Leslie Viscosity Coefficients of Nematic Liquid Crystals with Negative Dielectric Anisotropy Determined from Transient Current Analysis Using a Genetic Algorithm

M. Oka [a], K. Iwaya [a], H. Naito [a,b]
M. Inoue [c], H. Ichinose [d], M. Klasen-Memmer [e] and K. Tarumi [e]

[a] Dept. of Physics and Electronics, Osaka Prefecture Univ. E-mail: m_oka@pe.osakafu-u.ac.jp
[b] The Research Institute for Molecular Electronic Devises, Osaka Prefecture University, 1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, Japan
[c] FPD Measurement System Project, TOYO Corp.,1-1-6 Yaesu, Chuo-ku, Tokyo 103-8284, Japan
[d] Liquid Crystals Division, Merck Ltd.,4084 Nakatsu, Aikawa-machi, Aiko-gun, Kanagawa 243-0303, Japan,
[e] Liquid Crystals Division, Merck KGaA, Frankfurter Strasse 250-64293 Darmstadt, Germany

Abstract

The transient current, induced by step voltage excitation, in homeotropic nematic liquid crystals (NLCs) cells with negative dielectric anisotropy ($\Delta\varepsilon < 0$) has been explained by the theory of NLCs in which the flow effects and the free slip boundary condition [1] are taken into account. We have shown that the Leslie viscosity coefficients of NLCs with $\Delta\varepsilon < 0$ are determined by fitting the numerically calculated transient current to the experimental data [2]. In this presentation, we have derived the analytical expressions of the transient current in homeotropic NLC cells and determined the Leslie viscosity coefficients by fitting the analytical expressions for transient current to the experimental data. We have determined the complete set of the Leslie viscosity coefficients (α_1, α_2, α_3, $\alpha_4+\alpha_5$) with high accuracy and short calculation time using a combination of genetic algorithm and the Levenberg- Marquardt method compared to the numerical method. This algorithm gives the Leslie viscosity coefficients without suffering from the initial value problem.

The NLC material used in the experiment was Mix.A with $\Delta\varepsilon < 0$ (Merck Ltd.). The thickness and the electrode area of the NLC cell are 56.8 μm and 1.13 cm^2, respectively. The transient current in the homeotropic NLC cell with $\Delta\varepsilon < 0$ was measured using a transient current measurement system (LCM-2, TOYO Corp.). Fig.1 shows the transient current in the homeotropic NLC cell with $\Delta\varepsilon < 0$ measured for 300 V at 293 K.

In general, the coupling between the director orientation and fluid flow is described using the continuity equation, the linear momentum equation and the angular momentum equation, according to the continuum theory of Ericksen and Leslie [3,4]. We have derived the analytical expressions of the transient current in homeotropic NLC cells by solving the Ericksen-Leslie equations for coupled reorientation and fluid flow under the free slip boundary condition. The Leslie viscosity coefficients of the NLCs with $\Delta\varepsilon < 0$ have been determined by fitting the analytical expressions for transient current to the experimentally obtained transient current that excited by a step-voltage application. The fitted result of the transient current is shown in Fig. 1. We note that the calculated waveform is in excellent agreement with the experimental result. The values of Leslie viscosity coefficients of Mix.A determined in this way are α_1=44 mPa·s, α_2= -134 mPa·s, α_3=8 mPa·s, $\alpha_4+\alpha_5$=159 mPa·s. We will discuss the temperature dependence of these Leslie viscosity coefficients to show that a wide range of the viscosity coefficients can be accurately determined using the genetic algorithm and the Levenberg–Marquardt method.

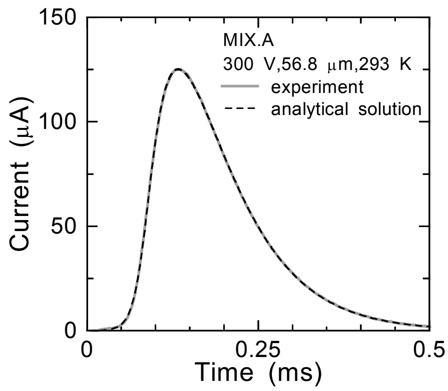

Fig. 1. Least squares fitting result of the analytical expressions and experimental transient currents in the homeotropic Mix.A cell with $\Delta\varepsilon < 0$. The least-squares fitting was carried out using a genetic algorithm and the Levenberg–Marquardt method.

References

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