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Heat Transport Anisotropies in Aligned Octylcyanobiphenyl (8CB) Liquid Crystal

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HEAT TRANSPORT ANISOTROPIES IN ALIGNED OCTYLCYANOBIPHENYL (8CB) LIQUID CRYSTAL

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Abstract The behaviour of the specific heat (c), thermal conductivity (k) and thermal diffusivity (D) in the Smectic-A, Nematic and Isotropic phases of aligned 8CB has been studied with the photopyroelectric technique (PPE). The critical behaviour of c, k and D has been also determined at the smectic-A/nematic phase transition for different alignments. As expected, the behaviour of the thermal transport parameters is substantially different for omeotropic and planar alignment. It has been shown however that the thermal diffusivity critical behaviour is characterised by the same critical exponent in the two cases so that it does not seem to be connected to the absolute values of D. The thermal conductivity remains substantially flat at the transition temperature.

INTRODUCTION

In statics a number of theories have been proposed to describe the critical phenomena occurring at the smectic-A/nematic (AN) phase transition. They are all characterised by some difficulties in combining a good description of the c critical behaviour with the experimental evidence of the anisotropic critical behaviour shown by the correlation length ξ.

Due to de Gennes, a theory[1] based on the helium analogy places the AN phase transition into the 3D*XY* universality class. In this case the predictions for the c critical exponent and amplitude ratio of the critical term agree quite well with the experimental results for compounds having a McMillan ratio $T_{AN}/T_{NI}<0.93$ [2], being T_{AN} and T_{NI} the AN and nematic/isotropic (NI) transition temperatures respectively. Such a theory could not account for the anisotropy in the ξ critical behaviour. A gauge transformation theory proposed by Lubenski[3] predicts an anisotropic critical behaviour for ξ but also a c amplitude ratio

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inverted with respect to the 3D*XY* one which has never been experimentally observed. Finally a self consistent one-loop theory[4] which is based on an anisotropic coupling between the nematic order parameter fluctuations and the smectic order parameter ones predicts an anisotropy in the ξ critical exponent ν. Such a theory, however, cannot be applied close to the tricritical point where the system shows a crossover to a tricritical behaviour because of the coupling between the nematic order parameter and the smectic one.

In dynamic no comprehensive theory is available to describe the thermal transport processes occurring at the AN phase transition and very few measurements of the thermal parameters critical behaviour have been reported up to now. This is the reason why an important contribution to the understanding of the thermal transport processes could come from the study of the *k* and *D* critical behaviour and of their thermal anisotropy.

In the present work a photopyroelectric technique has been employed to simultaneously determine the *c*, *k*, and *D* behaviour on omeotropic and planar 8CB aligned samples in the temperature range from 29°C to 45°C. Their critical behaviour at the AN phase transition for both the alignments has been also determined. Preliminary measurements on 8CB/9CB mixture and on 9CB omeotropically aligned compounds have been also performed to investigate the effects of tricriticality on the dynamic thermal parameters critical behaviour.

EXPERIMENTAL

The used experimental setup is the standard photpyroelectric one in its back detection configuration[5]. The sample is sandwiched between a glass cover and the pyroelectric sensor. The two surfaces in contact with the sample itself can be treated in order to induce omeotropic or planar aligment[6].

RESULTS

The *c* vs temperature behaviour (not reported) coincides for the two alignments and agrees quite well with the data previously reported in literature. In Fig.1 the k and *D* behaviours as a function of temperature for both omeotropic (hereby indicated with the subscript $\|$) and planar (subscript $\perp$) alignments are reported. In the isotropic phase (I) the molecules are randomly oriented and the two behaviours coincide. When the molecules align along the

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heat flow direction (black dots) in the nematic phase (N) the thermal conductivity value $k_{\parallel}$ jumps up, it then varies smoothly over the AN transition, where it does not show any anomaly, and the smectic-A (S_A) phase.

