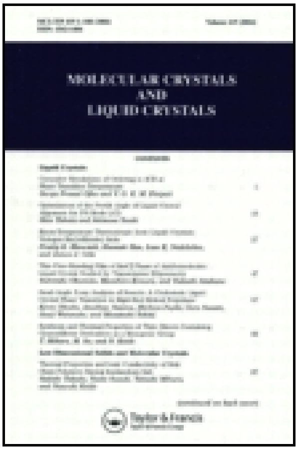

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Observations on Ionic Contamination in AFLC Mixtures

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Observations on Ionic Contamination in AFLC Mixtures

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This paper details the systematic investigations on ionic contamination in three different room-temperature AFLC mixtures. By comparing the measured ion content, in cells with different combinations of aligning material and mixture, clear relations have been observed between certain components present in the mixtures and the ions detected therein. Furthermore, our results suggest that certain species of ions originate from interactions between the liquid crystal and the alignment layers. The implications of the results on the optimum combination of AFLC and alignment layer is discussed.

Keywords: Ionic contamination; alignment layers; AFLC

INTRODUCTION

Antiferroelectric liquid crystals are suitable candidates for use in the next generation of high information-content display devices [1]. In addition to wide viewing angles and response times fast enough to facilitate video frame-rate, in combination with field sequential colour, these devices offer the possibility to achieve analogue greyscale by means of waveforms designed for passive matrix addressing [2].

The operation of display devices based on nematic and ferroelectric liquid crystals (LCs) is known to be sensitive to the presence of ionic impurities in the liquid-crystalline mixtures and the effects have been studied extensively [3, 4]. Liquid crystal displays based on AFLCs were initially regarded to be less susceptible to the effects of ionic contamination, principally as a consequence of the symmetric addressing schemes employed in devices utilising these materials. This so-called "dc auto-compensation" is believed to prevent the separation of positive and negative ions within the liquid crystal which in turn prevents the accumulation of ions at the electrodes. Recent investigations on test cells containing different AFLC mixtures have, however, suggested that ion transport in these devices may play a more significant role than previously speculated [5 - 7].

In this paper we present the results from our measurements collected from various investigations on ionic contamination in three AFLC mixtures: **mmx11**, **pent2**, and **pent6'** [5]. The transition temperatures and physical properties of the mixtures are listed in Table 1. Test cells with different surface treatments were used for these studies in order to clarify the role of the alignment layers on the observation of the different ionic species.

(a)

Mixture	SmC_A*		SmC*		SmA*		I	Recrys
pent2	•	83.4	•	89	•	107.1	•	<25
mmx11	•	75.4	-	-	•	113.1	•	<25
pent6'	•	72.8	-	-	•	94.6	•	<25

(b)

Mixture	V_{th} ($V_{ac}\mu m^{-1}$)	τ (μs)	θ (°)	Max P_s ($nCcm^{-2}$)
pent2	9.5	100	27.7	94.0
mmx11	10.0	80	22.5	57.0
pent6'	13.2	60	28.5	83.2

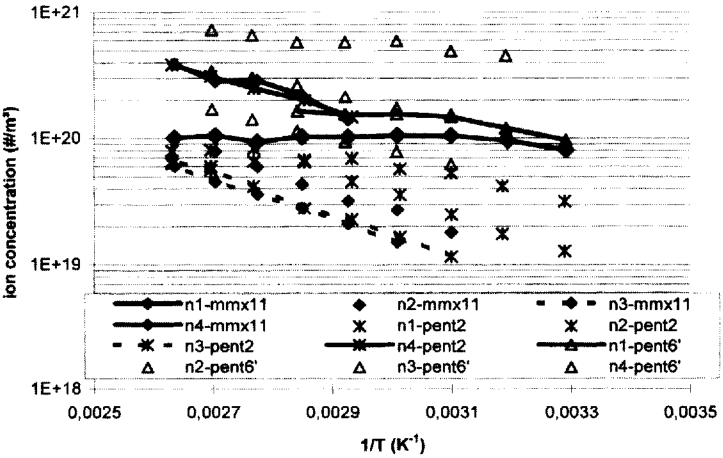
TABLE 1 Transition temperatures (°C) (a), and physical properties (b), of the mixtures investigated.

