Nonlinear Optical Molecular Orientation Behavior of Fluorescent Nathalimide-Doped Liquid Crystal

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1. Introduction

Photoalignment technique of liquid crystal (LC) has attracted increasing attention in recent years due to its application to alignment layer for LCDs, retardation films and refractive-index modulation devices [1]. LC molecules are known to reorient parallel to the polarization of irradiated light in the field of nonlinear optics [2]. In 1990, dye-doped LC system has been found to enhance the photoinduced reorientation of LC significantly [3]. So far, several dyes, such as anthraquinone [4], oligothiophene [5] and coumarin [6] derivatives, were clearly found to exhibit photoalignment behavior in LCs. Although, the alignment behavior was interpreted as a phenomenon based on interaction between the dye molecule and the electric field of light, the reorientational mechanism have not been clear in molecular structural levels.

In this study, photoalignment behavior of LC doped with a fluorescent 4-amino-1,8-naphthalimide derivative was investigated.

2. Method

2.1. Sample Preparation

The chemical structure of the guest dye used in this study is shown in Fig. 1. 2-Butyl-6-(butylamino)-1*H*-benz[de]isoquinoline-1,3(2*H*)-dione (Fluorol 7GA) was obtained from Exciton Inc. E7 was obtained from Merck Ltd. used as a host LC without further purification and the guest dye was doped at a several concentrations. Fluorol 7GA and E7 were dissolved separately in THF and the solution was mixed together. After the solvent was removed completely under vacuum, the LC

mixture was sandwiched between two parallel transparent glass substrates with a gap of 100 μm by silica particles as a spacer. The inner surfaces of the two substrates were coated with *n*-octadecyl trimethoxy silane to obtain homeotropic alignment of LCs. The monodomain structure of the LC cell was confirmed by POM, and highly homeotropic alignment was observed. This cell was used as a sample for optical measurement.

Fig. 1. Chemical structure used in this study.

2.2. Optical Setup

Photoinduced reorientation was evaluated by self-diffraction measurement at room temperature. The optical setup is shown in Fig. 2. A linearly polarized Gaussian beam at 488 nm from an Ar⁺ laser was focused normally onto the sample cell by a lens with a focal length of 150 mm to induce reorientation of LC system. The diameter of irradiated spot was about 60 μm measured with a beam profiler (Ophir Optonics, Beam Star FX-50). The polarization direction of the Ar⁺ laser beam was maintained with a polarizer. The transmitted beam pattern created after the sample cell was observed on a screen behind the sample. Additionally, linearly polarized light at 633 nm from a He–Ne laser (NEC, GLG5370) was used as a probe beam. The polarization direction of the polarizer and analyzer were maintained +45 and –45 degree to that of the Ar⁺ laser beam.

Fig. 2. Schematic representation of the experimental setup for the pump-probe measurement.

3. Results and Discussion

Fig. 3a shows the UV-Vis spectra of Fluorol 7GA in a THF solution and a sample cell of Fluorol 7GA 0.5 mol%-doped in E7. The spectrum of Fluorol 7GA in E7 was slightly red shifted by about 4 nm compared with that in THF. The absorption band due to the π - π^* transition of the dye is close to the wavelength of 488 nm and can hence be excited with Ar^+ laser beam.

Fig. 3. UV-Vis spectra of Fluorol 7GA in THF and in E7 (a); photographs of the diffraction patterns of the Ar^+ laser beam (b) and the probe beam (c) on a screen.

When the laser beam was irradiated to the sample cell over threshold intensity, clear diffraction patterns on a screen was observed in Fig. 3b. Appearance of the diffraction rings can be explained by the self-phase modulation effect, which indicates photoinduced reorientation of LCs. Fig. 3c shows a diffraction pattern of the probe beam on the screen. This phenomenon indicates that anisotropic gradient refractive index was induced by the unidirectional alignment of the LC system.

To investigate the alignment direction of LC system, the polarization of the probe beam was maintained parallel or perpendicular to that of the pumping beam. Fig. 4 shows diffraction patterns of the probe beam parallel (a) and perpendicular (b) to that of the pumping beam. The clear diffraction pattern was appeared when parallel to the polarization direction of the pumping beam was used. On the other hand, when perpendicular to that of the pumping beam was used for the probe beam, no diffraction pattern was observed. This phenomenon indicates that there is a gradient of

the refractive index probed by parallel polarization, while no change in the refractive index is detected by perpendicular polarization. There is no large difference in the behavior of reorientation based on the oligothiophene and coumarin derivatives [5,6].

Fig. 4. Photographs of the diffraction patterns of the probe beam parallel (a), perpendicular (b) to the pumping beam.

Thus, Fluorol 7G was found to function as a dye for photoinduced orientation of LC system. Further detailed investigations about the alignment directions of the dye in LCs, dependence of the irradiated intensity, selectivity in the excitation wavelengths and change in the molecular structure of the dye between the excited and the ground states are now in progress.

4. Conclusion

Photoinduced reorientation behavior of Fluorol 7G-doped LCs was explored. Fluorol 7G was found to function as a dye for photoinduced alignment of LC system.

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