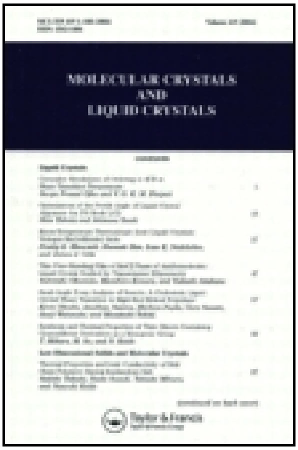

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Two-Frequency Driven Liquid Crystal Electrooptic Cell with Nematic-Cholesteric Phase Change

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TWO-FREQUENCY DRIVEN LIQUID CRYSTAL ELECTROOPTIC CELL WITH NEMATIC-CHOLESTERIC PHASE CHANGE

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Abstract Electrooptic properties were measured of the two-frequency driven guest-host type electrooptic cells with nematic-cholesteric phase change. The realization of temperature indicators with tunable critical temperature is proposed on the basis of electrooptic cells or PDLC films filled with dichroic (chiral) nematic mixtures which show low frequency dielectric relaxation phenomena.

INTRODUCTION

The electrooptic cells of guest-host type with a nematic - cholesteric phase change[1,2] give possibilities of a realization of displays with positive color contrast without polarizers. Unfortunately, for cells of this type the long turn-off-times are characteristic as relaxation from the cholesteric to nematic structure is very slow, especially in the cells with the high d/p ratio having a high contrast.

In this paper we present some experimental results of the observations on the two-frequency driven electrooptic cells utilizing dichroic nematic or chiral nematic mixtures (under condition $p > d \cdot 2K_{22}/K_{33}$) which show low frequency dielectric relaxation phenomena[3].

Finally, possibilities of new practical applications based on high temperature dependence of dielectric cross-over frequency f_c are proposed.

MATERIALS AND EXPERIMENTAL CONDITIONS

Commercial 2F-nematic mixtures (Table I) doped with cholesteryl nonanoate (CN) to adjust a proper pitch p were used. 1.2 wt.% of red dichroic dye D2 (BDH Limited) was added to all mixtures.

TABLE I Physical data for 2F-nematic mixtures

Mixture	t_i (^oC)	f_c (kHz)	$\Delta\varepsilon_H$	$\Delta\varepsilon_L$	Δn	q ($Hz/^oC$)
ZLI 2979	126	2.0	-1.2	+1.9	0.12	350
ROCHE 3333	68	3.2	-4.7	+4.1	0.1	990
ROCHE 3421	81	0.4	-4.7	+5.7	0.1	88

t_i - clearing point, $\Delta\varepsilon_{H,L}$ - dielectric anisotropy in high and low frequency range, Δn - birefrigence, f_c - cross-over frequency, $q = \Delta f_c / \Delta t$ for temperature range from 0 ^oC to 40 ^oC.

For observations and measurements were used polarising microscope and optical bench, both equipped with heating /cooling stage and photocell. The electro-optic measurements were performed in transmission using unpolarized monochromatic light (λ = 465 nm) and square-wave driving voltage. Digital storage oscilloscope and x-y plotter were used for record of dynamic characteristics.

Electrooptic cells were conventional type with 10 μm Mylar spacers. Cell gap d was determined interferometrically. Homeotropic boundary conditions on ITO electrodes were ensured with lecithin layers (Lecithin aus Eiern, E.MERCK).

EXPERIMENTAL RESULTS

The optical transmission of the cells comprising dual-frequency addresable mixtures depends on frequency, voltage, and temperature as can be seen in Figure 1.

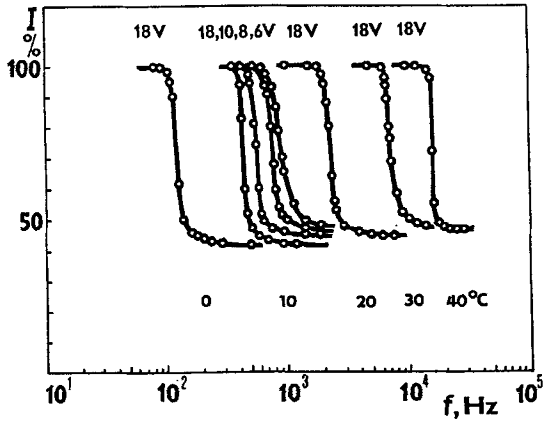

FIGURE 1 Frequency dependences of optical transmission of the electrooptic cell with nematic-cholesteric phase change at various temperatures and driving voltages. Dichroic chiral nematic mixture: ZLI 2979 + CN + D2, d/p = 0.75 .

From the figure it follows that virtually no change of transmission occurs for frequencies $f < 100$ Hz at temperatures as low as $0^{o}C$, i.e. ZLI 2979 exhibits maximum positive dielectric anisotropy $\Delta\varepsilon_L$. At the high frequency and temperature end $f \sim 30$ kHz is sufficient up to 40 ^{o}C to obtain maximum negative dielectric anisotropy $\Delta\varepsilon_H$. Thus the mixture ZLI 2979 allows full dual-frequency addressing between $0^{o}C$ and $40^{o}C$ with driving frequencies $f_L < 100$ Hz and $f_H > 30$ kHz respectively. At room temperature f_H can be reduced to 5 kHz. Unfortunately, relatively high driving voltage (15 V) is needed owing to both low $\Delta\varepsilon_L$ and $\Delta\varepsilon_H$, and response times are also relatively long (about 500 ms at 10 ^{o}C). Results of electrooptic response time measurements will be published elsewhere.

