Quasicritical behavior of dielectric permittivity in the isotropic phase of *n*-hexyl-cyanobiphenyl in a large range of temperatures and pressures

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Results of studies of the dielectric permittivity and nonlinear dielectric effect (NDE) in the isotropic phase of *n*-hexyl-cyanobiphenyl are presented. The data reported cover both pressure and temperature dependence. Measurements under atmospheric pressure were carried out in a wide range, up to 100 K from the clearing temperature. The application of a weak measurement frequency ($f=67\,\mathrm{kHz}$) resulted in a negligible influence of relaxation processes on NDE results. For both temperature and pressure paths, the dielectric permittivity and the NDE exhibited strong pretransitional effects, described by ''critical'' exponents $\phi=1-\alpha\approx0.5$ and $\gamma=1$, respectively. Scaling expressions for the pretransitional behavior of the NDE and of the dielectric permittivity have been proposed. The relationship between pretransitional effects in the isotropic phase of nematogens and in critical solutions has also been discussed. [S1063-651X(99)05205-8]

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INTRODUCTION

Almost three decades have passed since the mean-field, phenomenological Landau–de Gennes model (LdG) has made it possible to describe the strong pretransitional anomalies of the Kerr effect (KE), Cotton-Mouton effect (CME), or the intensity of the scattered light (I) on approaching the isotropic-nematic (I-N) phase transition [1–3]. Their similarity and practical application in determining the value of discontinuity (ΔT) of isotropic-nematic transition ([1–14], and references therein) stems from the fact that each of them is proportional to the susceptibility $\chi=\chi_0^*(T-T^*)^{-\gamma}$ with $\gamma=1$, $T>T_C$, $T^*=T_C-\Delta T$: T_C and T^* denote the clearing temperature and extrapolated temperature of hypothetical continuous phase transition, respectively; $\chi_0^*=a^{-1}$ and a is a constant amplitude of the second rank term in the LdG series. Later it was shown [14] that the nonlinear dielectric effect (NDE) also belongs to this group of physical quantities. NDE describes the shift of dielectric permittivity caused by a strong electric field. On the whole in liquids [15,16]

$$\varepsilon^E=\varepsilon+\varepsilon_1E^2+0(E^4)$$

so

$$\mathcal{E}_{\mathrm{NDE}}=\frac{\varepsilon^E-\varepsilon}{E^2},\tag{1}$$

where ε^E and ε are dielectric permittivities in a strong (E) and weak (measuring) electric field.

The application of the LdG model gave the following relation for the pretransitional effect of ''nonlinear'' dielectric permittivity in the isotropic phase of nematogens [17–19]:

$$\mathcal{E}_{\mathrm{NDE}}=\frac{A_{\mathrm{NDE}}}{T-T^*}=\frac{2\varepsilon_0}{3a}\,\frac{\Delta\varepsilon^0\Delta\varepsilon^f}{T-T^*},\tag{2}$$

where $\Delta\varepsilon^0$ and $\Delta\varepsilon^f$ are molecular anisotropies of dielectric permittivity in the zero-frequency limit and the measurement radio frequency f.

In the NDE experiment one can change the radiofrequency of the weak measuring field which is not possible in experiments involving light (KE, CME, I). This gives the possibility to test the dynamic behavior of pretransitional phenomena from the stationary NDE measurements [20]. For frequency f low enough the $\mathcal{E}_{\mathrm{NDE}}^{-1}(T)$ is a linear function up to about $T_C+50\,\mathrm{K}$, with no distortions in the vicinity of T_C [18–21]. This case can be called the low-frequency NDE (LF NDE). For $\mathcal{E}_{\mathrm{KE}}^{-1}(T)$, $\mathcal{E}_{\mathrm{CME}}^{-1}(T)$, or $\mathcal{E}_I^{-1}(T)$ the range of linearity is typically limited to 5–10 K, with permanent distortions in the immediate vicinity of T_C [5,7–13]. The unique feature of LF NDE pretransitional effect is that a similar pretransitional behavior is observed for the nematic and smectic clearing points [19,20].

