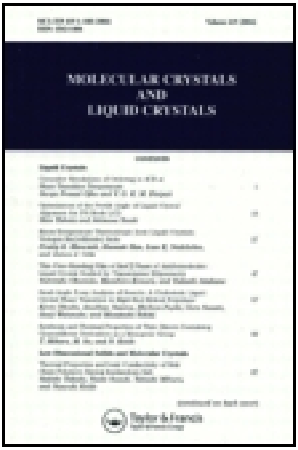


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# Nematic-Cholesteric Relaxation in some Cholesteric Liquid Crystals

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# Nematic-Cholesteric Relaxation in some Cholesteric Liquid Crystals*

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## INTRODUCTION

It is well known that a cholesteric liquid crystal of positive dielectric or diamagnetic anisotropy can be transformed into an aligned nematic with the director parallel to the field, by an electric or magnetic field higher than a threshold value. Such a phase transition corresponds to a cholesteric helix unwinding with an intermediate state of focal conic structure which is optically cloudy, whereas the nematic is transparent. This phase transformation has been currently used in display devices during the last few years.

Various authors[1,2] have studied, by optical and electrical measurements, the relaxation of a nematic state into a helicoidal texture when the electric field is decreased or rapidly removed. These studies of the relaxation process revealed the following results:

i) by decreasing the voltage applied to the liquid crystal, a hysteretic behavior has been observed by some authors[3,4] and ourselves; this effect is schematically shown in Figure 1;

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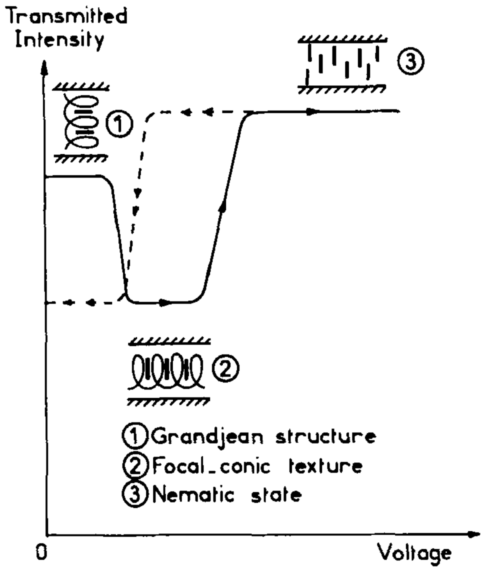


FIGURE 1 Schematic of the transition cholesteric ⇄ nematic.

ii) for a sharp cut-off in the applied voltage, the nematic-cholesteric transition time is short, approximately a few tens of ms or less for certain products;

iii) Kwok and Liao[5] have shown that the duration of the nematic-cholesteric transition depends upon the turn-off rate of the voltage applied during this transformation; they have considered that two processes, i.e., helix winding and molecular reorientation, take place during the voltage decrease.

In this paper, we report experiments on this latter effect, in particular on the variation of the relaxation time with the voltage turn-off rate and with other parameters—especially for a slow turn-off rate, in view of its application to display devices.

## EXPERIMENTAL

The cells are conventional. The sample is held between two conducting glass plates separated by mylar spacers (thickness ≈ 10 $\mu$m). The homogeneous initial alignment of the liquid crystal is obtained by rubbing the electrodes or by oblique deposition of silicon monoxide layers on the glass plates. The liquid crystals used are mixtures of a nematic of positive dielectric anisotropy and a cholesteric substance. Almost all of the experiments mentioned here have been achieved with a mixture of 1132 TNC (92%) from E. Merck, having a dielectric anisotropy $\varepsilon_a = +10.3$, and cholesteryl nonanoate CN (8%), but the influence of the dielectric anisotropy $\varepsilon_a$ has been also examined with other nematics of $\varepsilon_a$ between +5 and +14.

A pulse-generator gives a triangular-shaped signal applied to the electrodes; it has an abrupt rise followed by a linear decrease in the voltage; the amplitude $V$ and the duration $t_0$ of this ramp, and therefore the turn-off rate of the voltage applied to the cell can be varied within a very large range.

The experiments have been made using a Leitz polarizing microscope. The light transmitted by the liquid crystal impinges on the microscope photomultiplier from which the anodic signal is registered as a function of the applied voltage on an X-Y recorder. The transition times between the various stable or metastable states are determined from the recorder chart. Furthermore, photographs of the liquid crystal textures have been taken during the relaxation processes.

In white light, the contrast between the nematic and the focal-conic states, which are those used for display devices, is relatively low. It can be improved if polarized monochromatic light is passed through the cell. Indeed, with the planar texture, an optical rotation occurs and the rotation angle is a function of the wavelength. By varying the latter, it is then possible to select a wavelength of the incident light so as to obtain (between crossed polarizers) a maximum transmission for the planar texture and a total extinction for the electric field-induced nematic state, corresponding to complete contrast. In this case, the microscope is illuminated through a monochromator.

