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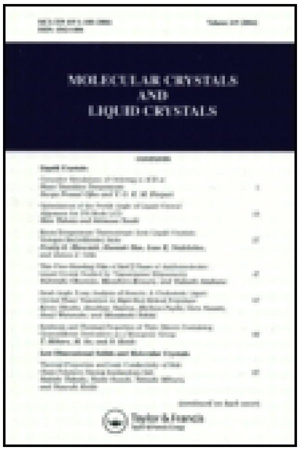

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Evidence for Anisotropic Expansion of Secondary Dynamic Scattering

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EVIDENCE FOR ANISOTROPIC EXPANSION OF SECONDARY DYNAMIC SCATTERING

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ABSTRACT: An experimental study of generation and propagation of the secondary dynamic scattering mode /DSM2/ in the nematic liquid crystal MBBA in the conduction regime is presented. In homogeneously aligned samples a strong anisotropy of the velocity of propagation of DSM2 was found and measured. The frequency dependence of the threshold voltage for DSM2 was determined by light transmission measurements and microscopic observations.

INTRODUCTION

The dynamic scattering mode /DSM/ [1] in NLC belongs to the class of phenomena generally called electrohydrodynamical /EHD/ instabilities [2]. Sussman [3], Nehring, Petty [4] and Chang [5] have found two different states of DSM. The first DSM1 state exists at voltages above the grid pattern range, when the domain pattern continously, step by step becomes not steady. The domains are oscillating giving rise to irregular changes of refractivity indices resulting in wide-angular forward light scattering. When the voltage exceeds a threshold V_m, a new DSM2 mode appears and propagates within the DSM1 area until the whole sample is covered, cf. Fig.1. Our nomenclature of DSM1,2 is in accordance with [3,5], however differs from [6].

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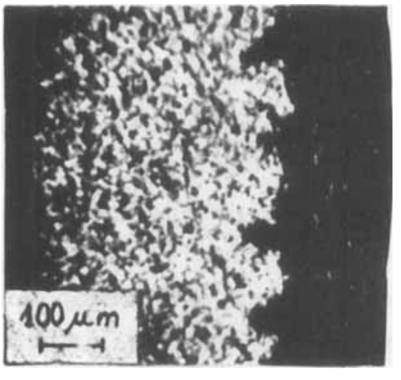

FIGURE 1. Propagation of DSM2 generated at the edge of a sample /40 V, 60 Hz/.

DSM2 produces particularly strong light scattering and therefore in transmission the DSM2 regions are recorded as dark expanding spots. Nematic threads are visible in light polarized perpendicularly to the sample alignment. This threaded structure does not appear in DSM1. DSM2 is generated at boundaries, at different inhomogeneities or on inclusion of impurities. The present work gives results of studies of generation and propagation of DSM2 in the regime below the cut-off frequency.

EXPERIMENTAL

Samples of nematic MBBA, Riedel de Häen AG, were investigated without further purification /conductivity 2.5 $10^{-10}\ \Omega^{-1}\ cm^{-1}$/. A conventional sandwich cell with a 35 um gap was used. The original homogeneous orientation was produced by rubbing. A polarized light beam of 2 mm diameter from a He-Ne laser was attenuated before entering the sample. The plane of polarization was parallel to the molecular alignment. The transmitted beam after passing a 2 mm aperature and a concave lens was directed into a photomultiplier. A polarising microscope was used to photograph and for visual observations. The results were taken at room temperature, 298 K.

RESULTS AND DISCUSSION

The optical contrast between DSM1 and DSM2 decreases markedly at low voltages and the estimation of the V_m threshold by visual methods becomes less accurate. Therefore we estimated V_m as a function of the electric field frequency by measuring the intensity of the transmitted light. The results are shown in Figs.2,3. The light intensity corresponded to DSM1, when measured just after the application of the field. In the subsequent lapse of time DSM2 appeared and finally covered the whole observed area. The light intensity corresponded then entirely to DSM2 /lower curve in Fig.2/. The measurements were carried out for seven frequencies in the range 20 - 350 Hz and were performed in the same area of the sample.

