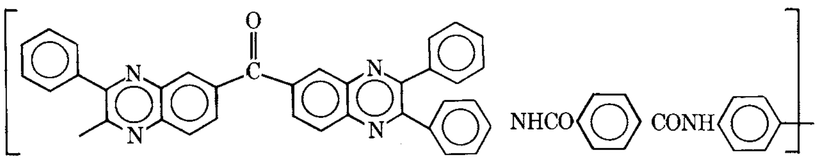
Electrical Resistivity of a Polyamide Quinoxaline Polymer

Previously we have reported[1] the very high electrical volume resistivity of a crosslinked glassy amorphous resole-type phenolic polymer. We now wish to report on the volume resistivity of a linear, amorphous, polyamide quinoxaline (PAQ) which also has very high electrical resistivity and very high thermal stability. Additionally, PAQ differs from the rigid phenolic polymer in that it is soluble and to some degree flexible and can be employed as a film or fiber.

The polymer which was studied is a linear polymer of the following structure:



Details of the preparation of this polymer have been reported.[2,3]

The polymer was obtained in the form of a 10% solution of PAQ in *m*-cresol. This was poured into a cylindrical electrode,[4] and most of the solvent was allowed to diffuse away at 25°C over several days. The sample was then heated for 24 hr at 30°C, increasing the temperature about 25°C for each 24-hr period, with the final being 252°C. Thus, the heating cycle for PAQ was very similar to that employed for the phenolic polymer except that three additional heating periods were employed

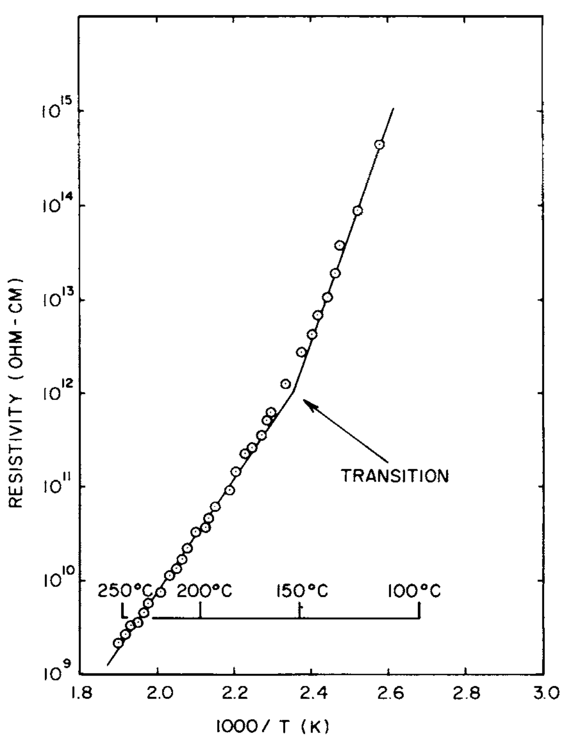


Fig. 1. Resistivity of polyamide quinoxaline as function of temperature.

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resulting in a final temperature at 252°C. All the *m*-cresol had vaporized following this heat treatment. All heating was done in air, and while some degradation was visually noted at temperatures above 252°C in air, this polymer has been shown to be stable up to 450°C under vacuum.[2] The phenolic exhibited degradation at about 175°C.

The PAQ polymer was a reddish brown solid with a density of 1.22 g/cc. Once the solvent was removed, the temperature dependence of the resistivity was determined. Previously,[4] we have described how resistivity measurements may be employed to ascertain the completeness of polymerization. With the PAQ polymer, no resistivity measurements could be made below about 125°C because the resistivity was too high to measure. Thermal cycling at temperatures greater than 252°C exhibit a reduced temperature dependence of the resistivity which indicates the onset of degradation. All resistivity measurements were made as the polymer was cooled.

A semilog plot of electrical volume resistivity versus the reciprocal of the absolute temperature is shown in Figure 1. In the absence of any transitions, plots of this type are usually linear. In the case of PAQ, however, a change in slope occurs at about 160°C. Such changes of slope are indicative of a transition but resistivity measurements do not indicate the exact type of transition.[1,5]

The resistivity at temperatures below 160°C exhibits a high temperature dependence from which the activation energy for electrical conduction, E_c, is found to be 53 kcal/mole. This is a high value for a linear polymer. The highly crosslinked phenolic exhibited an E_c value of 69 kcal/mole. If the data of Figure 1 are extrapolated to 25°C a value of $\sim 10^{24}$ ohm cm for the resistivity at 25°C, ρ(25°C), is obtained. The phenolic had a value of $\sim 10^{26}$ ohm cm for ρ(25°C).

While these are high values for ρ(25°C), both are reasonable. Previously,[6] we have shown that a general linear relationship exists between E_c and ρ(25°C), and the values for PAQ and the phenolic polymer fit this relationship.

Comparison of the results obtained on linear PAQ with those obtained on phenolic polymer indicate that while the phenolic has slightly higher values of E_c and ρ(25°C), its rigid crosslinked structure limits its use in applications where a flexible dielectric is required. PAQ, which can be prepared in several forms, has resistivity properties almost as good as a phenolic and is thermally more stable.

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