Pretransitional effect also exhibits a ''linear'' dielectric permittivity (ε). The recent studies carried out in few nematogens with a permanent dipole moment parallel to the long axis of the molecule showed that [21]

$$\varepsilon(T)=\varepsilon_C+A^T(T-T^*)^{1-\alpha}+B^T(T-T^*),$$
$$\text{for } T>T_C \quad\text{and}\quad \alpha\approx0.5,\tag{3}$$

where ε^* is the extrapolated dielectric permittivity at T^*, A^T, and B^T are amplitudes and α is the classical exponent of the specific heat.

This equation is the same as that applied for the homogeneous phase of critical solutions: in this case T^* is the critical consolute temperature and $\alpha\approx0.11$ [22–24]. The validity of relation (3) conforms with the hypothesis of the pretransitional, critical-like effect of $\varepsilon(T)$ in the isotropic phase of nematogens which was suggested nearly two decades ago by Bradshaw and Raynes [25] and Thoen and Metiu [26], and (quite surprisingly) hardly explored since then ([6,27], and references therein). The exponent α is explicitly involved in the pretransitional anomalies of specific heat $c_P(T)\propto(T-T^*)^{-\alpha}$ [5,28,29] or density $\rho(T)\propto(T-T^*)^{1-\alpha}$ [30]. However, the smallness and the limited range of appearance ($T-T_C<3-4\,\mathrm{K}$) of those anomalies makes a conclusive discussion of experimental data difficult. Nevertheless those

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studies indicated the value $\alpha \approx 0.5$ to be very likely [5,28–30]. When discussing the properties of the I-N phase transition it should be noted that the mean-field (MF) models strongly overestimate the value of discontinuity of the transition $\Delta T = 24-7.7$ K [31–33], whereas experiments point out the weakly discontinuous character of the I-N transition: $\Delta T = 0.5-2$ K [1–14,17–21]. Noteworthy in this respect is the new idea for the isotropic-nematic transition proposed by Mukherjee *et al.* [34–36]. They assumed that the I-N point falls upon a hypothetical coexistence curve and used the fluidlike equation of state. This gave $\alpha = 0.5$, $d = 3$, and $\Delta T = 1-3$ K.

To the best of the author's knowledge only a few experiments for pretransitional effects in liquid crystalline materials have so far been conducted which considered the pressure (P) as a prime thermodynamic variable [18,37,38]. The review of pressure studies in liquid crystalline materials may be found in Refs. [27,39]. The importance of such studies stems from the fact that they show the difference between temperature and pressure: the change of temperature is related mainly to the activation energy shift whereas the shift of pressure influences rather density and the free volume. On the other hand, the postulate of isomorphism of the critical phenomena states that pressure and temperature paths on approaching the critical point are isomorphic and governed by the same values of universal, critical parameters, e.g., critical exponents [5]. To the best of my knowledge there are no experimental studies on the pressure dependence of properties associated with the exponent α (i.e., c_P, ρ, or ε).

This paper presents results of isobaric (for $P = 0.1$ and $P = 30$ MPa), temperature and isothermal, pressure studies of a ''linear'' (ε) and nonlinear (LF NDE) dielectric permittivity in the isotropic phase of *n*-hexyl-cyanobiphenyl (6CB), a nematogen with the permanent dipole moment parallel to the long axis of the molecule. Temperature studies under atmospheric pressure were carried out up to $T_C + 100$ K, i.e., in the region as yet not explored in the studies of pretransitional effects in the isotropic phase. The results obtained made it possible to examine the pressure evolution of T_C, T^*, and ΔT and to show the scaling behavior of the studied pretransitional effects.