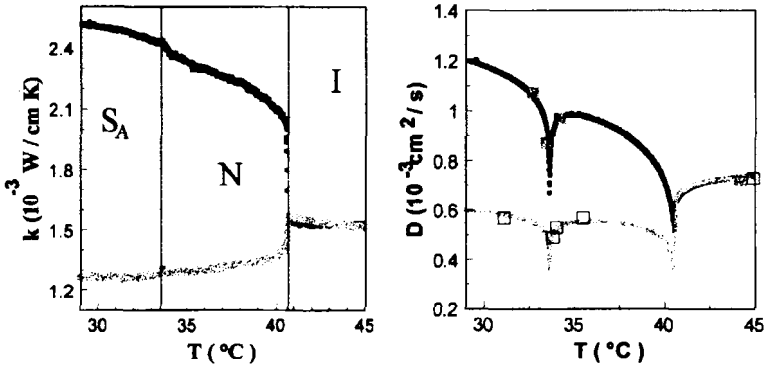

FIGURE 1 Thermal conductivity and thermal diffusivity vs temperature

For planar alignment (grey dots) again we find a regular $k_{\perp}$ behaviour over the N and S_A phases but with values lower then the isotropic phase ones. Again $k_{\perp}$ shows no anomaly at the AN phase transition.

In the thermal diffusivity behaviour the AN and NI transitions are evident. The squares reported on the graph correspond to absolute values of the thermal diffusivity obtained from frequency scans of the pyroelectric signal at fixed temperatures.

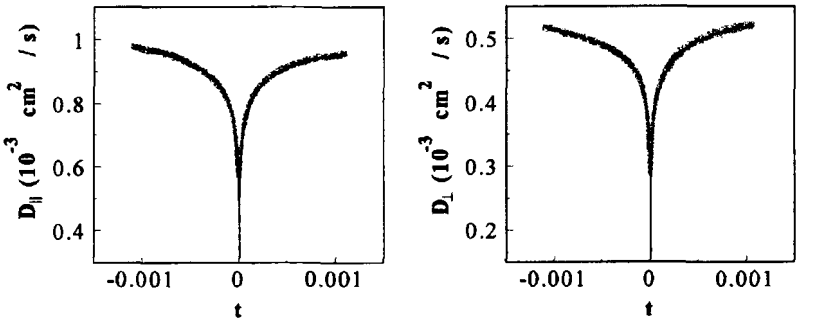

FIGURE 2 $D_{\parallel}$ and $D_{\perp}$ critical behaviour vs $t=(T-T_{AN})/T_{AN}$ the solid line corresponding to the best fit curve.

Clear anomalies at the transition temperature are also evident. High resolution measurements of the D critical behaviour at AN phase transition have been performed

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(Fig.2). The data have been fitted and the critical exponents determined. The obtained values show that the thermal diffusivity critical behaviour is characterised by the same critical exponent for the two different alignments so that it does not seem to be connected to the different absolute values of $D_{\perp}$ and $D_{\parallel}$ found away from the transition temperature.

In Fig.3 the D critical behaviour for different cyanobyphenil compounds is shown.

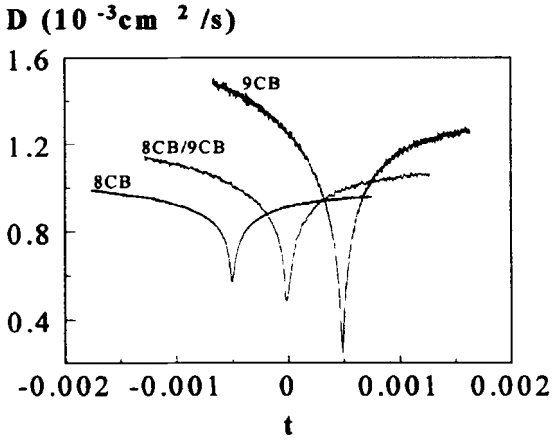

FIGURE 3 Thermal diffusivity critical behaviour vs $t=(T-T_{AN})/T_{AN}$ for two different compounds of the nCB series and for a their 50% in weight mixture. The samples are omeotropically aligned and the 8CB and 9CB data have been shifted of -0.0005 and +0.0005 respectively along the t axis.

Keeping in mind that $T_{AN}/T_{NI}=0.977$ for the 8CB, $T_{AN}/T_{NI}=0.989$ for the 8CB/9CB mixture, and $T_{AN}/T_{NI}=0.994$ for the 9CB, from the graph of Fig.3 it can be noted how the D anomaly at the AN phase transition becomes sharper for samples with increasing values of the McMillan ratio.

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