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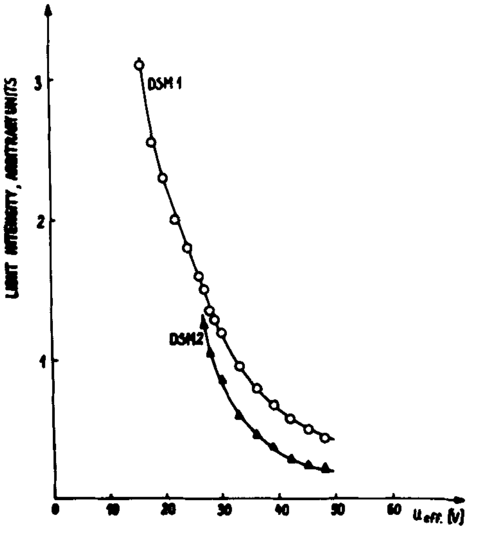

FIGURE 2. Transmitted light intensities vs voltage /180 Hz/.

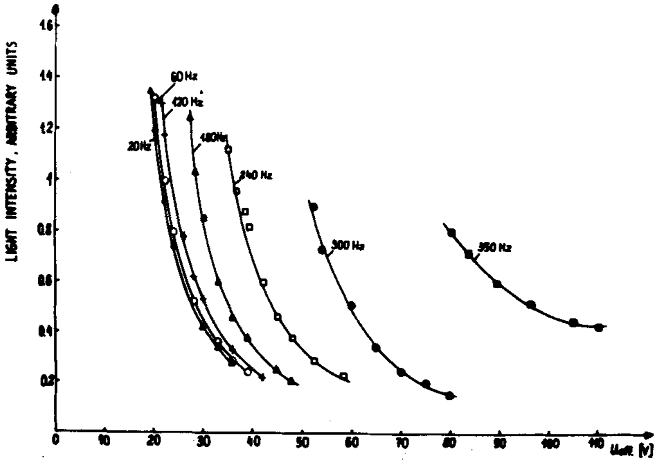

FIGURE 3. Transmitted light intensity for DSM2 vs voltage in the range 20 - 350 Hz.

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The curves in Fig.3 can be discussed in terms of the scattering abilities of DSM2 at different frequencies. The results were taken at voltages not exceeding $2V_m$. The values of V_m established in transmission were verified by visual microscopic observations /upper curve in Fig.4/. The lower curve in Fig.4 is the Williams domains threshold V_c.

We observed that in general the increase of voltage rises the DSM2 propagation velocity, whereas the increase of frequency lowers it. This behaviour follows the well-known shift of EHD instabilities towards higher voltages with the increase of frequency.

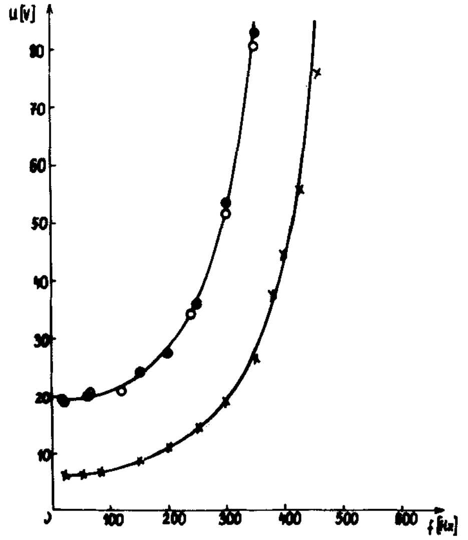

FIGURE 4. Upper curve - DSM2 threshold voltage V_m vs frequency. Open circles - transmission measurements; filled circles - visual observations. Lower curve - the Williams domains threshold $/V_c/$ vs frequency.