RESULTS AND DISCUSSION

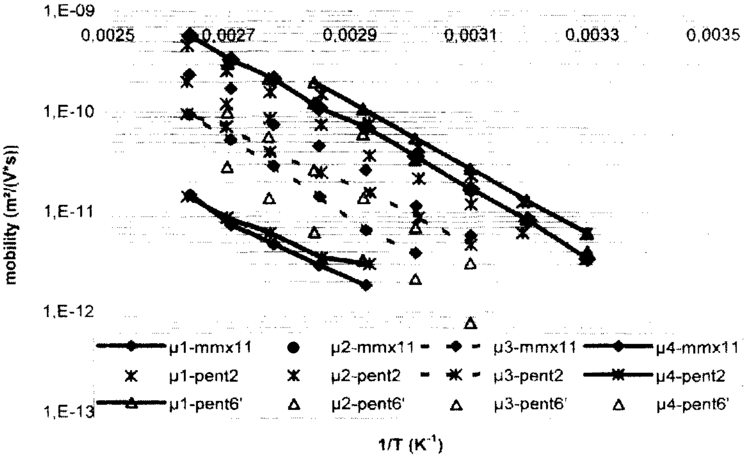
1. Ion Content in Different AFLC Mixtures

The technique used to measure the ion content in the liquid-crystalline mixtures is the transient leakage current method which has been described in detail before [5 - 7]. From the current profile, the ion mobility and concentration can be calculated. The measurements for each mixture were repeated at different temperatures in order to improve the reliability of the measurements and to allow us to study the temperature dependence of the observed ionic impurities. In order to allow fair comparisons to be made between the different mixtures the same alignment material (polyimide, abbreviated PI1 in the following text) was used in all of the test cells for the first investigation.

Figure 1 shows the measured ion mobility and concentration in the three mixtures. Figure 1(a) shows that ion1 in **pent6'** and **mmx11** have the same activation energy of concentration (around 0.1 eV) at low temperatures and the concentration saturates at around 50 °C in both cases. It is likely that they are identical ion species present in both mixtures. Since **pent6'** and **mmx11** contain the same ferroelectric dopant and one common chiral component, this ion species should come from one of them. Since ion1 in **pent2** has a different temperature behaviour of concentration it may originate from a chiral component which is not present in either **pent6'** or **mmx11**. By comparing the composition of these mixtures, it is found that this common component in **mmx11** and **pent6'**, which is not present in **pent2**, is IGS97. This is a standard non-mesogenic chiral dopant, which is frequently called a "ferroelectric-like" dopant since it is used to induce a spontaneous polarisation into the mixtures.



(a)



(b)

FIGURE 1 Comparison of ion mobility and concentration vs. 1/T in **pent2**, **mmx11** and **pent6'**.

Ion2 in the three mixtures shows different concentrations and different activation energies. Consequently these must be different ionic species present in the three mixtures that we believe originate from different mixture components.

Furthermore, one can also find that the concentrations of ion3 and ion4 in **pent2** and **mmx11** are almost identical at all measured temperatures. Consequently they may be the same ion species in both mixtures. These two ion species should come from the two common chiral components in **pent2** and **mmx11**. For **pent6'** the concentration of ion3 and ion4 is higher than that of **pent2** and **mmx11**, at all temperatures, while the activation energy is lower. Thus the ions may originate from a chiral component which is not present in either **mmx11** or **pent2**. After comparing the various components used in the mixtures, we come to the conclusion that (*S*)-TFMHPODBC, used in both **pent2** and **mmx11**, is responsible for the common ion species (ion3 and ion4) in these two mixtures.

Figure 1(b) illustrates the comparison of ion mobilities in the three mixtures at different temperatures. First note that the mobility of ion1 in **pent6'** is larger than that in **mmx11** at all measured temperatures. From the above discussion, if one assumes that ion1 in **pent6'** and **mmx11** is the same ion species, then the viscosity of **pent6'** should be lower than that of **mmx11** since the ions move faster in **pent6'**. Secondly, the mobilities of ion3 and ion4 in **pent2** are larger than the mobilities of the same ions in **mmx11**. If they are two types of common ion species in the two mixtures, as deduced from the above study of ion concentration and its temperature behaviour, **pent2** must have a lower viscosity than **mmx11**.

