# Dielectric properties of biphenyl



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# Dielectric properties of biphenyl

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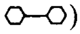
**Abstract.** The dielectric constant along the crystallographic axes was measured. The dielectric anomalies at $T_I$ along the $a$ and $b$ axes show critical exponent $\beta = 0.50 \pm 0.01$ in the incommensurate phase II. At the second phase transition $T_{II}$ no anomaly in dielectric constant was observed.

## 1. Introduction

In recent years, biphenyl (diphenyl) ($C_{12}H_{10}$, ) has been studied intensively (Cailleau *et al* 1979). Two low-temperature incommensurate phases of biphenyl have some unusual features. Phase II, existing for $T_I = 40$ K $> T > T_{II} = 17$ K, is one of the few known systems whose order parameter has four components (Cailleau *et al* 1979, Cailleau 1986, Toledano and Guilluy 1984). This allows the existence of two different incommensurate states A and B, called quilt and stripe like. In recent work (Golzhauser *et al* 1989) it was shown that phase II is stripe like. In the present work we report a dielectric study of biphenyl. We show that dielectric anomalies along the $a$ and $b$ axes at around 40 K have a critical exponent $\beta = 0.50 \pm 0.01$.

## 2. Experimental procedure

Single crystals of biphenyl were grown from the melt. Samples were cut normal to the $a$, $b$ and $c$ axes (Charbonneau and Delugeard 1976). The homogeneity of the samples was controlled using a polarising microscope. The capacity of the samples, with silver paste electrodes, was measured with a GR 1616 capacitance bridge at 1 kHz. The temperature of the sample was controlled with an Oxford ITC4 instrument, and the temperature was stable to ±0.1 K.

## 3. Results

We studied the dielectric constant parallel to the crystallographic $a$, $b$ and $c$ directions. The results for the $b$ axis are shown in figure 1. The dielectric constant increases on

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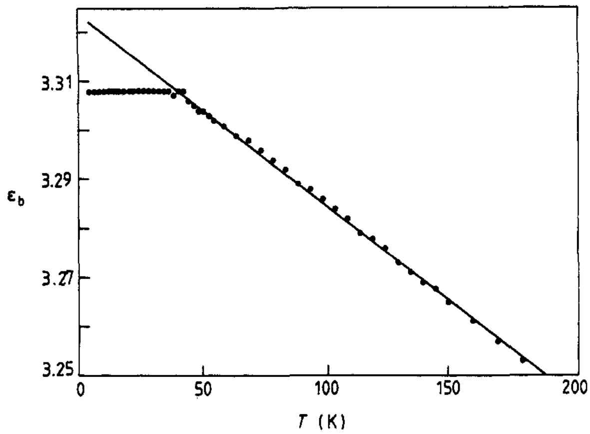


**Figure 1.** Dielectric constant $\varepsilon_b$ as a function of the temperature.

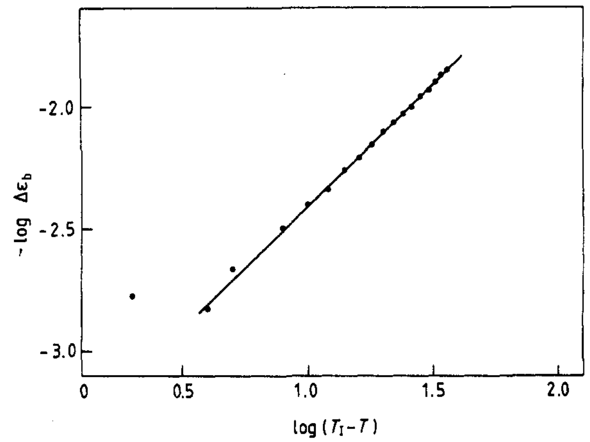


**Figure 2.** Double-logarithmic plot of the dielectric anomaly of the $b$ axis below $T_I$ for biphenyl.

approaching $T_I$ at 40 K from higher temperatures and is temperature independent below 40 K; it shows no change on going through $T_{II}$. The anomaly in $\varepsilon_b$ is determined by extrapolating the linear high-temperature behaviour to below $T_I$ and taking the difference $\Delta\varepsilon_b$ with respect to the measured values. An isotropic coupling modifies the dependence (Unruh and Stromich 1981)

$$\varepsilon = 1/(\varepsilon_0 + \eta |Q|^2)$$

so that, below $T_I$, $\varepsilon$ behaves linearly because $|Q|^2 \propto (T_I - T)^{2\beta}$. Figure 2 shows that such a relation holds with an exponent $\beta$ of $0.50 \pm 0.01$. The dielectric constant along the $a$ axis has almost the same value as along the $b$ axis and gives the same critical exponent. A similar behaviour was observed for $Rb_2ZnCl_4$ and $K_2SeO_4$ by Unruh and Stromich (1981) and Unruh *et al* (1979); only the value for $\beta$ was smaller.

Figure 3 shows the temperature dependence of $\varepsilon_c$. Below $T_I$ the dielectric constant is constant. The temperature dependence for $T > T_I$ is unusual.

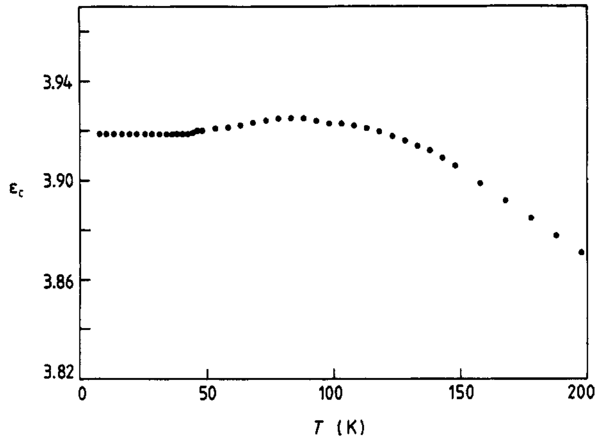


**Figure 3.** Dielectric constant $\varepsilon_c$ as a function of the temperature.

## 4. Conclusions

The dielectric anomalies in biphenyl at $T_I$ have a critical exponent $\beta$ of 0.50 along the *a* and *b* axes. The dielectric constant does not show any anomaly at the $T_{II}$ phase transition. The dielectric constant $\varepsilon_c$ has an unusual temperature dependence at $T > T_I$.

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