EXPERIMENT

NDE measurements were carried out in an apparatus described in details elsewhere [40]. Experimental technique made use of two electric fields, the weak measuring ($U_{\text{peak-peak}} \approx 3$ V) and the strong, steady, inducing nonlinearity ($U = 300-900$ V). The frequency of the measuring field ($f = 67$ kHz) was the lowest ever applied in NDE measurements. This gave the measurement time scale $t' = 1/f \approx 0.15$ ms, whereas the longest relaxation time of pretransitional processes in the isotropic phase was [41] $\tau(T_C) \approx 0.5\,\mu$s: thus the condition $t' \gg \tau$ was fulfilled even well below the clearing temperature. The additional averaging introduced by the low measurement frequency effectively eliminated the influence of relaxation processes [19–21]. The strong electric field was applied in the form of rectangular pulses of length $\Delta t' = 8-16$ ms and repeatability 3 s. The high voltage was decreased on approaching the clearing point to keep the sample response in the same range, from 5 to 30 fF. The fulfillment of the condition $\Delta \varepsilon^E \propto E^2$ was tested at each measurement point. All values of the NDE were determined in the stationary condition $\Delta t' \gg \tau(T)$. The sample was placed in a flat-parallel capacitor (gap$\approx$0.6 mm, $C_0 \approx 4$ pF). Its design had two advantages: only 0.8 cm^3 of a sample was needed, the liquid tested was in contact only with Invar, quartz, and Teflon. Dielectric permittivity was measured using SOLARTRON 1260A impedance analyzer. The averaging over 1000 periods gave the accuracy of five digits. The results presented below were taken for the measurement frequency $f = 10$ kHz, i.e., much below the frequency where dispersion of dielectric permittivity is observed [6,27]. Temperature was measured by means of a platinum resistor (Al class, DIN 43 260) located in a jacket of the pressure chamber and a copper-constantan thermocouple placed inside the chamber. The temperature was also monitored by another copper-constantan thermocouple inside the chamber. For temperature studies under atmospheric pressure the platinum resistor was placed in one of the covers of the measurement capacitor. Temperature was stabilized with precision better than 0.02 K/h. A Nova Swiss tensometric pressure meter measured pressure with accuracy ± 0.1 MPa. The sample of *n*-hexyl-cyanobiphenyl (6CB, $T_{I\text{-}N} \approx 30.80\,^\circ$C) was obtained due to the courtesy of Dabrowski and Czupryński from the Military Technical Academy, Warsaw, Poland. Each sample was outgassed immediately prior to measurements. All data were analyzed using the ORIGIN 3.5 software.

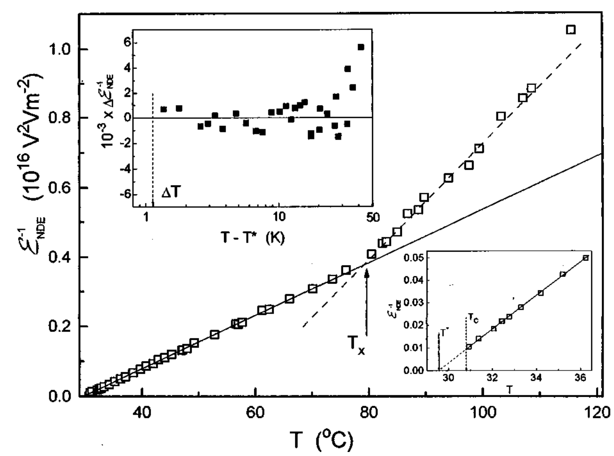

FIG. 1. Reciprocals of the experimental NDE values in the isotropic phase of 6CB determined under atmospheric pressure. The upper inset shows distortions from the solid, straight line fit of the pretransitional effect presented in the main part: $\Delta \mathcal{E}_{\text{NDE}}^{-1} = \mathcal{E}_{\text{NDE}}^{-1}$ (experiment) $- \mathcal{E}_{\text{NDE}}^{-1}$ (fit). The bottom inset shows details of the behavior in the immediate vicinity of the clearing point. The dashed line in the main part of the figure is only a guide to the eye.

RESULTS AND DISCUSSION

Figure 1 presents the reciprocals of the measured temperature dependence of LF NDE at atmospheric pressure. The data cover a wide range of temperatures from T_C to $T_C + 100$ K. The strictly linear behavior of $\mathcal{E}_{\text{NDE}}^{-1}(T)$ extends up to a temperature around $T_x = T_C + 47 \pm 2$ K, with no distortions in the immediate vicinity of T_C, as can be clearly seen in the inset. A broad range of linearity made it possible