In order to investigate further the relationship between the components used in the mixture and the ions detected, we have measured the AFLC mixtures using other alignment materials: Nylon6,6 (polyamide), pyraline (another type of polyimide) and SiO_x. The results of using Nylon6,6 as alignment layer are summarised in figure 2. Interestingly, similar results have been obtained as those using PI1 as alignment layer. Here, one can see once more that ion1 in **pent6'** and **mmx11** has the same activation energy of concentration, being roughly 0.1 eV, which is the same as using PI1 alignment layer. Furthermore, the mobilities of ion1 in **pent6'** using both PI1 and Nylon6,6 always have the same values within the temperature range of the SmC_A* phase. All this information indicates that although different alignment layers are used, the same ion species ion1 is present in **pent6'** and **mmx11**, with both PI1 and Nylon6,6 alignment layers. The component responsible for this ion species should be IGS97. In addition, comparing the mobility of ion1 in the two mixtures leads to the same result as before, ie. the viscosity of **pent6'** is lower than that of **mmx11**.

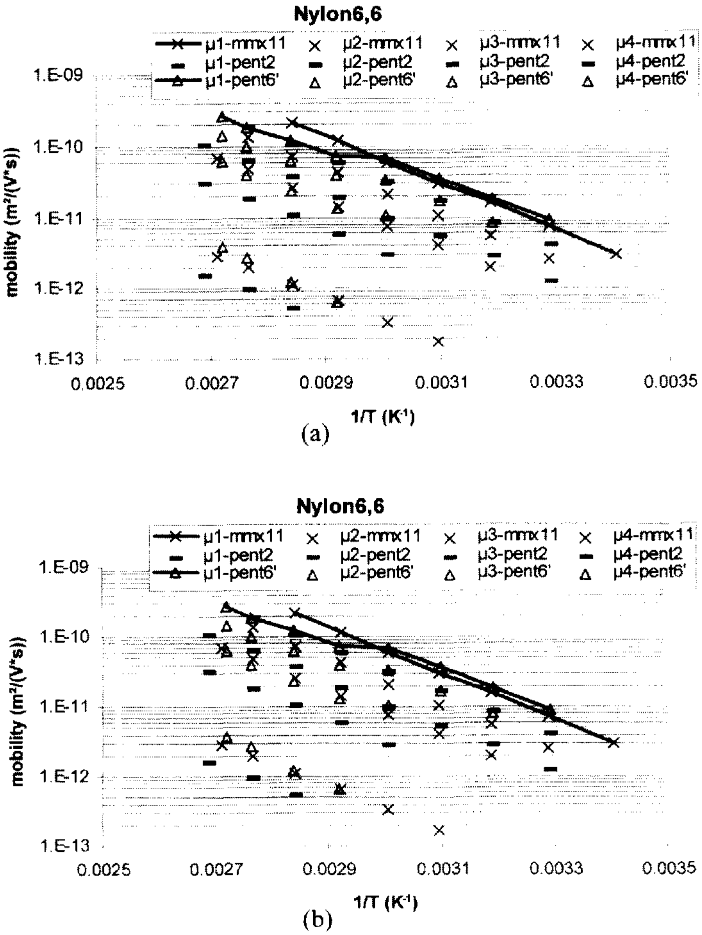


FIGURE 2 Comparison of ion mobility and concentration vs. 1/T in **pent2**, **mmx11** and **pent6'**, using Nylon6,6 as alignment layer.

Measurement results in the same three mixtures, using pyraline (another type of polyimide, abbreviated as PI2) as alignment layers supports the previous conclusion that ion1 in **pent6'** and **mmx11** comes from the same electrochemical dissociation equilibrium. These measurements also indicate that **pent6'** possesses a lower viscosity than **mmx11**.