## RESULTS

In Figure 2, the change in the time $t$ of the phase transformation between the nematic state and the planar texture is shown, *e.g.*, for a cell illuminated with polarized monochromatic light and submitted to decreasing ramps having the same amplitude $V$ and durations $t_0$ = 100, 200, 300 s. From these curves, the presence of two different relaxation processes separated by an intermediate state which scatters the light strongly, can be seen. More precisely, it appears that:

i) a relatively fast transition takes place from the nematic to this intermediate state: the time $\tau_1$ characterizing this transformation depends on $t_0$ as shown below;

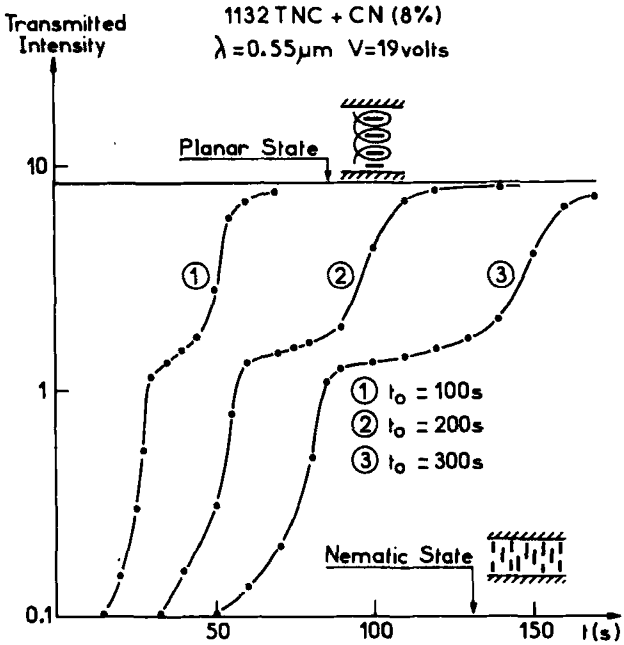


FIGURE 2 Variation of transmitted monochromatic light intensity with time for various durations $t_0$ of the decreasing ramp.

ii) the intermediate state relaxes back to the planar texture with a time constant $\tau_2$ larger than $\tau_1$, which increases with $t_0$: the stability of this intermediate state increases also with the ramp duration as shown by the curves of Figure 2;

iii) the final structure observed at the ramp end is a mixture of two textures, i.e., the planar structure which is transparent and the focal-conic which scatters the light, the importance of each type depending on the value of $t_0$; the first (planar) for example is preponderant for small values of $t_0$. Therefore, it is easy to produce a contrast variation by increasing or decreasing the ramp slope.

As mentioned above, it is also possible to vary the contrast by selecting suitably the wavelength of the incident light. Such a variation, obtained for the cell in Figure 2 by increasing the wavelength from 0.55 to 0.65 $\mu$m other parameters being equal, is shown in Figure 3. A contrast improvement could be obtained with a thicker cell, but then the applied voltage should also be raised; in addition the time $\tau_2$ of the relaxation to the planar texture becomes very long (for example with thicknesses of 25 $\mu$m).

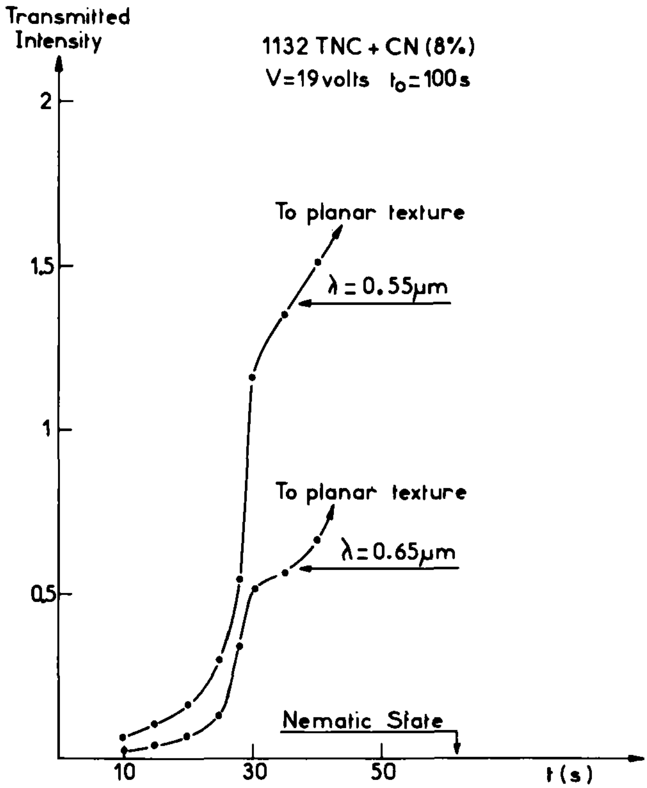


FIGURE 3 Influence of the incident light wavelength on the intensity transmitted during the nematic-cholesteric transition.

