Research of Electro-Optics Characteristics of Polymer Dispersed Liquid Crystals Doped with Thulium Oxide Nanoparticles Gd_2O_3 in UV Based on Numerical Fitting

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Abstract: **Currently, the new electro-optic properties of polymer dispersed liquid crystal (PDLC) have attracted considerable attention. By adding the thulium oxide nanoparticles (NP) of Gd_2O_3 to PDLC, and testing transmittances of PDLC changing with voltage in visible light, and studying the thulium oxide modulation for PDLC. Nonlinear numerical fitting investigated the transmittance of PDLC that were doped with Thulium Oxide Nanoparticles Gd_2O_3, which was given the function of experimental data to be a Gauss function in the given experimental driving voltage. Fitting results showed that minimum correlation coefficient (R) was 0.9993 and the maximum mean square error (RMSE) was 0.004974. The results show that transmittance of Gd_2O_3-NP-PDLC decreases with increasing voltage when voltage is less than 10v. The relaxation phenomenon of the sample appears in 15v, and its transmittance curve fluctuates slightly around that in 10v .PDLC doped with Gd_2O_3 nanocrystals exhibits diverse electro-optical property, which makes the Gd_2O_3-doped PDLC be a kind of potential material in filter, color display, electro-optical switch applications. Fitting results indicated that the mathematical fitting results were closed to the experimental data, which could deeply discuss electro-optical properties of the polymer dispersed liquid crystal (PDLC) were doped with Gd_2O_3 and provide a theoretical basis for it.**

Keywords—thulium oxide Gd_2O_3; nanoparticles; polymer dispersed liquid crystals (PDLC); electro-optics characteristics; nonlinear numerical fitting

I. INTRODUCTION

In recent years, polymer dispersed liquid crystal (PDLC) materials have been widely used in many fields. Therefore, polymer dispersed liquid crystals and their high-tech properties have attracted considerable attention for the application. In the high-tech properties, the liquid crystal that is doped with something [1-8] is part of techniques. N. Kamanina et al. [9] reported a method to controlled the transmittance of liquid crystals and polymers by doping C60 to PDLC, thus, meeting the desired holographic recording function. Interestingly, PDLC showed grating effect when doped with C60 [10, 11]. O.V. Yaroshchuk et al. [12] studied the electro-optical characteristic of PDLC doped with oxides nanocrystals, such as SiO2, TiO2 and Sb2O5. However, rarely there are any reports on the properties of polymer adjusted by rare earth oxides. The study of employed rare earth oxide modulation polymers of relevant experimental data are given in our previous work [13]. In this study, PDLC (PMMA: TEB30A) were prepared by doping with rare earth oxides Gd2O3. Electro-optical properties were studied by measuring the transmittance spectra meanwhile applying voltage on the samples. This paper continues to do our previous work. The transmission numerical fitting of PDLC doped with Thulium Oxide Nanoparticles Gd2O3 gives the data to meet the functional relationship. The transmittance in the given experimental driving voltage could be calculated According to this function. Fitting results showed that minimum correlation coefficient (R) was 0.9993 and the maximum mean square error (RMSE) was 0.004974. The results show that transmittance of Gd2O3-NP-PDLC decreases with increasing voltage when voltage is less than 10v. The relaxation phenomenon of the sample appears in 15v, and its transmittance curve fluctuates slightly around that in 10v .Fitting results indicated that the mathematical fitting results approached to the experimental data, which could deeply discuss electro-optical properties of the polymer dispersed liquid crystal (PDLC) doped with Gd_2O_3 and provide a theoretical basis for it.

II. EXPERIMENTAL METHODS

3 g Polymethylmethacrylate (PMMA) was dissolved in 10 ml of N, N-Dimethylformamide (DMF) with the assist of magnetic stirring process. Then commercial liquid crystals were added to the mixture prepared before by 1:1 in volume in order to obtain PDLC. Rare earth oxides Gd_2O_3 with average grain size of 300 nm were doped in as-prepared PDLC,

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respectively. The proportion of rare earth oxides to PDLC was fixed at 0.0517 g: 10 ml and the purity of rare earth oxides exceeded 99.99%. pure and doped PDLC were coated on the Indium Tin Oxide (ITO) glasses with an controlled thickness of 30 um. Finally, coated samples were solidified at ~55 ºC for 120 min.

