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Publisher: Taylor & Francis

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Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/gmcl16>

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Version of record first published: 17 Oct 2011.

To cite this article: J. P. Parneix, S. Villers, M. El. Kadiri, G. Froyer, F. Maurice & J.Y. Goblots (1985): Complex Conductivity of Lightly Doped Polyparaphenylene (P.P.P.), Molecular Crystals and Liquid Crystals, 118:1, 295-299

To link to this article: <http://dx.doi.org/10.1080/00268948508076227>

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COMPLEX CONDUCTIVITY OF LIGHTLY DOPED POLYPARAPHENYLENE (P.P.P.)

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Abstract The evolution of the frequency and temperature dependence of the complex conductivity $\sigma^*(f, T)$ of lightly doped polyparaphenylene is reported.

The main features of the experimental devices are the followings : a) an automatic determination of σ^* within a large frequency range from 1Hz up to the microwave region; b) a cell structure allowing the measurement of films or pellets (thickness < 1mm); c) a large temperature range (70K-400K).

The d.c. conductivity (σ_{dc}) is found to be strongly temperature dependent (our data are consistent with the Kivelson's model: $\sigma'_{dc} \propto T^n$ with $n \sim 11$). The a.c. conductivity (σ'_{ac}) is proportional to f^s where $s \sim 0.9$. The T-dependence of σ'_{ac} slightly decreases as the frequency increases.

EXPERIMENTAL TECHNIQUES

P.P.P. was synthesized by using the Kovacic method. The powder was doped with AsF₅ or Iodine and then pressed into pellets of various thickness ¹.

Conductivity measurements were made in a pellet-cell (figure 1). The sample was located at the end of a coaxial line (APC 7 standard) and it was maintained in a nitrogen atmosphere during the experiments.

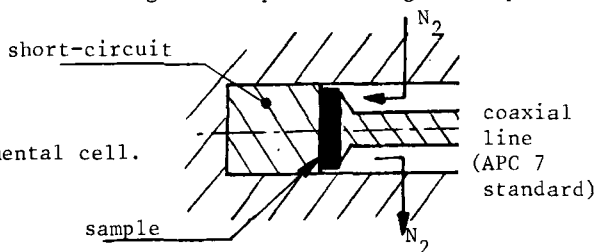


Figure 1 The experimental cell.

The $\sigma(f)$ was obtained at fixed temperature using Hewlett-Packard Impedance Analyzers driven by a H.P. table computer (Figure 2).

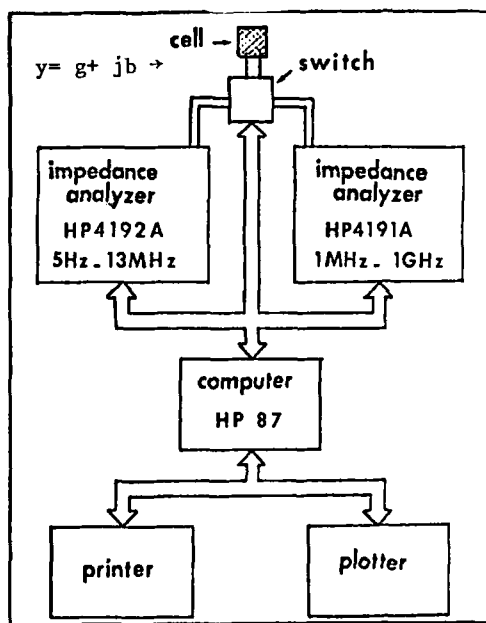


FIGURE 2 The $\sigma(f)$ experimental set-up.

For a given frequency automatically fixed by the calculator via an IEEE bus, the input admittance y was obtained and then the complex conductivity σ^* deduced :

$$y = g + jb = \sigma^* C_a = (\sigma' + j\sigma'') C_a \quad (1)$$

where C_a is the active capacitance.

The real part (σ') of the complex conductivity (σ^*) is usually divided in a f -independent contribution σ'_{dc} and a f -dependent contribution σ'_{ac} according to Eq.2 :

$$\text{Re}(\sigma^*) = \sigma' = \sigma'_{dc}(T) + \sigma'_{ac}(f, T) \quad (2)$$

From the imaginary part (σ'') of σ^* one uses to deduce, the dielectric constant of the material ϵ' using equation(3):

$$\sigma'' = \omega \epsilon'' \quad \text{where } \omega = 2\pi f. \quad (3)$$

Our data are given using the following three forms:

$$\sigma'_{dc}(T), \sigma'_{ac}(f,T), \epsilon'(f,T)$$

EXPERIMENTAL RESULTS

Figure 3 shows the variation of dc-conductivity σ'_{dc} with temperature. In the range of temperature investigated, the data are seen to fit the form: $\sigma'_{dc} \propto T^n$. For all doping levels and dopants, $n \approx 11$ which is consistent with the Kivelson's model² and other data previously published³.

