Hydrogen Effects on Diamond-like Carbon as the LC alignment Layer of FFS mode

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Abstract

In this paper, we have investigated the hydrogen effects on Diamond-like Carbon (DLC) as an LC alignment layer of the FFS mode. By change of a Hydrogen content in the DLC sputtering process, the image sticking and electro-optic characteristics of Black-White panel with DLC / IB technology were examined.

1. Introduction

The conventional rubbing method has been widely used and is being used in the LCD industry because of its stability and productivity[1, 2]. However it has limitation as a contact method. Hereafter, its problems such as rubbing scratch, debris, particle, gray screen mura, and rubbing uniformity in high resolution and large size LCD displays will be highlighted. So many researchers have studied and are studying on several non contact alignment (NCA) method. A leading candidate of NCA was the photo alignment[3,4]. However, that has still issues in the thermal stability and the image sticking caused by low anchoring energy. Development of the new material related of the photo alignment with high anchoring energy is required urgently.

Recently, diamond-like carbon thin film with inclined ion beam irradiation technology was studied as an LC alignment layer. First IBM group developed this technology for the IPS mode application [5~7], after several groups studied the ion beam irradiation technology with various materials for non-contact LC alignment application. But image sticking issue was not much examined.

Astonishing progress in both technology and production of liquid crystal displays has been achieved rapidly for the last ten years. However, most of currently available LCDs still utilize the twisted-nematic (TN) mode. The TN mode is not yet free of image quality problems, since it suffers from a slow response speed and a narrow viewing angle. So more advanced LCD modes have been continuously studied and proposed. LCD modes suitable with wide viewing angle are introduced as like a optically compensated birefringence (OCB) mode, a patterned vertivally alignment (PVA) mode, a multidomain vertical alignment (MVA) mode, and a in-plane-switching (IPS) mode. However, the VA modes require compensation film creating cost up for wide viewing angle and have a slow response speed unsuitable for moving pictures. The OCB mode requires a high initial voltage to change LC directors to the bend state and bias voltage is also needed to maintain the bent state while switching, and the IPS mode has the problem of aperture ratio in spite of many merits of in-plane switching. A More free mode in these problems is the FFS, which is representative mode

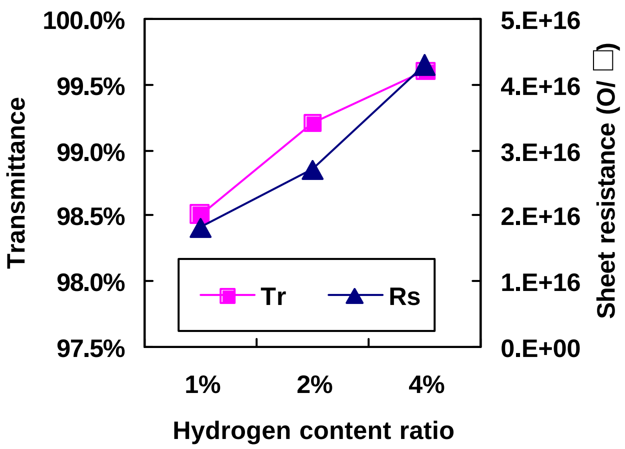
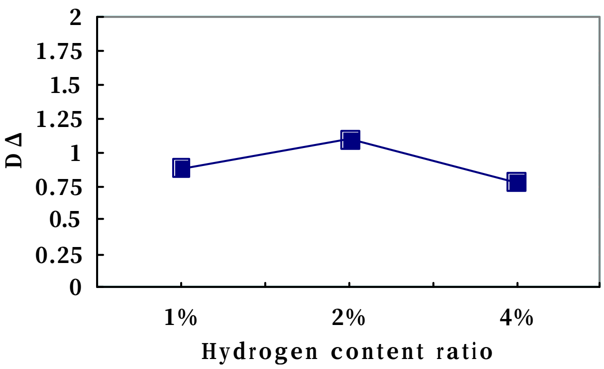


Fig. 1 Transmittance and sheet resistance of DLC for various hydrogen content ratio in deposition process.

developed by BOE-Hydis[9, 10].

