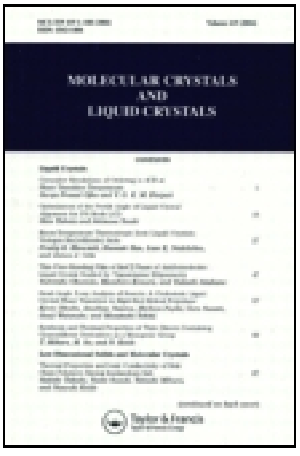

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DIELECTRIC RELAXATION OF NEMATIC MBBA UNDER SHEAR

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A reduction of the parelectric relaxation time in a magnetically orientated and sheared layer of MBBA to 37 % of its nonsheared value has been observed for the first time. The transition between the two values at the beginning and the end of the shear deformation is not instantaneous but exponential, with two rather different time constants of 60 ms and 1.5 s, respectively. This behaviour could be related to roll instabilities observed optically by others under similar experimental conditions.

INTRODUCTION

Polar nematic liquid crystals with components of the electric moment not perpendicular to the long axis of the molecule exhibit two parelectric relaxation regions: one, in the GHz range, corresponds to rotations of the molecules about the long axis, the other, usually in the low MHz range, is correlated with rotations about an axis perpendicular to the former.[1] This latter rotation is strongly hindered by the intermolecular field of the parallel neighbouring molecules. Using a theory by Maier and Meier[2] based on the Onsager theory, and their measured temperature dependence of relaxation time, Meier and Saupe[3] found a potential barrier of 0.2 eV between the parallel and perpendicular orientation of a PAA-molecule with respect to its neighbours. Influences of simultaneous rotations of the neighbours as well, i.e. cooperative effects, or of fluctuations or defects in the short range order are not contained in the theory applied nor discussed elsewhere. Hence we were interested whether a shear flow applied to the nematic layer between capacitor plates would show an influence on the relaxational behaviour. One would expect such an influence either from the interaction between orientational fluctuations and shear flow or from a flow-induced change in the short- or long-range order.

EXPERIMENTAL

The aim of the experiment was to take as many measurements of the full parelectric relaxation per unit time as possible, hence a time-domain method seemed appropriate. We charged a capacitor (704 mm^2 electrodes, spaced 186 μm apart, flatness about 50 nm) by a current pulse of 20 mA and less than 100 ns duration and recorded the resulting voltage response by use of a transient recorder Biomation 8100. The shortest sampling time of 10 ns has been used. The results were then transferred into the semiconductor memory of a hp 21 MX 20 computer, the capacitor was discharged and the next charge pulse applied. The whole sequence has been processor-controlled, repetition rates up to 40 measurements per second and up to a total number of 35 (limited by the memory space of the computer) were possible. The shear deformation was applied by a longitudinal motion of one capacitor plate via a micrometer spindle. A magnetic field up to 0.3 Tesla was perpendicular to the capacitor plates. No particular preparations of the electrodes for homeotropic boundary conditions were done. Only room temperature measurements could be taken.

Results

An analysis of the voltage responses in MBBA with respect to relaxation time and quasistatic dielectric constant yielded not significant change in the dielectric constant itself. The sample, however, showed a reduction of the relaxation time to 37 % while a shear deformation of 5 s^{-1} was applied. Furthermore, no instantaneous relation between the presence of shear flow and the variation of the relaxation time exists. Rather, exponential transitions between the two relaxation time values at the beginning and at the end of the shear deformation seem to occur (see Fig. 1). The respective time constants are quite different: 60 ms after the beginning, 1.5 s after the end of the shear motion.

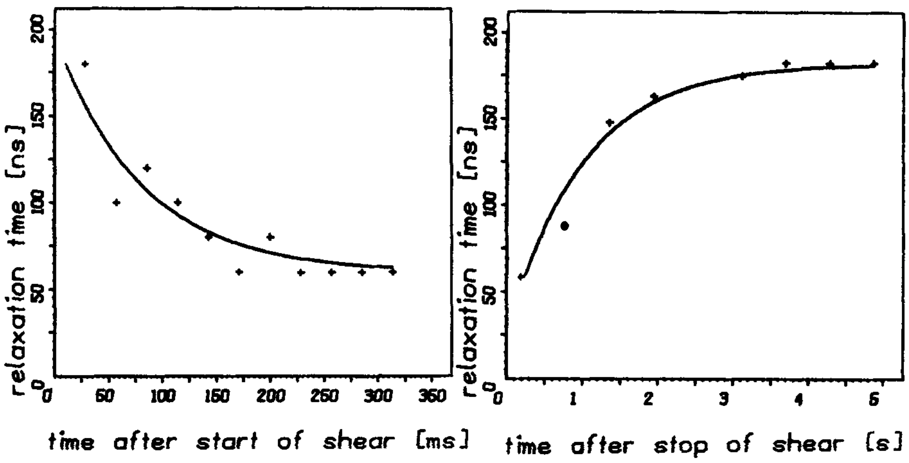

FIGURE 1 Decrease and Increase of the Parelectric Relaxation Time of MBBA After the Beginning and After the End of a Shear Deformation, Respectively.

DISCUSSION

The fact that the dielectric constant itself did not respond to the shear demonstrates that the director field was distorted by only a few degrees because the relatively high magnetic field of 0.3 Tesla stabilized the homeotropic orientation. An extrapolation of optical investigations by Waltermann and Fischer[4] for our shear rate and field strength leads to a similar result. Anyway, the time dependence between relaxation time and shear flow history leads to a particular hypothesis: for similar rates and magnetic fields in MBBA Pieranski and Guyon[5] observed roll instabilities similar to Williams-domains. If they existed in our experiment as well (unnoticeable because of nontransparent electrodes), they could be the reason for the reduction of the relaxation time, since it seems reasonable that the molecules in domain walls could rotate much more easy. The time constants of 60 and 1500 ms for the appearance and disappearance of such domains seem reasonable as well. Further investigations including optical observations are planned.

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