2. Influence of Alignment Layer on the Ionic Contamination

From the above studies, certain relations have been found between the ions detected in the AFLC mixtures and the components present in the mixtures. This information is of use to LC manufacturers for achieving liquid-crystalline mixtures with a higher resistivity (and lower conductivity).

A question is now raised: do these ions originate from the dissociation of the neutral ionic species introduced with the liquid-crystalline components themselves or are they a result of the interaction between the alignment layer and the ions affiliated with the components? Previous investigations have suggested that the alignment layers play a significant role in contributing to the ionic contamination in nematic LCs, and that they may even be the major source of ionic impurities in some cases [8, 9]. In order to investigate the situation in AFLC mixtures **pent6'** was selected for further investigations in test cells with various alignment materials.

In figure3, ion mobility and concentration of **pent6'** are compared in test cells with two different types of polyimide (PI1 and PI2, respectively). Figure 3(a) clearly shows that the mobility of ion1 ($\mu 1$) in both samples is the same at all measured temperatures. Furthermore, figure3(b) shows that their activation energies of concentration are also identical (0.18 eV) even though the concentration of ion1 in the PI1 cell saturates at higher temperatures. Since the ions are moving in the same liquid-crystalline mixture, and the same temperature behaviour concerning their dissociation process has been measured, it is not unreasonable to speculate that they are the same ionic species present in both cells. Since the two cells are filled with the same mixture it is possible that these common ions originate from the AFLC mixture itself.