In this paper, we examined the image sticking of the DLC and IB technology applied to the FFS mode. By various hydrogen content ratio range of 1% ~ 4% in the DLC sputtering process, we checked the electro and optic properties. A useful method to reduce image sticking of FFS mode with the DLC/IB process is also suggested.



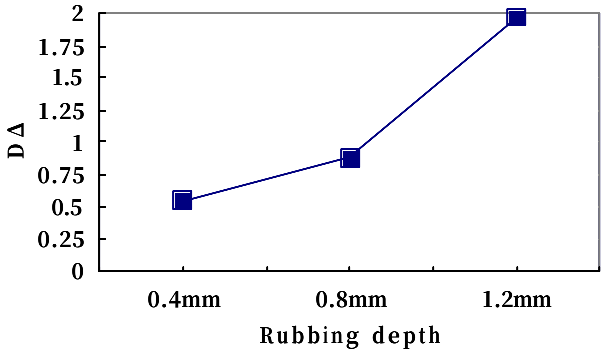


Fig. 2 Optical anisotropy(D?) data for the ion beam irradiated DLC (upper) and the rubbed PI (lower) respectively.

2. Experiment and Results

Diamond-like carbon thin films were prepared on a glass substrate by using the RF magnetron sputtering system with a carbon target. Here we used the hydrogen gas ratio of 1 mol% ~ 4 mol % range in the mixed gas Ar and H_2 at 4kW power process condition. DLC thickness was about 10nm with a deposition ratio 0.44 A/s. DLC substrate was irradiated with incident angle 15 degree and ~10^{15} /cm^2 Ar dose of ion beam equipment.

In order to check the hydrogen dependent physical quantities of DLC thin film, sheet resistance and transmittance of DLC were measured in fig. 1. The more content of the hydrogen ratio is included in DLC sputtering process, the higher resistance and transmittance of DLC thin films were obtained. The hydrogen gas seems to play a critical role which determines the electric and optic properties [11, 12]. In reference, the sheet resistance and the transmittance of the conventional polyimide which is used for the low pretilt angle LC mode were measured as 6.7×10^{16} ohm/box and 98.5% respectively, with a 70 nm thickness.

Before we examined the image sticking of the various hydrogen ratio of DLC, the optical anisotropy (D?) of the DLC irradiated with ion beam was measured and compared to that of the rubbed PI by using Toyo PI checker system as shown in fig. 2. In case of DLC, D? was less sensitive to the hydrogen content ratio, and was around 0.9 values. D? of DLC thin film was originated from a preferential orientation of net excess of remaining pi bonds perpendicular to the ion beam direction. In comparison to PI / Rubbing case, D? of 0.8 mm depth condition was measured as 0.8, which was the typical data in the PI / Rubbing product process in my experience. So, this DLC and ion beam irradiation condition was expected to show a similar

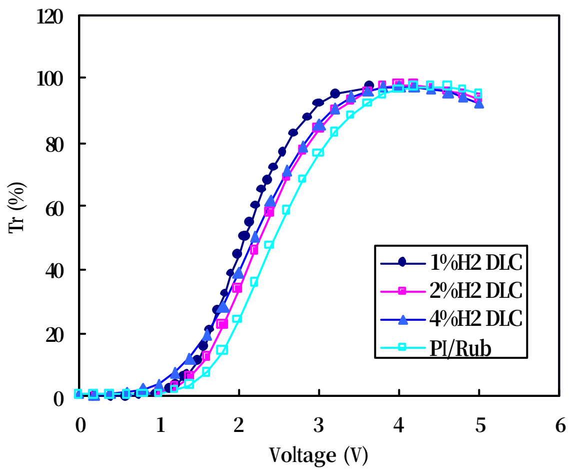


Fig. 3 Transmittance vs. voltage curve

LC alignment property as PI / Rubbing.

