이온빔 배향을 이용한 네마틱 액정의 프리틸트각 제어를 위한 통계적 모델링

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Statistical modeling of pretilt angle control for NLC using ion beam alignment

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Abstract : The response surface modeling of the pretilt angle control using ion-beam (IB) alignment on nitrogen doped diamond-like carbon (NDLC) thin film layer is investigated. The response surface model is used to analyze the variation of the pretilt angle under various process conditions. IB exposure angle and IB exposure time are considered as input factors. The analysis of variance technique is used to analyze the statistical significance, and effect plots are also investigated to examine the relationships betweenthe process parameters and the response. The model can allow us to reliably predict the pretilt angle with respect to the varying process conditions.

Key Words : response surface model, pretilt angle, nitrogen doped DLC (NDLC), ion beam (IB) alignment, nematic liquid crystal (NLC)

1. INTRODUCTION

Liquid crystals (LCs) are widely used in flat panel display (FPD) technology. The pretilt angle is the main factor that determines the alignment of the liquid crystal display (LCD). A non-contact alignment technique would be highly desirable for future generations of large, high-resolution LCDs. However, very few attempts have been made to statistically model the pretilt angle using ion-beam (IB) alignment. The statistical modeling will allow us to reliably predict the pretilt angle with respect to the varying process conditions. The methodology of characterizing the process using the response surface model has been applied to various fields. May et al. used it to design plasma etch modeling experiments [1]. Garling and Woods applied the analysis of variance (ANOVA) technique to wafer processing [2]. Hu et al. optimizedthe hydrogen evolution activity on a zinc-nickel deposition using a statistical methodology [3].

2. EXPERIMENT

NDLC thin films are deposited on indium-tin-oxide (ITO)-coated glass substrates by plasma enhanced chemical vapor deposition. Substrates are pre-sputtered for 10 minutes using the Ar plasma in the chamber. The NDLC thin film is deposited using C_2H_2 : He : N_2 gas for 30 seconds in order to settle the working pressure the total flux is 33 sccm. Namely, as the flow amount of N_2 is increased, that of He is correspondingly decreased as the same rate. However, the quantity of C_2H_2 is fixed. The thickness of NDLC thin film layer is about 10 nm. We use a Kaufman type IB exposure system. The NDLC thin films are bombarded by an Argon IB. After the NDLC deposited substrates are bombarded by the IB, cells are arranged in an anti-parallel configuration, which is used for pretilt angle measurements. Two substrates are assembled together and filled with a nematic liquid crystal (NLC) (Tc = 72°C, $\triangle\varepsilon$=8.2, MJ001929 from Merck Co.). The thickness of the LC cells for pretilt test sample is 60 ㎛. The pretilt angle of anti-parallel cell is measured by a crystal rotation method. LC alignment effects are observed using a polarized microscope.

3. RESULT AND DISCUSSION

Two input factors, IB exposure angle and IB exposure time, are used to analyze the variation of the pretilt angle. The input factors are explored via full factorial design with five levels for IB exposure angle and three levels for IB exposure time. Three more center points were added. All experimental runs are made in random order.

The analysis of variance of the response is summarized in Table 1. The p-value of the model is 0.000. This indicates that the model can explain the variation of the pretilt angle. The adjusted R-square value is 0.952. This means that 95.2% of the variation is explained by the model.

Table 2. ANOVA for pretilt angle.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	3	49.4786	49.4786	16.4929	114.05	0.000
Linear	2	12.4843	48.3107	24.1553	167.04	0.000
Square	1	36.9942	36.9942	36.9942	255.83	0.000
Residual Error	14	2.0245	2.0245	0.1446		
Lack-of-Fit	11	2.017	2.0170.1	8 34	73.59	0.002
Pure Error	3	0.0075	0.0075	0.0025		
Total	17	51.5031				

The regression model for the pretilt angle is

Y = 2.61462 - 0.01858 * time + 0.34016 * angle - 0.00375 * angle * angle (1)

Where Y is the pretilt angle, time is IB exposure time and angle is IB exposure angle.

The modeling result exhibits a good agreement between the predicted and the measured response values, as shown in Fig. 1.

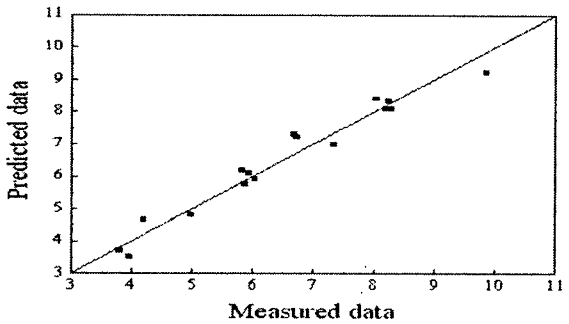

Fig. 1. Modeling result showing predicted and measured responsevalues.

The effect plots of the response are shown in Fig. 2. As the IB exposure time is increased, the pretilt angle is decreased and stabilized in Fig. 2(a). IB irradiation contributes to the generation of the pretilt angle. Because IB irradiation causes the increase of surface roughness and the decrease of the thickness of the NDLC thin film. Figure 2(b) shows a plot of the pretilt angle variation as a function of incident angle of IB. The pretilt angle is maximum at 45°. The pretilt angle gradually decreased with becoming more distant from 45°.

The response surface plot of the pretilt angle as a function of the IB exposure angle and IB exposure time is shown in Fig. 3. The largest pretilt angle is generated by applying the shortest IB exposure time and the middle IB exposure angle.

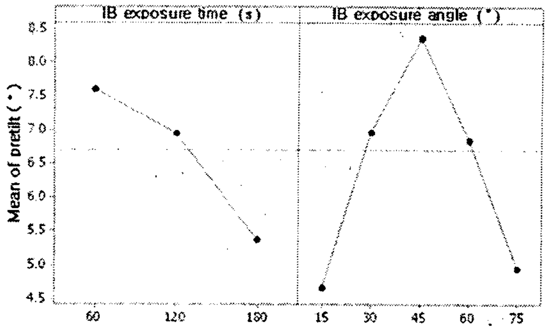

Fig. 2. Main effect plots of IB exposure time and IB exposure angle.

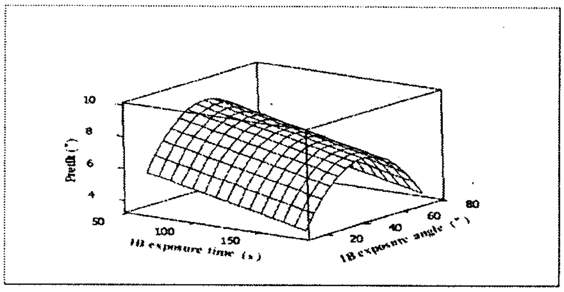

Fig. 3. Response surface plot ofpretilt angle.

4. Conclusions

In conclusion, the control of the pretilt angle using IB alignment on NDLC thin film layer as a function of the IB exposure angle and IB exposure time is investigated via response surface modeling. The statistically significant factors are determined by ANOVA and these factors are compared with those of the varying process conditions, and are analyzed using effect plots. The response surface modeling is in agreement with the experimental data and represents a comprehensive characterization of the pretilt angle. From the results, the model allows us to reliably predict the pretilt angle with respect to the varying process conditions. As a consequence, this is very informative for the control of the pretilt angle. The response surface plot of the pretilt angle can provide the conditions for setting the desired pretilt angle.

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