Transmittance spectra were performed on a grating spectrometer (SpectraPro-500i, Acton Research Corporation) in the range of 490 and 680 nm. In order to elevate accuracy of measurement, incident light was filtered by a micro-pore, then reached the samples perpendicularly. All the measurements were carried at room temperature. Adjustable dc voltage was applied to the sample.

III. Data analysis and fitting

Fig. 1 showed the comparison between the transmission spectra and the experimental data through the nonlinear curve fitting. In the interval 490 nm-640 nm, the transmission rate decreased along with the increase of wavelength when the driving voltage increased gradually. Furthermore, the color interference effect was obviously driving low voltage, but this effect decreased gradually along with the increase of driving voltage. The transmission rate of PDLC decreased along with the increase of driving voltage when the driving voltage was lower than 10V.

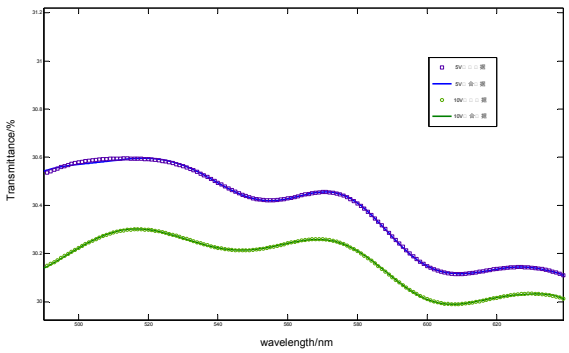

Fig. 1. Comparison between the experimental data and the fitting results, the solid line is the curve fitting.

Though analysis the shape of the curve in Fig. 1, we found a function that is a form of a Gauss 7 function and could be described accurately the relationship of experimental data in Fig. 1. Expression is given by:

$$T(\lambda) = \sum_{i=1}^{7} a_i \exp(-((\lambda - b_i)/c_i)^2) \quad (1)$$

a_i , b_i , c_i were to be optimized parameters, λ is the wavelength, $T(\lambda)$ is the transmission rate.

From expression [1], we could see that a_i adjust the amplitude of transmission rate, and b_i can be seen as the phase of light wave which adjust the position of the wave crest. There are two transmission wave crest at 513nm and 574nm driving voltage 5V and 10V. c_i can be seen as a constant varying with the expression [1]. $T(\lambda)$ is a sum of seven different exponeneial functions.

The optimized parameters, the correlation coefficient, and RMSE had been given in Table I. Fitting results illustrated that the experimental data corresponded to fitting results in the expression [1] very well. Therefore, we could obtain conveniently the transmission rate of Micro Nano Gd_2O_3 doped PDCL at given driving voltage in 490-640nm through using expression [1].

Fig. 2 showed the relaxation phenomenon of the sample appears in 15v, and its transmittance curve fluctuates slightly around that in 10v.

Though analysis the shape of the curve in Fig. 2, we found a function that is a form of a Gauss6 function and could be described accurately the relationship of experimental data in Fig. 2. Expression is given by:

$$T(\lambda) = \sum_{i=1}^{6} a_i \exp(-((\lambda - b_i)/c_i)^2) \quad (2)$$

a_i , b_i , c_i were to be optimized parameters, λ is the wavelength, $T(\lambda)$ is the transmission rate.

From expression [2], we could see that a_i adjust the amplitude of transmission rate, and b_i can be seen as the phase of light wave which adjust the position of the wave crest. There are two transmission wave crest at 521nm driving voltage 15V. The relaxation phenomenon of the sample appears in 15v, and its transmittance curve fluctuates slightly around that in 10v. c_i can be seen as a constant varying with the expression [2]. $T(\lambda)$ is a sum of six different exponeneial functions.

The optimized parameters, the correlation coefficient, and RMSE had been given in Table Ⅱ.