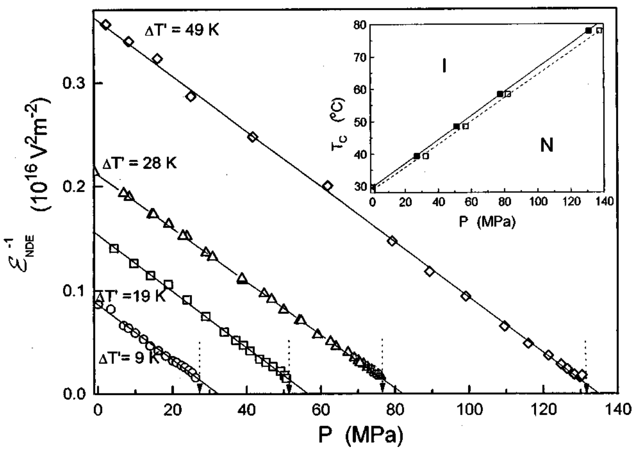

FIG. 2. Reciprocals of the experimental NDE values for the isothermal, pressure studies in the isotropic phase of 6CB. The data are for isotherms $\Delta T' = T_c(P) - T_c(P_{\text{atmospheric}})$ away from the clearing temperature under atmospheric pressure. The average reciprocal of the slopes of solid lines $A^P_{\text{NDE}} \approx 37(10^{-15}\,\text{m}^2\,\text{V}^{-2}\,\text{MPa})$. The inset shows the pressure dependence of the clearing temperature (solid squares and solid line) and the extrapolated temperature T^* (open squares and dashed line).

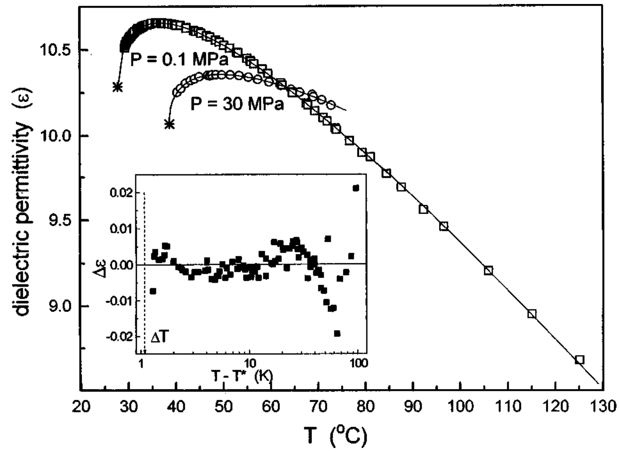

FIG. 3. Results of temperature studies of dielectric permittivity in the isotropic phase of 6CB for the atmospheric pressure and $P = 30$ MPa. Solid lines represent the fit by relation (3). Fitting parameters are given in Table I.

to determine the parameters with fair precision: $\Delta T = 1.2 \pm 0.05$ K and $A_{\text{NDE}} = 132 \pm 5$ $(10^{-16}\,\text{m}^2\,\text{V}^{-2}\,\text{K})$. Using these values and putting $\Delta\varepsilon^f \approx \Delta\varepsilon^0 \approx 10.8$ (the value determined for $f = 100$ kHz [8]) into relation (2) one can obtain $a \approx 0.051\,\text{J}\,\text{cm}^{-3}\,\text{K}$ which conforms with the value determined in the KE experiment ($a \approx 0.053\,\text{J}\,\text{cm}^{-3}\,\text{K}$ [8]). Thus one may conclude that the LF NDE pretransitional effect qualitatively complies with the LdG based relation (2) in the range from T_C to T_X. It is worthwhile noting that no additional ''nonpretransitional'' background effect term has been introduced as was often the case in the earlier KE, CME, or I studies [9–12]. The obtained value of $T_x - T_C$ agrees with that determined in the transient grating optical Kerr effect (TG OKE) experiment [42–44]: the ceasing of the LdG description was found for $T > T_C + (40–50\,\text{K})$ where the correlation length $\xi = \xi_0 (T - T^*)^{-0.5}$ falls below $3\xi_0$. In that case prenematic fluctuations are reduced to a few molecules. One may expect that changes of the NDE begin to be sensitive to nonpretransitional, molecular properties above T_x. For a dipolar liquid the following relation holds [15,16]:

$$\mathcal{E}_{\text{NDE}} = -\Phi(\varepsilon, \varepsilon_\infty) \frac{\mu^4 N V^{-1} x}{45 k_B^3 T^3} R_s, \tag{4}$$