We made 18.1" SXGA panel with the DLC and ion beam conditions. First we measured the transmittance vs. voltage curve as shown in fig. 3. Basically a particular difference in the transmittance vs. voltage

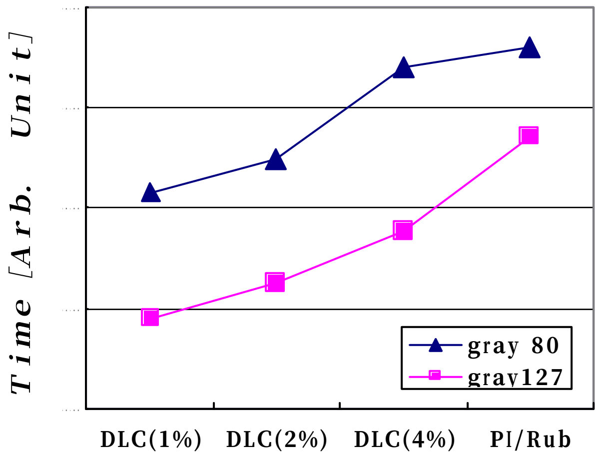


Fig. 4 Disappearing time of image sticking pattern

curve was not found between DLC / IB and PI / Rubbing. Next we measured the image sticking data for the various hydrogen content ratios and normal PI / rubbing as shown in fig. 4. Disappearing time of image sticking pattern in the panel of the lower hydrogen contented DLC was shorter than that of the higher hydrogen contented DLC. From the data of Fig. 4, we expected the resistance of alignment layer is important to the image sticking of FFS mode. This tendency is coincident to the previous study in the PI case, where image sticking data was very good in the case of low resistivity in IPS mode[8]. For the precise measurements of the azimuthal anchoring energy, two test cells, which were cut from the same assembled substrate, were filled with nematic LCs (from Merck) which have different rotational pitchs (+60 μm, 8 μm, respectively. The anchoring energy was calculated

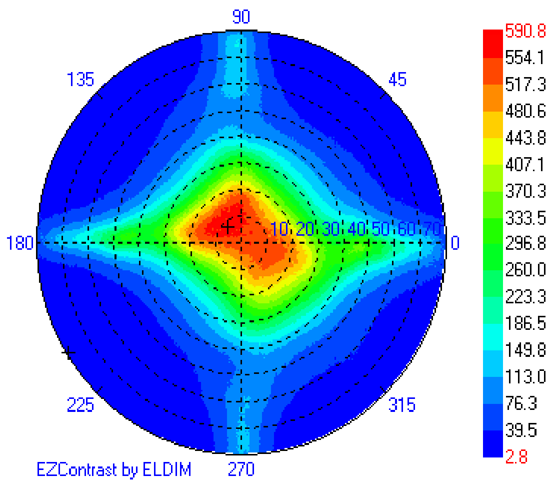


Fig. 5 the characteristics of the viewing angle with ion beam treated DLC.

from the experimentally measured twist angles in the cells [13]. Anchoring energy of DLC also was measured as 1.0^{4} J/m^2 ~ 1.0^{-3} J/m^2 using the torque balance method, but a trendy of hydrogen dependence was not found. By using the same method, anchoring energy of PI / Rubbing was about 4×10^{-4} J/m^2. And we could not find any LC flow traces in panel of DLC/IB. So we expected the anchoring energy of DLC was not less to that of PI / Rubbing.

Viewing angle vs. contrast ratio of the DLC/IB panel was shown in Fig. 5. Comparing with the conventional rubbing technology, DLC/IB showed nearly same viewing angle data.

3. Conclusion

In FFS mode, we applied the DLC / IB technology to 18.1" SXGA panel, and found that the image sticking could be reduced by controlling the resistance with change of hydrogen content in the DLC alignment layer.

4. Acknowledgements

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5. References

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