New Inorganic Vertical Alignment Material Suitable for Large Area LCD Panel

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Abstract

We investigated the liquid crystal (LC) alignment phenomena using a-C:H and a-C:F:H thin films. Homogeneous alignment is obtained using ion beam treated hydrogenated amorphous carbon (a-C:H) thin films. Homeotropic alignment is obtained using F treated a-C:H thin films, namely, fluorinated amorphous carbon (a-C:F:H) thin films. We investigated the relationship between the surface properties of amorphous carbon based alignment layer and LC alignment phenomena.

1. Introduction

Liquid crystal displays (LCDs) are realized by using the anisotropic electro-optical phenomena of liquid crystal (LC) molecules.[1] The unidirectional alignment of LC molecule should be required for these phenomena. The unidirectional alignment of LC is possible using LC alignment layer. Normally, LC alignment layer is organic material, such as polyimide.[2,3] The rubbing method [2], photoalignment method [3] and ion beam method [4] have been used for the alignment of LC molecules in one direction up to now.

However, there have been few reports on the amorphous carbon based inorganic alignment layer, such as, a-C:H and a-C:F:H thin films. [4-7] Also only small number of studies has been presented on the relationship between the surface properties of amorphous carbon based alignment layer and LC alignment phenomena.

In this paper, we investigated the relationship between the surface properties of amorphous carbon based alignment layer and LC alignment phenomena.

2. Experimental

a-C:H and a-C:F:H thin films were deposited on indium-tin-oxide (ITO) coated glass substrate by plasma enhanced chemical vapor deposition (PECVD). The surface of a-C:H thin films is treated with post-growth low energy argon ion beam. The surface morphology of a-C:H and a-C:F:H thin films were characterized by AFM (Atomic Force Microscope). The chemical bond structure of a-C:H and a-C:F:H thin films were characterized by Raman spectroscopy. The chemical composition of a-C:F:H thin films were characterized by XPS (X-ray Photoelectron Spectroscopy). For observation of LC alignment property, LC cells were assembled by twist nematic (TN) mode. Also the surface of a-C:H thin films is treated with F containing gas and then LC cells were assembled by vertical alignment (VA) mode.

3. Results and Discussion

3.1. Surface properties of a-C:H and a-C:F:H thin films

The surface morphology of a-C:F:H thin films were investigated by AFM and the results are shown in Figure 1.

(a) (b)

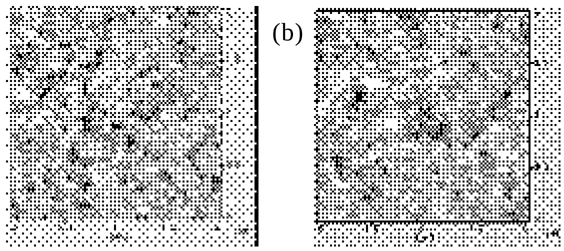

Figure 1 The surface morphology of a-C:F:H thin films (a) low F containing gas flow and (b) high F containing gas flow

As shown in Figure 1, a-C:F:H thin films have the isotropic and smooth surface morphology regardless of F containing gas flow. a-C:H thin films have the isotropic and smooth surface morphology regardless of ion beam irradiation condition. [7]

The chemical bond structure of a-C:H thin films were characterized by Raman spectroscopy and the results are shown in Figure 2.