where $\Phi(\varepsilon, \varepsilon_\infty)$ is associated with the local-field model, e.g., the Onsager model predicts $\Phi(\varepsilon, \varepsilon_\infty) = \varepsilon^4 (\varepsilon_\infty + 2)^4 / 2(\varepsilon^2 + \varepsilon_\infty^2)(2\varepsilon + \varepsilon_\infty)^2$, μ is the permanent dipole moment of the molecule, N is the Avogadro number, x is the concentration of the dipole constituent in the solution of the dipole constituent in a nondipole solvent, V is the molar volume of solution, k_B is the Boltzmann factor, and R_s is the correlation factor responsible for dipole-dipole interactions.

Orientation of noninteracting or weakly interacting permanent dipole moments ($R_S \approx 1$) gives a negative NDE value. All other molecular properties, including dipole-dipole interactions, give the positive contribution to the total measured NDE value ($R_S < 0$). Unfortunately, the application of relation (4) to the NDE measurements above T_x is not yet possible: to my knowledge the high-temperature data $\rho(T)$ and $\varepsilon_\infty(T)$ are not available. Recently Małecki and Nowak [45] carried out the isothermal, concentrational studies in n-heptyl-cyanobilphenyl (7CB) benzene solution, for $T \approx T_C$. They found the relation (4) valid only in a dilute solution, for $x < 0.4$ (remote from the clearing point). In the vicinity of the clearing point the LdG based description holds, as it was shown in NDE studies of MBBA-benzene solution [46].

Figure 2 presents results of isothermal, pressure measurements of LF NDE in the isotropic phase of 6CB. For all isotherms $\mathcal{E}^{-1}_{\text{NDE}}(T)$ is a linear function in the whole tested range of pressures, which suggests that the pressure analogue to Eq. (2) is valid [38]:

$$\mathcal{E}_{\text{NDE}}(P) = \frac{A^P_{\text{NDE}}}{P^* - P} = \frac{2\varepsilon_0}{3a_P} \frac{\Delta\varepsilon^0 \Delta\varepsilon^f}{P^* - P}. \tag{5}$$

TABLE I. Parameters of isobaric, temperature, behavior of dielectric permittivity in the isotropic phase of 6CB [relation (3), solid lines in Fig. 3].

Pressure of the isobar	ε^*	A^T (K^{-1})	B^T (K$^{-\phi}$)	$\phi = 1 - \alpha$	T^* (°C) (ΔT) (°C)
0.1 MPa	$10.295_{\pm 0.01}$	$-0.043_{\pm 0.003}$	$0.25_{\pm 0.04}$	$0.49_{\pm 0.03}$	$28.1_{\pm 0.06}$ $(1.2_{\pm 0.1})$
30 MPa	$10.08_{\pm 0.1}$	$-0.03_{\pm 0.007}$	$0.17_{\pm 0.02}$	$0.52_{\pm 0.05}$	$40.1_{\pm 0.1}$ $(1.5_{\pm 0.2})$

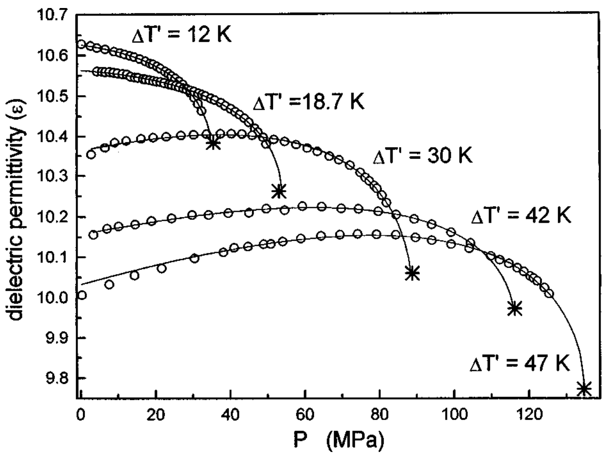

FIG. 4. Results of pressure measurements of dielectric permittivity for isotherms $\Delta T'$ away from the clearing temperature under atmospheric pressure. Solid lines represent the fit by relation (7). Fitting parameters are given in Table II.