PDLC doped with Gd_2O_3 nanocrystals exhibits diverse electro-optical property, which makes the Gd_2O_3-doped PDLC be a kind of potential material in filter, color display, electro-optical switch applications.

TABLE I. THE FITTING RESULTS OF TRANSMISSION SPECTRUM CURVE IN DIFFERENT DRIVING VOLTAGE.

Driving voltage	Parameters: a_i , b_i , c_i	R	RMSE
5V	a_1 ~a_7= 28.28,-0.6103,20.16,17.15,9.008, 18.39, 3.419e+008 b_1~b_7= 463, 642.3, 657.9, 625.2, 589.7, 556.2, 640.6 c_1~c_7 = 84.93, 13.18, 27.55, 31.99, 33.84, 57.91, 0.1169	0.9993	0.004974
10V	a_1 ~a_7=28.34, 0, 18.21, 14.45, 7.971, 16.81, 20.57 b_1~b_7=441.4, 641.9, 628.4, 593.2, 563.1, 529.5, 666.1 c_1~c_7 =84.02, 0.19, 34.22, 35.47, 36.64, 53.32, 32.43	0.9997	0.001826

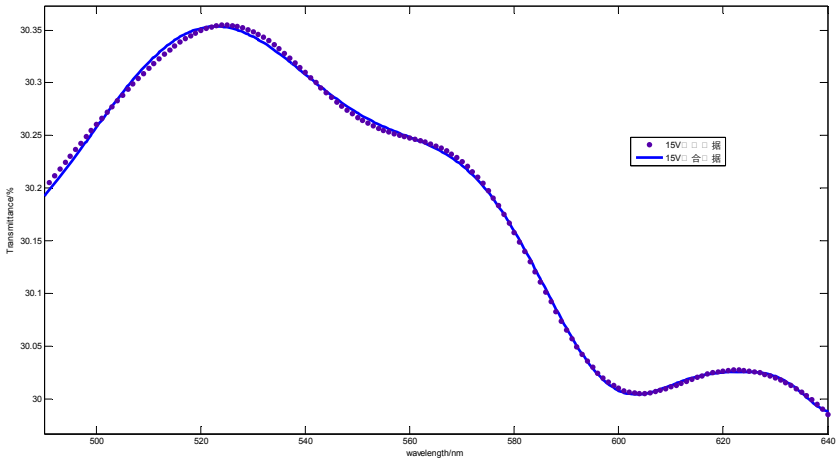

Fig. 2. Comparison between the experimental data and the fitting results, the solid line is the curve fitting. driving voltage 15V

TABLE II. THE FITTING RESULTS OF TRANSMISSION SPECTRUM CURVE IN DIFFERENT DRIVING VOLTAGE.

Driving voltage	Parameters: a_i , b_i , c_i	R	RMSE
15V	a_1 ~a_7= 27.6, -0.4112, 19.97 , 18.7, 9.248, 20.56 b_1~b_7= 425.2, 627.7, 682, 647.8, 601.2, 556.2, 552.7 c_1~c_7 =107.3, 16.65, 24.91, 39.89, 45.23, 57.91, 79.36	0.9993	0.003537

IV. CONCLUSIONS

This paper analyzes the variation of the transmission spectrum experimental data which is nanometer rare earth oxide Gd_2O_3 doped PDLC with trace amounts of in the different driving voltage. A mathematical function is obtained by mathematical nonlinear fitting. The function could be calculated transmission rate in this wavelength within a given experimental driving voltage. The theoretical data of mathematical fitting are consistent with the experimental data. PDLC doped with Gd_2O_3 nanocrystals exhibits diverse electro-optical property, which makes the Gd_2O_3-doped PDLC be a kind of potential material in filter, color display, electro-optical switch applications. The fitting results showed that minimum correlation coefficient is 0.9993; the maximum mean square error is 0.004974. Our work will be helpful to understand electro-optics characteristics of polymer dispersed liquid crystals doped with thulium oxide nanoparticles $Gd_2O_3$by mathematical perspective.

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