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Low Driving Voltage and Analysis of Azobenzene Polymer Doped Liquid Crystal Grating *

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We mix azobenzene polymer and liquid crystal in certain ratio. Then the mixture is injected into cells. Nonlinearly photoinduced birefringence takes place when linearly polarized ultraviolet is applied with the pattern photomask covering on the cells, which results in the formation of azobenzene polymer doped liquid crystal grating. The obtained grating is characterized by an optical microscope and a He–Ne laser. The results indicate that the samples have clear grating structure, and the diffraction efficiencies can be modulated by electric field. The sample driving voltage is 0.6 V/μm. It is lower than the driving voltage of holographic polymer dispersed liquid crystal transmission grating and could be matched with the driving integrated circuit.

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Gratings are useful for many applications such as optical communication, optical information processing, etc. The applications of conventional grating are limited because it can not be modulated by electric fields. Contrarily, the efficiency of holographic polymer dispersed liquid crystal (HPDLC) grating can be modulated by the applied electric field and has attracted much attention.[1,2] However, HPDLC gratings have problems of high drive voltage and low diffraction efficiency.[3] In recent years, birefringence gratings of azobenzene polymer doped liquid crystal have been studied and developed because of their various potential optical applications.[4−7] Reported investigations include nematic liquid crystal orientation and the photochemical transformation in azobenzene polymers.[8−11] Various configurations of dopant dye molecules lead to different optical properties of liquid-crystal molecules. In this study, we use one kind of azobenzene side-chain polymers and mix them with a liquid crystal (TEB30A) in a certain ratio.

In the experiment, TEB30A is purchased from the SHILIKE company. The azobenzene polymer contains a common azobenzene moiety in the side chain, and is compounded. We doped azobenzene polymer into liquid crystal in a certain ratio. The UV-visible absorption spectrum of the azobenzene polymer before exposed is shown in Fig. 1. It can be seen that azobenzene polymer has the intense absorption in 190 nm and 320 nm. To prepare the thin film, we put dilute solutions of the azobenzene polymer in tetrahydrofuran (THF) on a cleaned glass (quartz) substrate, and then removed the solvent.

The fabrication setup of the azobenzene polymer doped liquid crystal birefringence grating is shown in Fig. 2. A pattern photomask with period of 65 μm covers on the cell with thickness of 7 μm. The grating will form when LPUV illuminates the cell through the photomask. The power of LPUV is 3 mW. The exposure time is 25 min. The obtained grating observed with polarizing microscope is shown in Fig. 3. It depicts a typical structure of microgratings. The corresponding period of the grating is 65 μm.

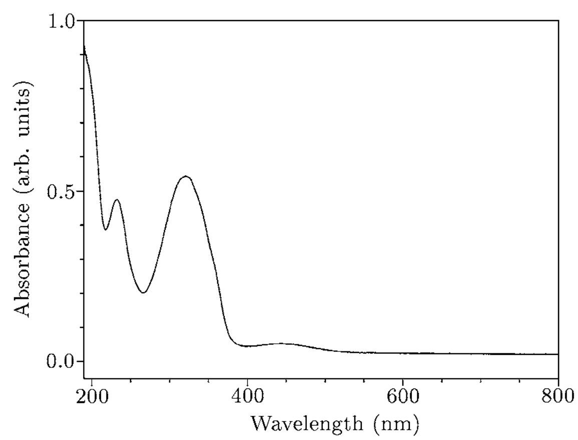

Fig. 1. UV-visible absorption spectrum of azobenzene polymer before irradiation.

The diffraction efficiency of the obtained grating can be modulated by an applied electric field. The diffraction patterns at different electric fields are shown in Fig. 4. The refractive index of liquid crystal in dark areas is different from that in bright areas, which leads to the diffraction for an incident light. Thus, 26 diffractive orders are observed at 0 V as

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shown in Fig. 4(a). When we apply an electric field, the liquid-crystal molecule is reoriented along the direction of the electric field. The refractive index difference between dark areas and bright areas will become small with the increasing applied electric field. Seven diffractive orders are observed at 7 V in Fig. 4(b). Five diffractive orders are observed at 10 V in Fig. 4(c). Finally, the light transmits directly the sample when the orders are the same, as shown in Fig. 4(d) at 20 V.

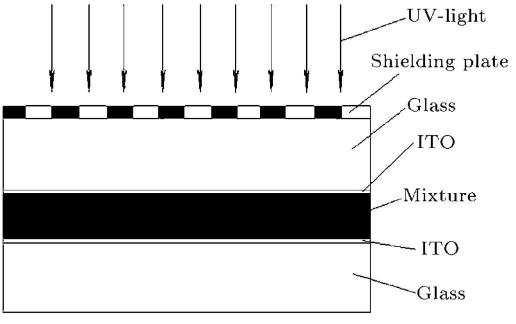

Fig. 2. Fabrication of azobenzene polymer doped liquid crystal birefringence grating.

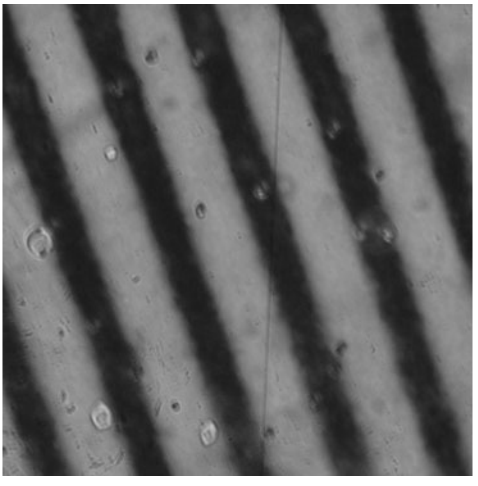

Fig. 3. Azobenzene polymer doped liquid crystal grating observed with a polarized microscope.