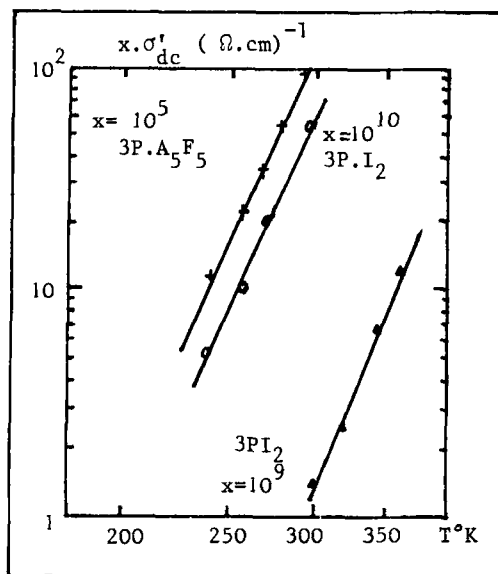


FIGURE 3 σ'_{dc} vs temperature for different doping levels and dopants

In figure 4, is given the dependence of ac-conductivity σ'_{ac} vs frequency and temperature. It shows that σ_{ac} increases as f^s with $s \approx 0.9$. Moreover, σ'_{ac} is much less dependent on T than σ'_{dc} . This dependence decreases as f increases.

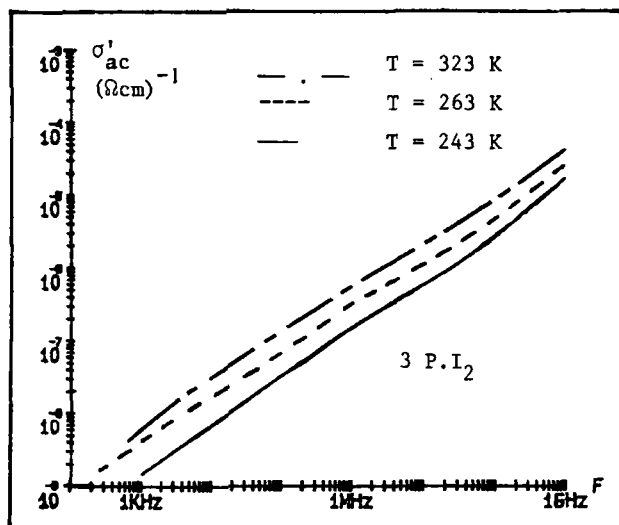


FIGURE 4 σ'_{ac} vs frequency at different temperatures

Finally, in Figure 5 is shown the variation of ϵ' with f and T . In the high frequency range ϵ' is only slightly temperature dependent and is independent on f . The value obtained with iodine (~ 4.5) is only slightly higher than the undoped P.P.P. pellet (~ 3.5). The variation of ϵ' with f and T in the low frequency range is connected with an electrode polarization effect due to the conductivity. It does not affect significantly the σ' results.

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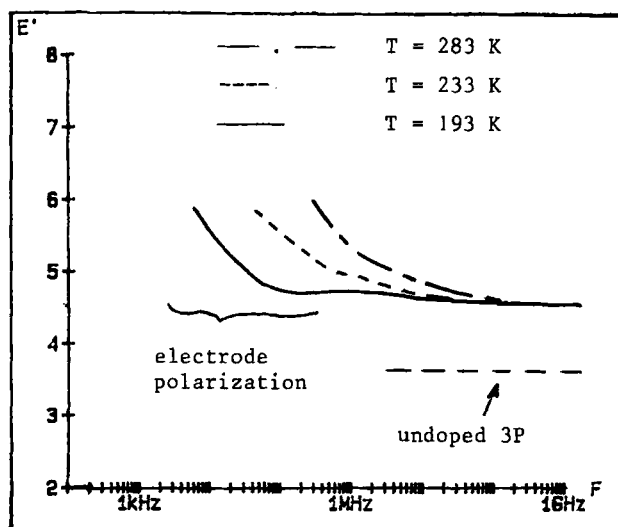


FIGURE 5 Frequency dependence of ϵ' for different temperatures