Effective Rotational Viscosity of Vertical Alignment Nematic Liquid Crystal Cells with Negative Dielectric Anisotropy

Keita Iwaya[1], Hiroyoshi Naito[1, 2], Hideo Ichinose[3], Melanie Klasen- Memmer[4], and Kazuaki Tarumi[4]

[1]Department of Physics and Electronics, Osaka Prefecture University,
1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, Japan, E-mail: iwaya@pe.osakafu-u.ac.jp
[2]The Research Institute for Molecular Electronic Devices, Osaka Prefecture University,
1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, Japan
[3]Liquid Crystals Division, Merck Ltd.,
4084 Nakatsu, Aikawa-machi, Aiko-gun, Kanagawa 243-0303, Japan
[4]Liquid Crystals Division, Merck KGaA, Frankfurter Strasse 250-64293 Darmstadt, Germany

Five independent Leslie viscosity coefficients α_i (i=1,2,…5) in nematic liquid crystals (NLCs) with negative dielectric anisotropy ($\Delta\varepsilon < 0$) are important factors for the response time of vertical alignment (VA) NLC displays [1]. The response time of VA-NLC cells is governed not only by $\gamma_1=\alpha_3-\alpha_2$ but also by the other Leslie viscosity coefficients of NLCs with $\Delta\varepsilon < 0$ [2]. We have derived an effective rotational viscosity $\gamma_1^*(\theta)$ governing the electric-field-induced director response in VA-NLC cells with $\Delta\varepsilon < 0$ [3]. $\gamma_1^*(\theta)$ is a function of five independent Leslie viscosity coefficients. In this study, we have shown that the response time of the NLC materials with $\Delta\varepsilon < 0$ is examined by calculating $\gamma_1^*(\theta)$. The Leslie viscosity coefficients of NLC materials with $\Delta\varepsilon < 0$ used to calculate $\gamma_1^*(\theta)$ are determined from the analysis of transient current induced by step voltage excitation in VA-NLC cells.

The NLC materials used in the experiment were MLC-2039, MLC-2074, MLC-2078 and Mix.A (Merck Ltd.) with $\Delta\varepsilon < 0$. The NLCs with $\Delta\varepsilon < 0$ were introduced between two pieces of glass with transparent electrodes. The transient current in the VA-NLC cells with $\Delta\varepsilon < 0$ was measured at 293 K using transient current measurement system (LCM-2, TOYO Corp.).

The effective rotational viscosity $\gamma_1^*(\theta)=\gamma_1-b^2(\theta)/a(\theta)$, where $a(\theta)=\alpha_1\sin^2\theta\cos^2\theta+(-\gamma_2\cos2\theta+\alpha_3+\alpha_4+\alpha_5)/2$, $b(\theta)=(\gamma_2\cos2\theta-\gamma_1)/2$, $\gamma_2=\alpha_3+\alpha_2$, of VA-NLC cells are derived from the theory of NLCs in which flow effects and the free slip boundary condition [1] for fluid flow are taken into account. The Leslie viscosity coefficients of the four NLC materials are determined by fitting the calculated transient current to the experimental results. We have calculated $\gamma_1^*(\theta)$ of the four VA-NLC cells using the Leslie viscosity coefficients determined by the fitting. Fig. 1 shows the calculated results of the dependence of $|\gamma_1^*(\theta)/\Delta\varepsilon|$ on θ. Mix.A exhibits the smallest $|\gamma_1^*(\theta)/\Delta\varepsilon|$ over the whole range of θ, i.e., the fastest response of four VA-NLC cells. We have shown that the response time of VA-NLC cells can be examined by calculating $\gamma_1^*(\theta)$.

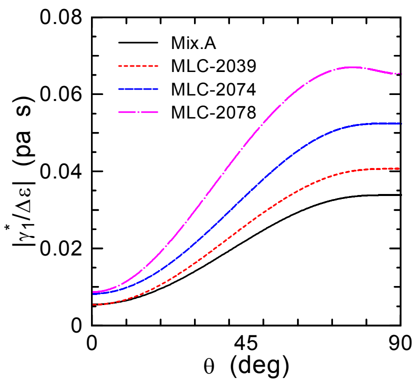

Fig. 1 The dependence of $\gamma_1^*(\theta)/\Delta\varepsilon$ of the four VA-NLC cells on θ calculated by using the each Leslie viscosity coefficients.

[1] Y. Iwata *et al.*, Jpn. J. Appl. Phys. **43**, L 1588 (2004).

[2] Y. Iwata *et al.*, Thin Solid Films **517**, 1417 (2008).

[3] Y. Iwata *et al.*, Mol. Cryst. Liq. Cryst. **516**, 228 (2010).