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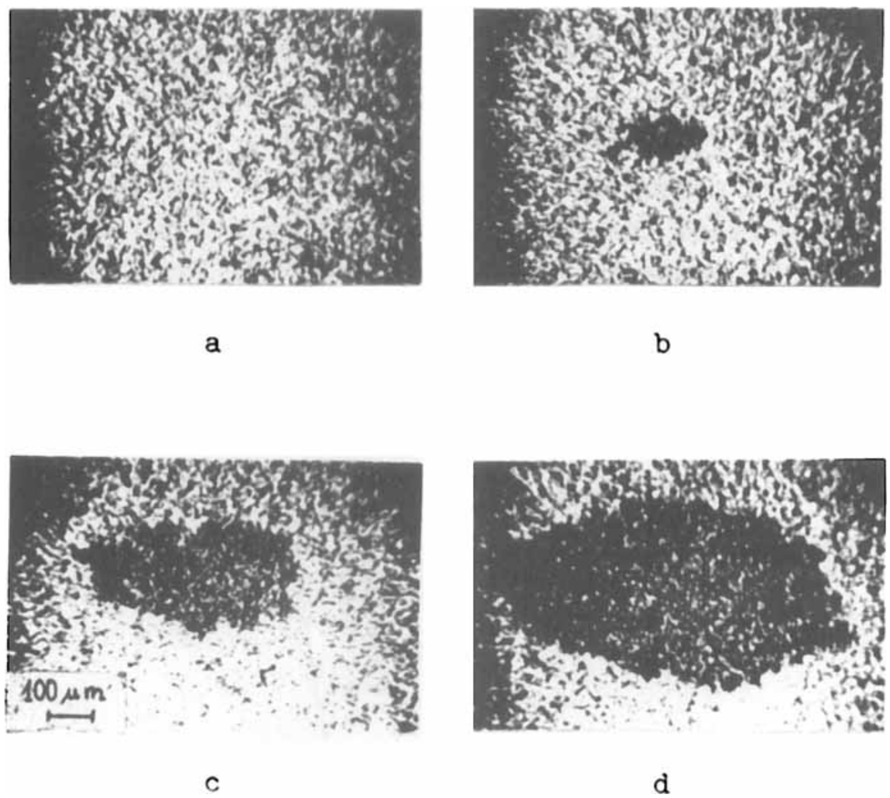

FIGURE 5. Development of DSM2 in a homogeneously orientated sample. The alignment is parallel to the shorter sides of the pictures.

a/ initial stage - only DSM1 present;

b/ DSM2 initiated by a point source - situation 1.5 s past generation;

c/ 4 s past generation;

d/ 7 s past generation.

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There are no reports in the existing literature on anisotropic behaviour of DSM2 propagation. Observing homogeneously aligned samples we found, that the propagation of DSM2 initiated by a point-like source is anisotropic /Figs. 6a - d/. The propagating front is fairly elliptic in shape, with the long axis perpendicular to the director $\vec{n}$ of the sample. The velocities $v_\perp$ and $v_\parallel$ /in respect to $\vec{n}$/ could be in principle estimated from the set of ellipses, however we preferred a more accurate procedure measuring the propagation initiated by parallel and perpendicular edges of the sample. Fig. 6 shows $v_\perp$ and $v_\parallel$ as functions of the voltage at 60 Hz. Both velocities increase nonlinearly with the voltage.

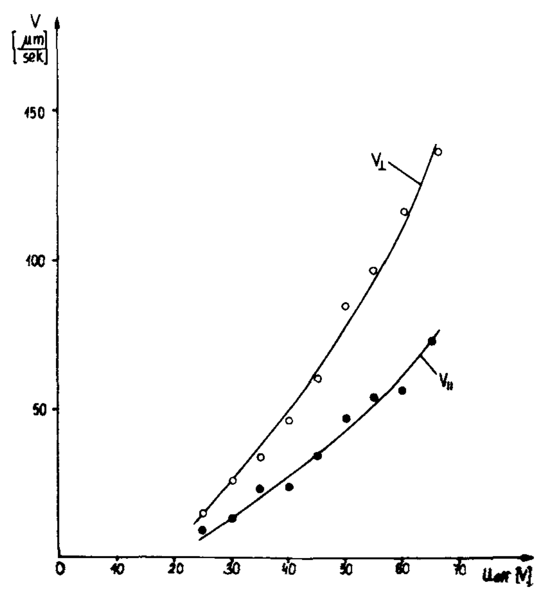

FIGURE 6. The DSM2 velocities $v_\perp$ and $v_\parallel$ vs voltage /60 Hz/.

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For frequencies below 200 Hz i.e. far from the cut-off frequency /amounting to some 400 Hz/ the mean value $v_{\perp}/v_{\parallel} \approx 1.8$. The multitude of our observations lead to the conclusion, that each case of DSM2 generation and propagation is to a certain extent an irregular fluctuating process with irreproducible individual details /cf. Fig.1/.

The anisotropic propagation is a characteristic feature of homogeneously aligned samples, whereas we could not find this behaviour in samples prepared homeotropically. The structure of homeotropic samples at higher voltages becomes planar as a result of the deformation of aligned phases /DAP/ effect, nevertheless the DSM2 propagation seemed to be isotropic even in small regions of a sample.

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