The pretransitional amplitudes are for all isotherms constant within the limit of experimental error. As in the temperature studies there are no distortions from the classical behavior (the exponent $\gamma=1$). The results presented in Figs. 1 and 2 were approximated to give pressure dependencies of T^* and T_C:

$$T^*(P)=28.75_{\pm 0.2}+0.356_{\pm 0.006}P,$$

$$T_C(P)=29.90_{\pm 0.2}+0.368_{\pm 0.006}P$$

$$[T(^\circ\mathrm{C}),\ \ P(\mathrm{MPa})], \tag{6}$$

which is shown in the inset in Fig. 2. The discontinuity of the transition increases from $\Delta T\approx 1.2\,\mathrm{K}$ at $P=0.1\,\mathrm{MPa}$ to $\Delta T\approx 2.8\,\mathrm{K}$ at $P=140\,\mathrm{MPa}$.

Figure 3 presents results of temperature (for $P=0.1$ and 30 MPa) studies of dielectric permittivity. Both data are well portrayed by relation (3) (solid lines) with the parameters given in Table I. The quality of this fit at atmospheric pressure is shown in the inset. It may be seen that for $P=0.1\,\mathrm{MPa}$ relation (3) describes experimental data up to $T_C+100\,\mathrm{K}$.

As was mentioned in the Introduction the relation describing the behavior of $\varepsilon(T)$ in the isotropic phase of nematogens and in critical solutions seems to be isomorphic. However, some differences between these cases exist. In the critical solutions an additional term associated with corrections-to-scaling should be taken into account. The critical effect seen as a deflection from a fairly linear behavior remote from the critical consolute temperature, is observed typically for $f>1$ MHz. At lower frequencies the opposite trend due to the Maxwell-Wegner effect may be seen [22–24]. None of these features pertains to the $\varepsilon(T)$ anomaly in the isotropic phase of nematogens (Ref. [21], and this paper).

Figure 4 shows the results of pressure measurements of dielectric permittivity in the isotropic phase for a number of isotherms. They can be parametrized by the pressure analog of relation (3)

$$\varepsilon(P)=\varepsilon^*+A^P(P^*-P)^{1-\alpha}+B^P(P^*-P) \tag{7}$$

shown by the solid lines in Fig. 4. The values of fitted parameters are collected in Table II. Note that for each isotherm the exponent $\phi=1-\alpha\approx 0.5$. The clear shift of $\varepsilon(P)$ dependencies towards higher pressures, is the consequence of the increase of T_C and T^* with pressure.

In the homogenous phase of critical solutions, the weak divergence of $d\varepsilon/dT$ should exhibit the anomaly proportional to that of the specific heat c_p [47]. For the isotropic phase of nematogens such a behavior is presented in Fig. 5. All derivatives of isothermic, pressure data can be easily superposed onto one curve, as it is shown in the inset in Fig. 5. The scale of the inset additionally proves that the exponent $\alpha\approx 0.5$ and shows that the nonuniversal amplitude B^P has approximately the same value in the tested range of $T^*(P)$ for all data given in Fig. 4. The differential analysis is very sensitive even to a subtle distortion of experimental data from the assumed description. For dielectric permittivity this gives

$$\frac{d\varepsilon}{dT}=A^P(1-\alpha)(T-T^*)^{-\alpha}+B^P. \tag{8}$$

The parameters of fitting, given in Fig. 5 [relation (8)] and that in Table I [relation (3)] are in good agreement within the limit of experimental error. Moreover relations (3) and (8) are valid in the same range of temperatures $T-T_C\approx 100\,\mathrm{K}$.

TABLE II. Parameters of isothermal, pressure behavior of dielectric permittivity in the isotropic phase of 6CB [relation (7), solid lines in Fig. 4]. For isotherms $\Delta T'=12.7$ K and 18.7 K the date were fitted assuming that $\alpha=0.5$ and $P^*=P_C+\Delta P$, as given by LF NDE measurements.