We have studied in more detail the variation of the relaxation from the nematic to an intermediate state as a function of the ramp slope, which can be changed by modification of the amplitude $V$ or of the duration $t_0$.

The plots of the intensity of the light transmitted by a mixture of 1132 TNC + NC (8%) against time are represented in Figure 4 for the same amplitude $V$ and various durations $t_0$. The time constant $\tau_l$ (defined as the time during which the transmitted intensity falls from 90% to 10% of its initial value) is determined for each value of $t_0$. It has been found that $\tau_l$ is, at constant voltage $V$, proportional to the ramp duration $t_0$.

The variation of $\tau_l$ with the ramp amplitude $V$ at a constant duration $t_0$ is shown in Figure 5 for the same mixture as above. As expected $\tau_l$ decreases when the amplitude $V$ increases and, to a good approximation, follows a linear law. As a result, it is possible to vary the time con-

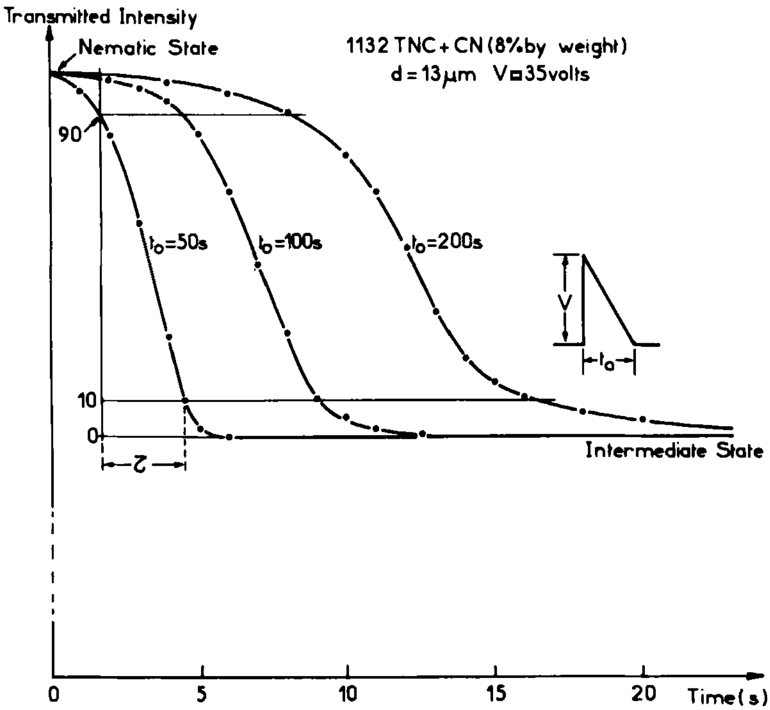


FIGURE 4 Influence of the ramp duration $t_0$ on the variation of transmitted light intensity with time.

stant $\tau_1$ and the transmitted intensity over a large range, particularly at low voltages.

As mentioned above, we have also performed similar experiments on other nematic-cholesteric mixtures of various anisotropies $\varepsilon_a$. The time constant $\tau_1$ is, in these cases also, proportional to the duration $t_0$ and increases with $\varepsilon_a$ for the same applied voltage and the same value of $t_0$.

## CONCLUSIONS

In conclusion, our results show that in display devices using the nematic-cholesteric phase transition, the contrast can be varied within a wide range by applying ramps of controlled slopes.

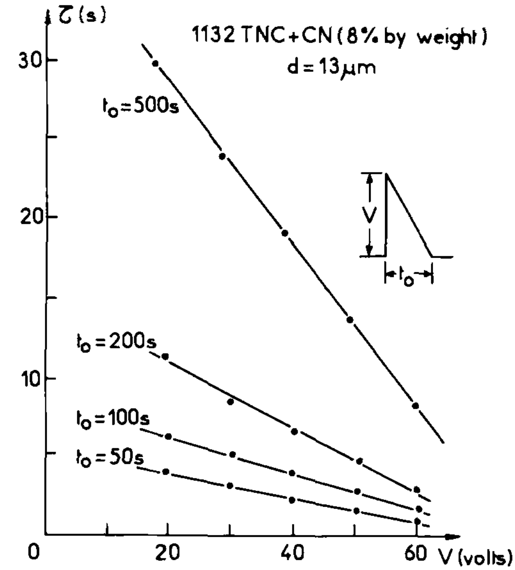


FIGURE 5 Variation of the transition time $\tau_1$ with the ramp amplitude $V$ at constant durations $t_0$.

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