

A New Variable Orienting Force for Liquid Crystals Which has its Origin in the Electric Property of Poly- γ -benzyl-L-glutamate CRA Film

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Liquid crystal (LC) quick response is achieved by switching the orienting force of poly- γ -benzyl-L-glutamate chemical reaction alignment (CRA) film in response to an electric field.

The organization of molecular films has been intensively investigated.¹ Chemical reaction alignment (CRA),² has been used to prepare an oriented poly- γ -benzyl-L-glutamate (PBLG) monolayer in which the PBLG molecules were aligned with a tilt angle of about 57° on the substrate.³ PBLG is rigid owing to its α -helical structure⁴ and has a large dipole moment parallel to its molecular axis.⁵ In a CRA film used in this experiment, each PBLG molecule was bonded to the substrate by its terminal carboxy group. Consequently, each dipole moment was not cancelled out and influenced the film structure. With this PBLG-CRA film, a novel texture named 'spiral texture', which could not be induced by either a PBLG Langmuir-Blodgett (LB) film or a PBLG cast film was observed in the LC cell.⁶ The orienting force for the LC was assumed to be due to the organized structure in a PBLG domain, not to an individual dipole moment. In addition to this distinctive texture under static conditions, the PBLG-CRA film is expected to induce some unique dynamical behaviour of LC molecules under the influence of an electric field owing to its large dipole moment. Generally speaking, a dipole moment can interact with an applied electric field, resulting in change of its direction. Assuming that the orienting force for LC molecules comes from the organized

structure in a PBLG domain, an application of an electric field would induce a change in the orienting force of the PBLG-CRA film. We studied the dynamic behaviour of the LC molecules oriented by a PBLG-CRA film under the influence of an electric field by using microsecond time-resolved IR spectroscopy⁷ and observed novel dynamical behaviour of LC molecules which may be interpreted in terms of the variable orienting force of the PBLG-CRA film under an electric field.

N-(2-Aminoethyl)-3-aminopropylmethyl dimethoxysilane and a Si wafer were used as the silane coupling agent and substrate, respectively. 4-*n*-pentyl-4'-cyanobiphenyl (5CB), a typical nematic LC, was used as the sample, and was obtained commercially from BDH and used without further purification. Two LC cells were prepared by a typical method. The cell (I) was constructed with a Si wafer coated with a PBLG-CRA film and glass plate coated with a polyimide film. Two glass plates treated with rubbed polyimide films were used for the cell (II). The cell gap was adjusted to ca. 10 μ m with a spacer. In cell (I) LC molecules were aligned spirally in the surface while they were aligned parallel in cell (II).

The microsecond time-resolved infrared spectrometer was based on a dispersive IR spectrometer equipped with an MCT detector and an AC coupled amplifier,⁷ and had a high sensitivity of 10^{-6} in the absorbance change with a time resolution of 2 μ s. By using polarised monochromated IR light, individual motion of a functional group can be monitored through the absorbance change of the corresponding IR band. Common time responses to an electric field were observed for functional groups in the rigid core part of 5CB, indicating that they move synchronously in an electric field like a rigid rod.⁷⁻⁹ Among them the CN stretch band (2225 cm^{-1}) was selected as the probe to monitor the motion of the rigid core.

The time responses of the CN stretch band of the cells to a pulsed rectangular electric field (pulse width 2 ms, voltage 10 V, repetition rate 5 Hz) are shown in Fig. 1. The decrease in the absorbance of the CN stretch band was induced by the electric field. The absorbance change of (I) was about 15 times larger than that of (II) under the same voltage. As shown in

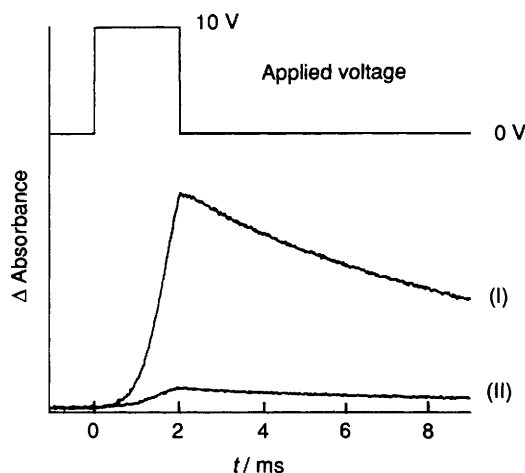


Fig. 1 Time response curves of 5CB in cells (I) and (II) to an electric field (pulse width 2 ms, voltage 10 V, repetition rate 5 Hz)

