than T6, had the partial defects again. It is reported that the p-bonding of internal DLC layer play an important role at DLC subjected ion bombardment.[5] The p-bonding parallel to IB is less destructed than perpendicular to IB. And because of such directional selective destruction of the p-bonding, LC is aligned to the direction we had chosen. At T4, first irradiation at 12 o'clock is generated the anisotropy of structure and the p-bonding parallel with 12 o'clock is dominant than the others. But by second irradiation at 3 o'clock, the p-bonding dominant to 12 o'clock is destructed again and the bonding state is returned the random distribution state. We called this phenomena ' off-set effect' . If the second irradiation is stronger than first irradiation, the new anisotropy to 3 o'clock will be generated. At T5, we increased the time of second irradiation and LC is aligned uniformly. This result was agreed with the

former assumption perfectly.

At experiment of T6, even if the irradiation time is the same as 1min at each direction, the p-bonding parallel to IB is the same at 12 and 6 o'clock. Therefore, the dominant direction is 12 and 6 o'clock and it is possible to perform the uniform alignment condition. Contrasted with T6, the total amount of irradiation time is same between vertical (12 & 6 o'clock) and horizontal (3 & 9 o' clock) and they are offset each other. In the result, there are no dominant p-bonding and no structural anisotropy. It is the reason of uniformly alignment result of T7.

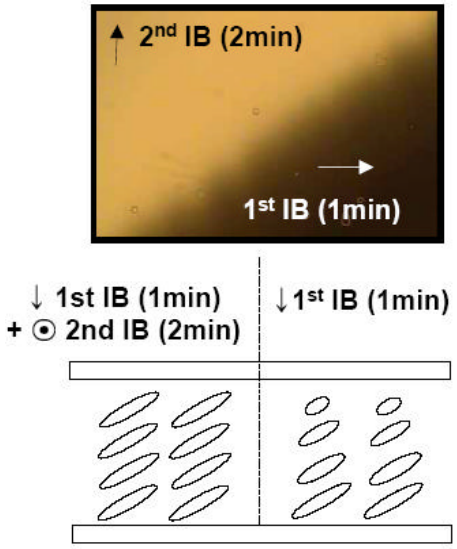

Fig. 3 two orientation of LC by multi-directional IB treatment

Based on these orientation changes of LC molecules, multi domain LC cell was fabricated. Fig.3 showed 2 directional LC orientations by 2 step IB treatment. In order to change the direction of LC, we used the metal mask. At first step, IB was irradiated without the metal mask. And then, the substrate was rotated about 90deg clockwise with metal mask. In the result, two directional domains which are oriented parallel and twist are achieved. By using this technique, it is possible that multi-directional LC orientation in pixel size.

3. Conclusion

We irradiated low energy ion beam on DLC layers, which varied irradiation time and direction.

As we changed irradiation time at same irradiation direction, the pretilt angle of LC is varied but the alignment direction is not changed. On the other hand, when we changed the IB irradiation direction at the same time, LC cells were shown various alignment results, since the effect of selective bonding destruction is reinforced or compensated in the DLC thin films

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