Deuterium NMR Study of the Nematic Director Distribution During the Relaxation Process

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There have been many investigations of the field-induced alignment of nematic liquid crystals. The basic features of the hydrodynamic processes have been characterized for nematics in their equilibrium and non-equilibrium states. Such macroscopic behaviour has been investigated with deuterium nuclear magnetic resonance (NMR) spectroscopy. Since the quadrupolar splitting for deuterons observed in the nematic phase is determined by the angle between the director and the magnetic field, time-resolved deuterium NMR spectroscopy has been employed to investigate the dynamic director alignment in a nematic film [1]. One of the prime advantages of the use of deuterium NMR spectroscopy to determine the director orientation is that the form of the spectrum is also influenced by the distribution of the director with respect to the magnetic field. This situation obtains because when the director is not uniformly aligned the observed spectrum is normally a weighted sum of the spectra from all director orientations.

We have studied the director dynamics for a low molar mass nematic using deuterium NMR. The sample was confined between two glass plates and subject to magnetic and ac electric fields. In the absence of the electric field the director for 4-pentyl-d_2-4'-cyanobiphenyl (5CB-d_2), is aligned parallel to the magnetic field. When a sufficiently large electric field is applied the director will be aligned with respect to the electric field (turn-on process). The dynamics of the director relaxation for the turn-on process can be followed by monitoring the spectrum during this alignment as a function of time. It has been found that for a range of cyanobiphenyl the sample moves as a monodomain during the turn-on process even when the angle, α, between the magnetic and electric fields is as large as 89.0°. This behaviour is in marked contrast to theoretical predictions and experimental observations for polymeric nematics. The basic features of the hydrodynamic processes have been characterized, and theoretical models based on continuum theory have been developed which successfully describe the phenomena for uniform director alignment. However, when α is very close to 90°, following the application of the electric field part of the director remains parallel to the magnetic field for a fairly long time and other parts show a broad director distribution over a range of orientations between 0° and 90°. That is the sample adopts a variety of non-uniform director states during the alignment process.

Using the results of our extensive experiments we have explored the factors that influence the nature of the non-uniform director distribution, we discuss unanswered questions stimulated by the measurements of the field-induced director dynamics. There are a number of mechanisms which contribute to the spectral form. One of these is the deviation of the initial director distribution from a perfect monodomain. One function has been found to be particularly successful in describing the director distribution [2]. We have simulated the time-dependent powder spectra with this initial director distribution function using the same parameters as for the measurements. It was found that the simulated spectra show good agreement with those from the experiments. In summary a preliminary Occam-like model is proposed to understand the factors influencing the non-uniform states of director alignment in nematics when the initial director orientation and aligning field are virtually orthogonal. It has been found that a spontaneous but narrow director distribution in a steady state is essential in order to account for a non-uniform director alignment observed in the deuterium NMR spectra during the alignment process.

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References

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