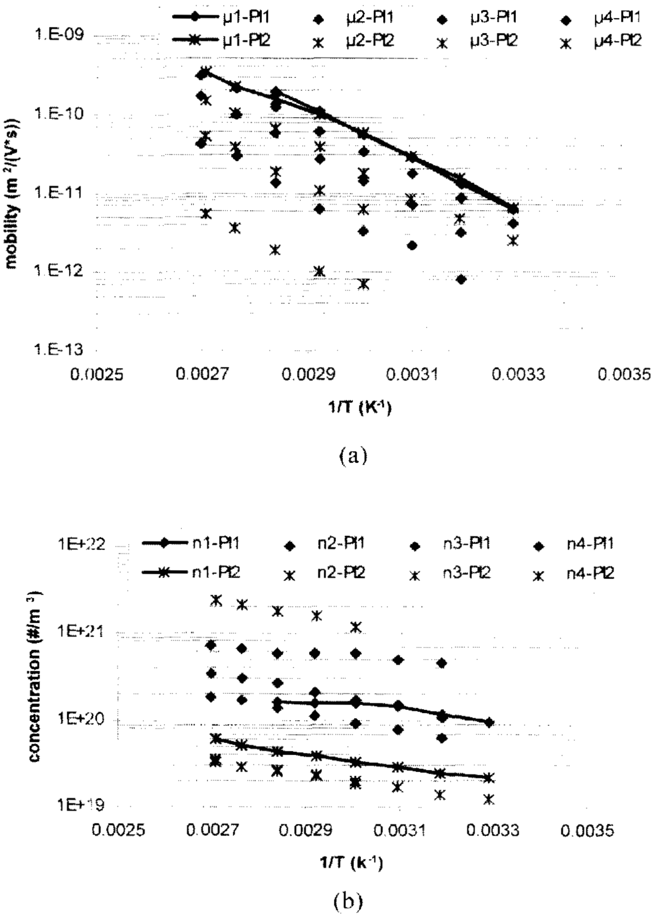


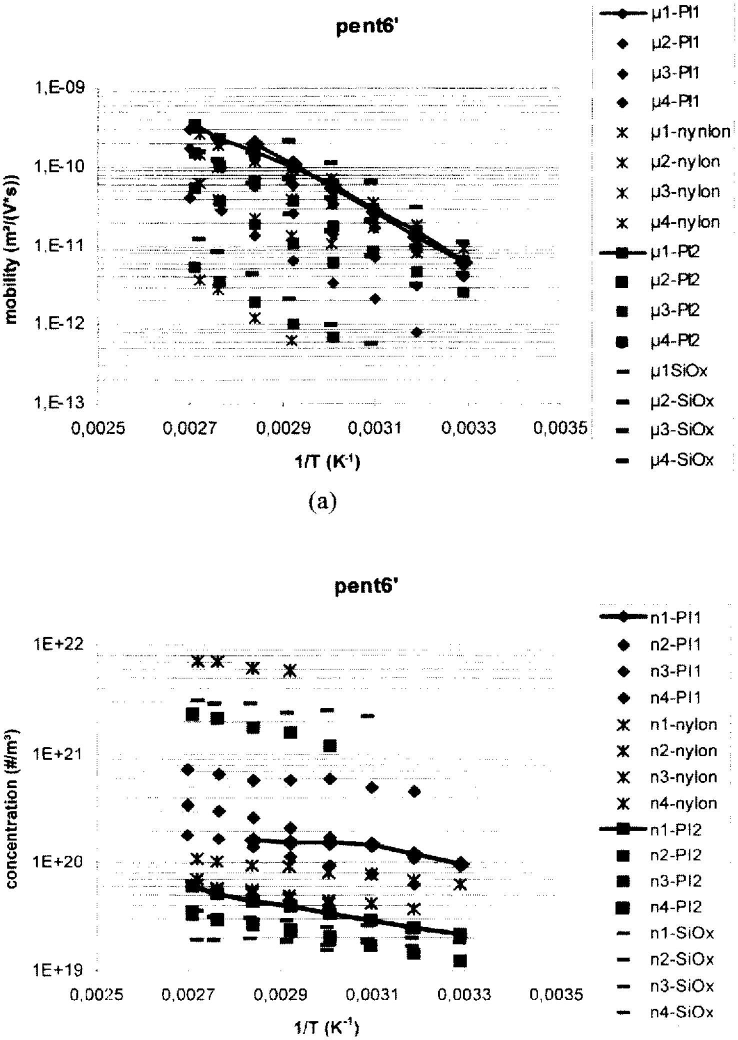
FIGURE 3 Comparison of ion mobility (a), and concentration (b), in two samples with similar alignment materials (PI1 and PI2).

Another possibility is that the two alignment materials have themselves introduced the same ionic species into the liquid crystal.

This hypothesis appears to be more logical since ion species that are unique in each sample have also been detected.

When we compare these results with those of the other test cells, with Nylon6,6 and SiO_x alignment layers (see figure 4), no common ion species are found to be present in all four samples. Therefore, the assumption that the ions originate from the AFLC itself can, in this case, be ruled out. The appearance of the two common ion species detected in the samples with PI1 and PI2 alignment layers may be explained by the fact that the two alignment materials are themselves similar in nature.

The postulation that the alignment layer is responsible for ionic contamination is further supported by comparing the ion concentrations in samples with different alignment layers, shown in figure 4(b). The ion concentrations in cells with PI2 are comparatively lower than those in the other cells, with regards to the "fast" ions (ion1, ion2 and ion3). From the application point of view, if only the influence of ions is taken into consideration, PI2 is the better choice of alignment layer from those studied. This is also consistent with the literature in which many authors have stated that the combination of the liquid crystal material and the alignment layer must be optimised that for each application [8, 10 - 12]. Therefore, we support the conclusion that the alignment layers are a principal source of ionic contamination in AFLC mixtures, which is a similar conclusion to that drawn for nematic liquid crystals. This is in spite of the fact that the mixtures prepared for these investigations were prepared under laboratory rather than industrial conditions. Similar results were obtained among the alignment materials investigated above using **mmx11** and **pent2**.



(a)

(b)

FIGURE 4 Comparison of ion mobility (a), and concentration (b), in two samples with different alignment materials.

CONCLUSIONS

In summary, by selecting three AFLC mixtures containing different types of components (chiral, racemic and achiral), and measuring the ion content in the mixtures at wide temperature ranges, we have succeeded in gaining information about certain relations between the components and the ions present in the mixtures. Furthermore, we have also found that the alignment layer plays a non-trivial role in contributing to the ionic contamination in AFLC mixtures which leads to the conclusion that the interaction between the alignment material and the LC is the principal source of ionic impurities in AFLCs.

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