The zeroth-order transmission changes with the applied electric field are shown in Fig. 5. Our HPDLC grating sample has driving voltage of 0.6 V/μm and saturation voltage of 2 V/μm, which are much lower than the results of 6 V/μm and 20 V/μm reported correspondingly.[12,13]

The microscopic mechanism by which the azobenzene polymer aligns liquid crystal in the diffraction grating is very complex. There has not yet been a generally accepted model of the diffraction grating formation mechanism so far. However, doping azobenzene polymer into the liquid crystal will certainly lead to mutual influence.[8,14,15] Firstly, the efficiency of azobenzene polymer isomerization is dependent on the polarity of liquid crystal molecules, free space of the molecules, the interaction between the two materials and so on. Secondly, the configuration variation of azobenzene groups changes the liquid crystal member physics and chemistry performance in photochemical reaction process.

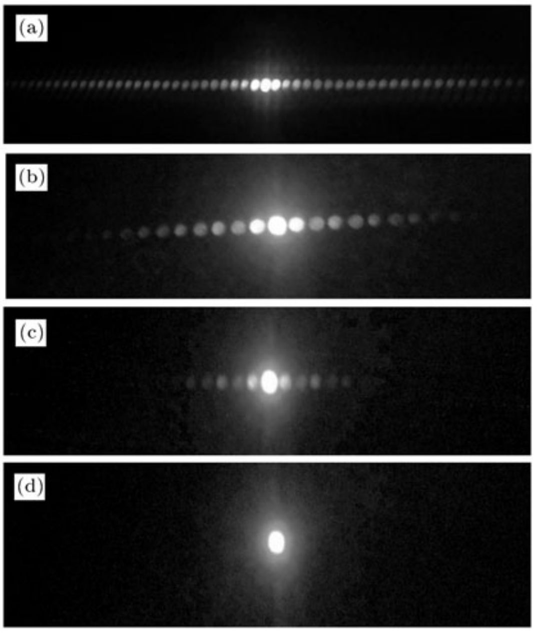

Fig. 4. Diffraction patterns of the sample at different applied electric fields: (a) 0 V, (b) 7 V, (c) 10 V, (d) 20 V.

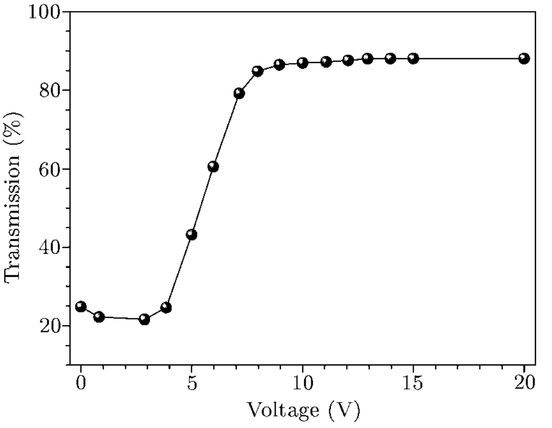

Fig. 5. The zeroth-order transmission as a function of drive voltage.

First, the mixture is injected into the cell. Liquid crystal molecule orientation is chaotic in the cell, as shown in Fig. 6(a). Then, LPUV is used to radiate the cell by the pattern photomask. The bright area is exposed to LPUV, which increases the energy and the interactions among the azobenzene polymer molecules in bright areas. Therefore, the polymer molecules wind with each other and the density of azobenzene polymer molecules increases. At the same time, the azo molecular concentration reduces in the dark areas. As a result, a periodical distribution of the azobenzene polymer density occurs. Additionally, cis-isomer accumulates along the light polarization direction, which leads to anisotropic depletion of the trans-isomer angular distribution. After the trans-cis-trans isomerization circulates for many times, azo-fragments induce not only liquid crystal molecules but also the polymer reorientation of the principal chains are vertical in the light polarization direction. Finally, the system needs the higher energy to restore the original isotropic condition. After the illumination, periodic distribution of the diffraction grating can be freezed. In the experiment, the sample can be stably preserved for eight months.

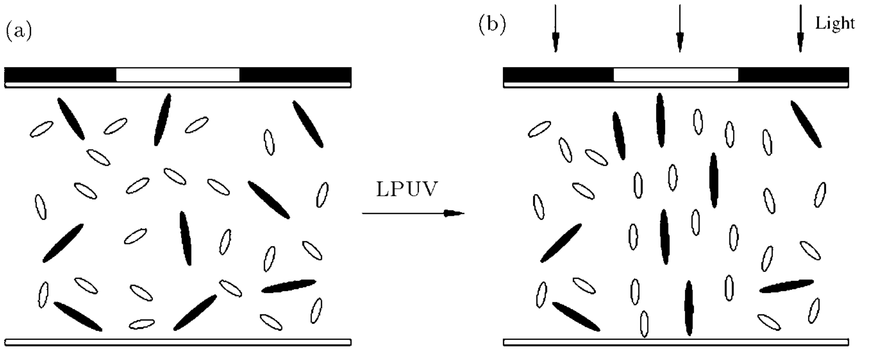

Fig. 6. Illustrative representation of molecular orientation of azobenzene polymer induced orientation of liquid crystal molecules, upon irradiation with a linearly polarized laser beam.

In conclusion, we have studied an excellent grating structure in azobenzene polymer doped liquid crystal films with an optical polarized microscope and a He-Ne laser. Compared with HPDLC gratings, azobenzene polymer doped liquid crystal gratings have many advantages, such as higher diffraction efficiency and lower drive voltage. The obtained gratings can be preserved for eight months without degradation of performance. If we can further improve stability of azobenzene polymer doped liquid crystal grating, its application prospect will be very widespread.

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