Temperature of the isotherm	ε^*	A^P (MPa^{-1})	B^P (MPa$^{-\phi}$)	$\phi=1-\alpha$	P^* (MPa) (ΔP) (MPa)
47 K	$9.77_{\pm 0.08}$	$-0.0096_{\pm 0.002}$	$0.16_{\pm 0.006}$	$0.50_{\pm 0.03}$	140.7 (13.6)
42 K	$9.97_{\pm 0.1}$	$-0.01_{\pm 0.002}$	$0.15_{\pm 0.003}$	$0.50_{\pm 0.05}$	117 (11)
30 K	$10.06_{\pm 0.15}$	$-0.011_{\pm 0.003}$	$0.14_{\pm 0.004}$	$0.50_{\pm 0.07}$	95.1 (9)
18.7 K	10.25	−0.07	0.13	0.5	95.1 (8)
12.7 K	10.38	−0.08	0.13	0.5	34 (6)

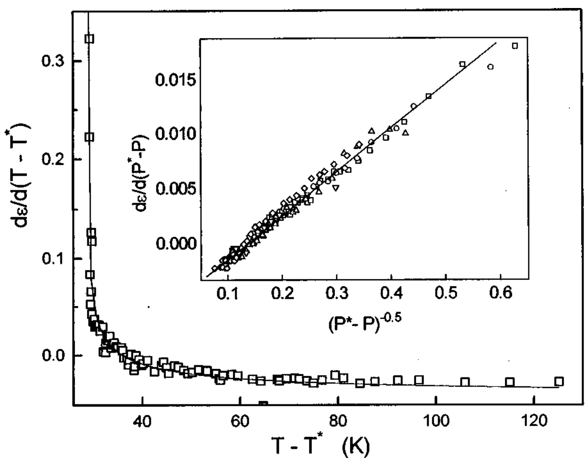

FIG. 5. The differential analysis of the NDE temperature data under atmospheric pressure (Fig. 1). The reciprocal of the value of a constant function (solid line) is equal to 136 ($10^{-16}\,\mathrm{m}^2\,\mathrm{V}^{-2}\,\mathrm{K}$). The inset shows the scaling behavior of temperature and pressure NDE pretransitional effects.

The pretransitional anomalies of $c_P(T)$ [28,29] detected in the isotropic phase are small and usually limited to the range $T-T_C<4\,\mathrm{K}$ which makes a conclusive discussion of experimental data difficult. These properties explain why $\alpha\approx0.5$ and $\alpha\approx0.11$ [5] did not give significantly different fits of experimental data. The crossover function between the tricritical ($\alpha=0.5$) and three-dimensional (3D) Ising critical ($\alpha\approx0.11$) behavior was also proposed [5,28]. It was shown that the $c_P(T)$ anomaly can be parametrized by the relation with a single power term and $\alpha=0.5$ if T^* is shifted due to fluctuational correction [48]. However, in this case the ΔT value was much smaller than that obtained in KE, CME, or *I* studies. The value $\alpha=0.5$ appears in the Ornstein-Zernike (OZ) extension of the mean-field approximation, for the tricritical point (TCP) (dimensionality $d=3$) and in the Gauss model (GM) ($d=3=4-2\alpha$) [49]. For the classical mean-field models $\alpha=0$ and $d>4$ [5].

Figure 6 shows the results of differential analysis of the LF NDE pretransitional effects. It can be seen that the dependence which can be expected from the relation (2), i.e.,

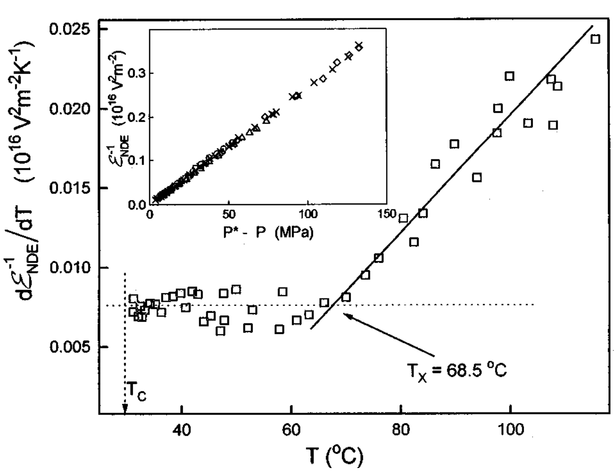

FIG. 6. The differential analysis of $\varepsilon(T)$ data under atmospheric pressure. The solid line shows the fit by means of relation (8). The inset collects all isothermal, pressure measurements.

$$\frac{d\mathcal{E}_{\mathrm{NDE}}^{-1}}{dT}=A_{\mathrm{NDE}}^{-1}=\mathrm{const} \tag{9}$$

is well fulfilled.