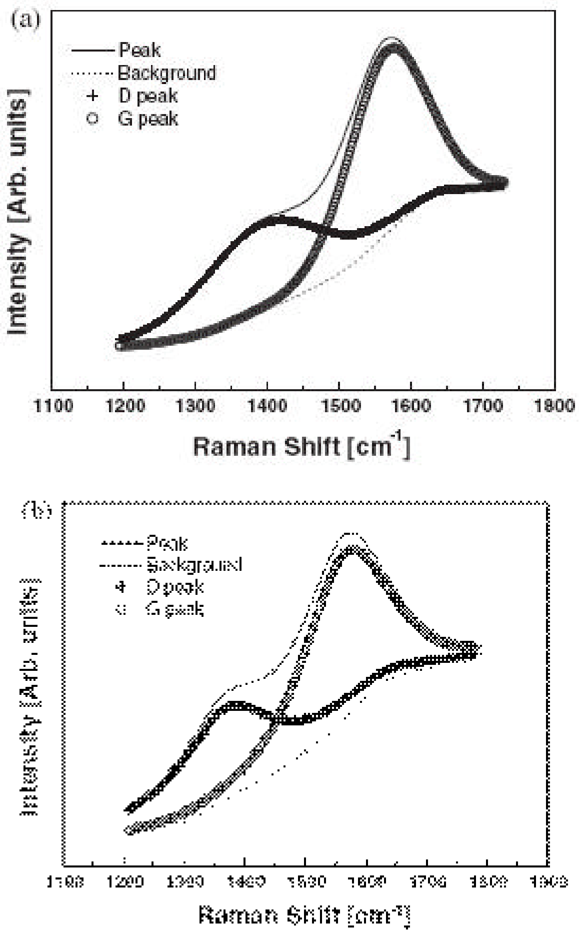

Figure 2 The Raman spectra of a-C:H thin films as a function of ion beam irradiation time (a) 0 min and (b) 1min

As the ion beam irradiation time is increased, I_D/I_G ratio is also increased. The increase in I_D/I_G ratio denotes the increase in sp^2 content in a-C:H thin films. Therefore ion beam must generate the graphite structure (C=C bond) in a-C:H thin films. This increase of graphite structure means the generation of the surface anisotropic structure.[4, 5, 7, 8]

The chemical bond structure of a-C:F:H thin films are characterized by Raman spectroscopy and the results are shown in Figure 3.

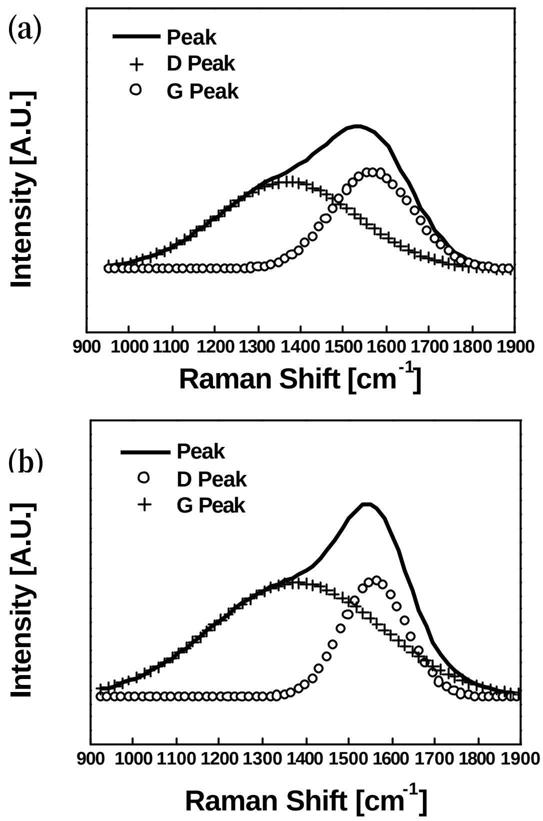

Figure 3 The Raman spectra of a-C:F:H thin films as a function of F containing gas flow (a) low F containing gas flow and (b) high F containing gas flow

In the case of a-C:F:H thin films, increase in F containing gas flow results in the increase of I_D/I_G ratio. It means the increase of graphite structure in a-C:F:H thin films. But, in this case, the increase of graphite structure does not mean the generation of the anisotropic surface structure.

The surface composition of a-C:F:H thin films was investigated by XPS. The XPS results shows that F content was over 30% depend on the F containing gas flow.

3.2. LC alignment property

In the case of a-C:H thin films, LC alignment showed up only ion beam treated a-C:H thin films observed with the photomicroscope.