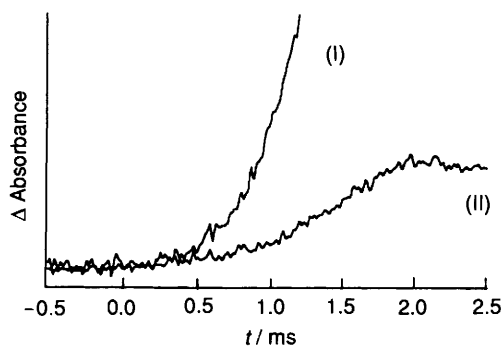


Fig. 2 Expanded view of time response curves for 5CB ca. $t = 0$

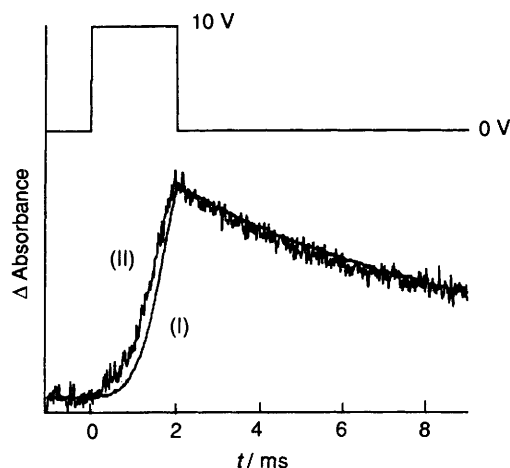


Fig. 3 Time response curves for 5CB normalised at $t = 2$ ms

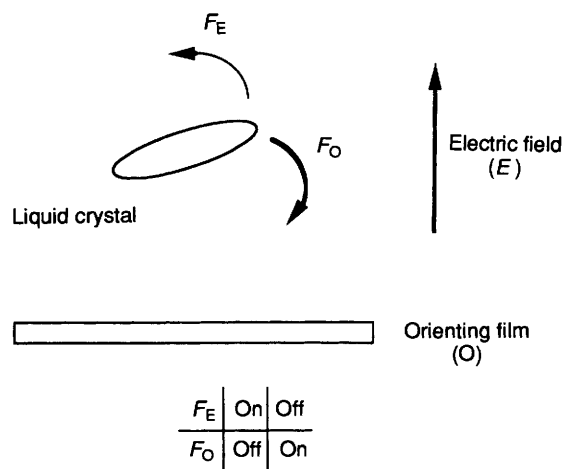


Fig. 4 Schematic drawing of an orienting film (O) whose orienting force (F_O) for LC can be switched off and on with the application and removal of the electric field (E , F_E : reorienting force induced by E), respectively

the expanded view around time $t = 0$ (Fig. 2), the time response curve for (I) was the same as for (II) in the reorienting process, that is, from $t = 0$ to 0.5 ms. After that, the response curve for (I) became drastically larger as if the strong force which anchors the LC molecules tightly disappears at $t \text{ ca. } 0.5$ ms. Two response curves normalized at $t = 2$ ms are shown in Fig. 3 to clarify the difference in the shape of the two curves. The shape of the curve for (I) was different from that for (II), indicating different dynamics in the reorientation process between the two cells. On the other hand, those of the recovery curves were common and fitted an exponential curve with a time constant ($\tau_{1/e}$) of $\text{ca. } 8$ ms. In (I), therefore, a quick response to an electric field, a high contrast between the two (on and off) states, and a quick recovery were achieved with a PBLG-CRA film as an orienting interface.

In order to interpret these observations consistently, a working hypothesis was constructed as follows: LC molecules are aligned under the strong orienting force of the PBLG-CRA film when no electric field is applied. An application of an electric field affects the electric property and/or alignment of PBLG molecules in the PBLG-CRA film through the interaction between its dipole moment and the electric field, resulting in the decrease in its orienting force. It takes $\text{ca. } 0.5$ ms for the PBLG-CRA film to lose its orienting force since this force would originate from the organized structure of the PBLG molecules in the film. At $t \text{ ca. } 0.5$ ms, LC molecules can make a large and quick reorientation under a small or no anchoring force of the PBLG-CRA film. After removal of the electric field, the PBLG-CRA film recovers its orienting force instantly, resulting in the same curves as for (II).

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