Figure 6 also shows that the range of the pretransitional region is equal to $T-T_C\approx38\,\mathrm{K}$ so it is smaller that the estimation made from Fig. 1. The inset in Fig. 6 demonstrates that both $\mathcal{E}_{\mathrm{NDE}}(T)$ and $\mathcal{E}_{\mathrm{NDE}}(P)$ data can be superposed onto the same scaling curve as a function of (P^*-P) provided the isobaric, temperature data are transformed by means of the relation [38]

$$T-T^*\rightarrow(P^*-P)=(dT^*/dP)^{-1}(T-T^*). \tag{10}$$

The same scaling remains valid for $d\mathcal{E}_{\mathrm{NDE}}^{-1}/dT$ and $d\mathcal{E}_{\mathrm{NDE}}^{-1}/dP$ and this property may be associated with the Ehrenfest-type relation [38]:

$$A_{\mathrm{NDE}}^{T}=A_{\mathrm{NDE}}^{P}\frac{dT^*}{dP}, \tag{11}$$

where $A_{\mathrm{NDE}}^{P}=2\varepsilon_0/3a_p(\Delta\varepsilon^0)^2$ and $A_{\mathrm{NDE}}^{T}=2\varepsilon_0/3a_T(\Delta\varepsilon^0)^2$.

On the whole this behavior makes it possible to determine the pretransitional amplitude of NDE or coefficients a_T, a_P at high pressures using the parameters extracted from experiments conducted under atmospheric pressure and the $T^*(P)$ dependence. Alternatively, basing on the specific pretransitional behavior of NDE one can determine dT^*/dP and consequently $T^*(P)$ from the measurement relatively remote from the clearing point.

CONCLUSIONS

Results presented above give a strong evidence in favor of the exponents $\alpha\approx0.5$ and $\gamma=1$ for both the pressure and temperature path approaching the clearing point. It should be noted that the properties related to exponent $\alpha(c_p,\rho,\varepsilon)$ appear in a group of ''weak'' critical anomalies, in contrast to ''strong'' critical anomalies related to the exponent γ (KE, CME, *I*, NDE, χ) [5]. This is due to different origins of pretransitional anomalies of the ''linear'' and ''nonlinear'' dielectric permittivity. Anomalies of $\varepsilon(T)$ and $\varepsilon(P)$ are caused by the cancellation of permanent dipole moments contained in prenematic fluctuations while for NDE the pretransitional effect is associated with fluctuations of the order parameter and with the susceptibility of these fluctuations to an external perturbation [21,50]. This difference gives rise to different ranges of appearance of pretransitional anomalies of $\mathcal{E}_{\mathrm{NDE}}(T)$ and $\varepsilon(T)$ (Figs. 1 and 3).

The discontinuity of the *I-N* transition is the same, within the limit of the experimental error, if estimated from NDE and dielectric permittivity measurements. The values of ΔT determined from temperature measurements coincide with the values of ΔP estimated from pressure measurements. Noteworthy are also consequences of the scaling of pretransitional effects mentioned above (Figs. 5 and 6).

In the opinion of the author all these facts support the hypothesis on the fluidlike, critical behavior in the isotropic phase of nematogens with dimensionality $d=3$, and exponents $\alpha=0.5$, (as mentioned in the Introduction) [34–36]. However, it should be noted that Ref. [35] seems to favor $\gamma=0.5$ whereas experimental studies give clear evidence for

$\gamma=1$ (Refs. [1–14,17–21,37,38,41–43], and this paper). Nevertheless this hypothesis of the fluidlike behavior in the isotropic phase of nematogens is additionally supported by the possibility of arriving at the relations for NDE and ε pretransitional effects starting from those derived for a homogeneous phase of critical solutions [21,50]. One may speculate that agreement between the presented experimental results and theoretical considerations may be obtained if the extrapolated point of the continuous phase transition had been a pseudospinodal [51,52] tricritical point.

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