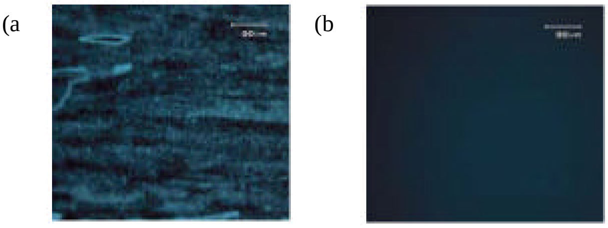

Figure 4 The photomicrographs of a-C:H thin films as a function of ion beam irradiation time (a) 0 min and (b) 1min

Ion beam treated a-C:H thin films have a pre-tilt angle in the range of 4 ~ 5°. Therefore the LC alignment phenomena are determined by post-growth ion beam treatment. The LC alignment phenomena on the surface of a-C:H thin films means the existence of surface anisotropy, which is generated by ion beam treatment, on the surface of a-C:H thin films. Therefore ion beam has an important role to generate the surface anisotropy on the surface a-C:H thin films & homogeneous LC alignment.

In the case of a-C:F:H thin films, the photomicroscope observation shows the homeotropic LC alignment phenomena occurred on the F treated a-C:H thin films.

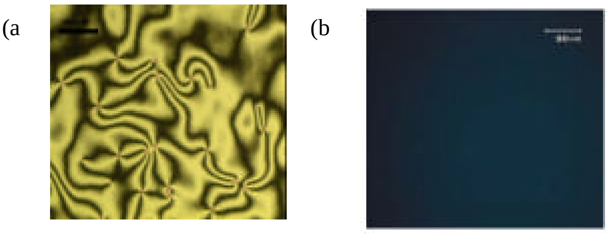

Figure 5 The photomicrographs of a-C:F:H thin films as a function of F containing gas flow (a) without F containing gas treatment and (b) with F containing gas treatment

The only difference between a-C:H and a-C:F:H thin films is the surface composition. In the case of a-C:F:H thin films, F content was over 30 %. The high F contents result in the high contact angle. Typically, the surface contact angle of F treated a-C:H thin films over the water is 80^0 or larger. It means that the surface property is hydrophobic.

3.3. Real panel application

a-C:F:H thin films are applied to 17 inch real panel and we measure the V-T curve. As shown in Figure 6, the V-T curve is similar to that of normal PI layer.

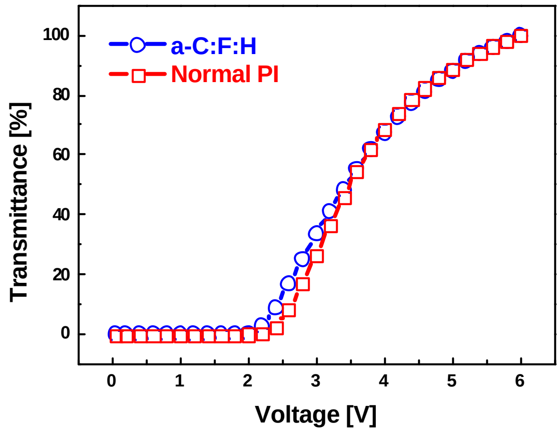

Figure 6 The V-T curve comparison between a-C:F:H thin films applied LCD cell and normal PI layer applied LCD cell

Figure 7 a-C:F:H thin films applied 17 inch PVA panel

Therefore we confirmed that a-C:F:H thin films are suitable for vertical alignment layer.

4. Conclusion

We investigate the surface properties of a-C:H and a-C:F:H thin films. Also we investigate the LC alignment properties using a-C:H or a-C:F:H thin films. The structure of ion beam treated a-C:H thin films is changed from high sp^3/sp^2 ratio to low sp^3/sp^2 ratio. It means the increase of graphite structure (C=C bond) on the surface of a-C:H thin films. This increase of graphite structure means the generation of the surface anisotropic structure. The surface anisotropic structure results in the homogeneous alignment. Therefore ion beam has the very important role to generate the homogeneous LC alignment.

a-C:F:H thin films have high F contents and it results in the hydrophobic surface state. The hydrophobic surface state results in the homeotropic LC alignment. Therefore hydrophobic surface state has the very important role to generate the homeotropic LC alignment.

5. References

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