Considerably lower driving voltages (below 10 V) are sufficient for the cells with ROCHE 2F-mixtures having higher dielectric anisotropy.

Threshold frequency, f_t, was defined as the one needed for the transmittance to change from 100 % to 10 % and voltage dependences of the f_t are presented in Figure 2 for the cells comprising mixtures ZLI 2979,

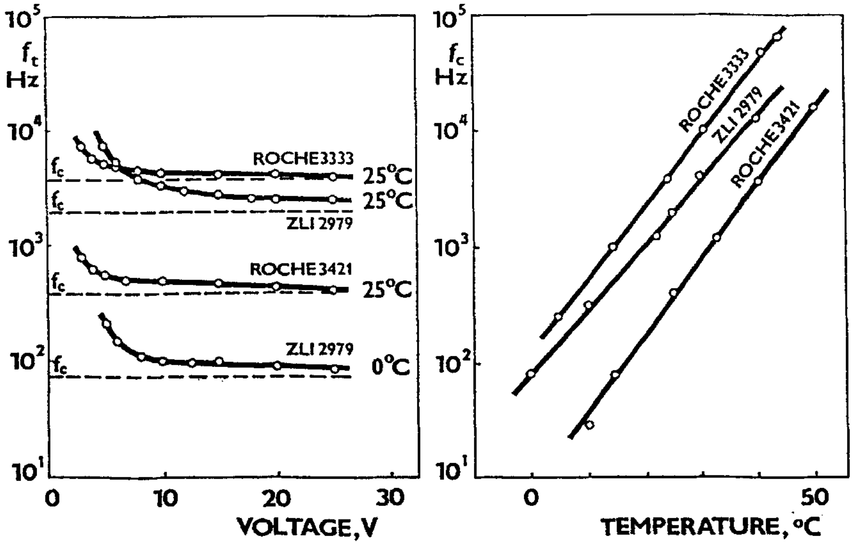

FIGURE 2 Voltage dependences of threshold frequencies f_t for 2F-nematic mixtures at 25 ^{o}C.

FIGURE 3 Temperature dependences of extrapolated cross-over frequencies for 2F-nematic mixtures.

ROCHE 3333, and ROCHE 3421. It can be assumed that the plot log f_t vs V is hyperbola asymptotic to $f_t = f_c$ and $V = V_{th}$. Thus, the relationship among f_t, V, and f_c can be written as the following equation

$$\log f_t = k/(V - V_{th}) + \log f_c, \qquad (1)$$

where k is a constant value, and V_{th} is a threshold voltage at $f \gg f_c$. Good linearity of the plotted dependences V log f_t vs V supports the validity of equation (1) and from the slope of this plots the values of f_c were obtained.

To characterize the temperature dependence the estimated cross-over frequencies, plots of log f_c vs temperature are shown in Figure 3. It can be seen that these plots are linear with high slopes of $q = \Delta f / \Delta T$. The average values of the q between $0^{o}C$ and $40^{o}C$ are summarized in Table I for three investigated mixtures.

With regard to the very high temperature dependence of the cross-over frequency we propose to use the two-frequency driven dichroic electrooptic cell with nematic -cholesteric (or cholesteric-nematic) phase change as a temperature indicator with tunable critical temperature. The colour of the indicator changes at certain critical temperature t_c whose value is determined by frequency and amplitude of a driving voltage (Figure 4). The indicator of this type may be interesting e.g. for the mapping of the IR lasers radiation. For sensibility increasing it is possible to supply the cell with IR absorbing layers.

Further it is possible to employ dichroic 2F-nematic or chiral nematic mixtures for the preparation of a film-like electrooptic temperature indicator with tunable critical temperature at which the film transparency is changed. PDLC films of this type may be useful for some special purposes in the field of thermal mapping, including IR radiation.

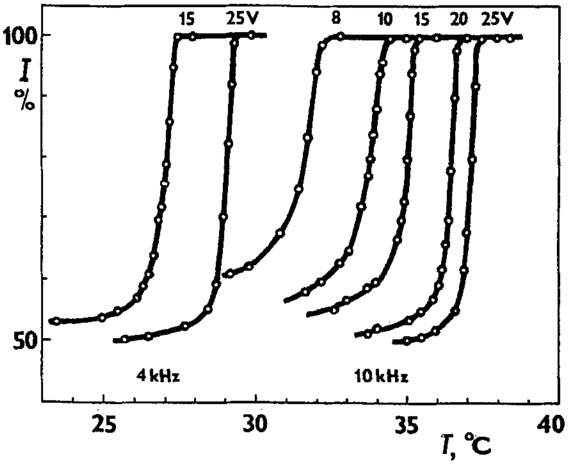

FIGURE 4 Temperature dependences of an optical transmission of the two-frequency driven electro-optic cell measured with driving frequencies of 4 kHz and 10 kHz at various voltages. Dichroic nematic mixture: ZLI 2979 + D2, d/p = 0.

ACKNOWLEDGEMENTS

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