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VOLTAGE DEPENDENCE OF SOME NEMATIC LIQUID CRYSTALS' ELECTRIC PROPERTIES

BAZI NEMATİK SIVI KRİSTALİN ELEKTRİK ÖZELLİKLERİNİN GERİLİME BAĞLILIĞI

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ABSTRACT

The nematic liquid crystals that are very important materials, using in the production of display systems and many technological applications. Due to this reason, it is important to investigate the physical and electrical properties of the nematic liquid crystals Voltage dependence of impedance, modulus and loss tangent of hexylcyanobiphenyl (6CB), octlycyanobiphenyl (8CB) pure and E7 coded nematic liquid crystal mixture were investigated at 0-20V DC volts range, room temperature and 1 kHz frequency. Although some electrical properties of mentioned liquid crystals exists in literature, comparison of these three liquid crystals has not been studied before. The real electric modulus of the 6CB and 8CB samples shows a small increase due to the increase in voltage and real modulus values of 8CB is higher than real modulus values of 6CB. The real modulus of the E7 nematic liquid crystal mixture decrease with increasing voltage. The imaginary electric modulus of the samples is decrease with voltage increase. The loss tangent values of the 6CB and 8CB samples decreases after a certain voltage value. Absolute impedance of the 6CB, 8CB samples have wavy behavior and the absolute impedance of E7 approaches zero at all voltage values.

Keywords: Nematic liquid crystals, 6CB, 8CB, E7, modulus, impedance.

ÖZET

Nematik sıvı kristaller, gösterge sistemleri üretiminde ve birçok teknolojik uygulamalarda kullanılan çok önemli malzemelerdir. Bu nedenden dolayı nematik sıvı kristallerin fiziksel ve elektriksel özelliklerinin araştırılması önemlidir. Hexylcyanobiphenyl (6CB), octlycyanobiphenyl (8CB) saf ve E7 kodlu nematik sıvı kristal karışımların empedans, modül ve kayıp tanjantı, oda sıcaklığında ve 1 kHz frekansında, 0-20V DC volt aralığında gerilime bağlı olarak incelenmiştir. Bahsi geçen sıvı kristallerin bazı elektriksel özellikleri ile ilgili bilgiler literatürde bulunmasına rağmen, literatürde bu üç sıvı kristallerin elektriksel özelliklerinin karşılaştırması ile ilgili bir çalışmaya daha önce rastlanmamıştır. 6CB ve 8CB numunelerin gerçek elektrik modülü gerilimdeki artıştan dolayı küçük bir artış gösterir ve 8CB gerçek modül değerleri 6CB gerçek modül değerlerinden daha büyüktür. E7'nin gerçek modülü ise gerilim artması ile azalmaktadır. Numunelerin sanal elektrik modülü voltaj artışı ile azalır. 6CB ve 8CB numunelerin kayıp tanjant değerleri, belirli bir voltaj değerinden sonra azalmaktadır. 6CB ve 8CB numunelerin mutlak empedansı dalgalı davranışa sahiptir ve E7 nin mutlak empedans değeri bütün voltaj değerlerinde sıfıra yaklaşmaktadır.

Anahtar Kelimeler: Nematik sıvı kristaller, 6CB, 8CB, E7, modül, empedans.

INTRODUCTION

Thermotropic liquid crystals are mesophase between the crystalline solid and isotropic liquid. Some organic substances pass through solid, mesopases as semectic, collesteric, nematic liquid crystals (LC's) and isotropic liquid phases due to increase in temperature (Bahadur, 1990; Vill, 1992). Nematic LC's are very important materials for display systems. Due to these important features, LC's have a wide range of applications in technology (Shen & Dierking, 2019). They are used for television, computer, machines display systems, electro-optic filters-lens (Lee, Gau, & Chen, 2005), holography (Chen & Brady, 1992), digital data storage (Matharu, Jeeva, & Ramanujam, 2007) and biosensor.

Due to the increasing importance of liquid crystals, many theoretical as Maier-Soupe and Mean Field theory (Özğan & Keskin, 1995; Wulf, 1976) and experimental researches (Eskalen, Kerli, & Özğan, 2017; Gupta & Kumar, 2019; Nafees, Kalita, & Sinha, 2019; Nimmy, Cherumannil Karumuthil, & Varghese, 2019; Okumus, 2013; Özğan & Okumuş, 2011; Ozgan, Yazici, & Ates, 2011; Sharma, Malik, Dhar, & Kumar, 2019) are carried out. Different types of liquid crystals are needed for different applications. This need is achieved by synthesizing new liquid crystals, mixing in two or more LCs, polymer, nano particles or dyes (Mahalingam, Venkatachalam, Jayaprakasam, & Vijayakumar, 2016; Okumuş, Özğan, Kırık, & Kerli, 2016; Okumuş, Özğan, & Yılmaz, 2014). The physical properties such as thermal, optical, dielectric and optical anisotropy and structural properties of two or more liquid crystal mixtures is investigated (Eskalen, Okumuş, & Özğan, 2019; Eskalen & Özğan, 2014; Özğan; Shiju et al., 2017). Thermal, electro-optical, properties were investigated by mixing zinc oxide, gold, graphene oxide nanoparticles and dyes in nematic liquid crystals (Eskalen, Özğan, Alver, & Kerli, 2015; Eskalen, Özğan, Okumuş, & Kerl, 2019; Okumuş, Eskalen, Sünkür, & Özğan, 2019; Özğan, Eskalen, & Tapkıranlı, 2018; Ye et al., 2016).

Although some electrical properties of 6CB, 8CB and E7 nematic liquid crystals exists in literature, comparison of these three liquid crystals has not been studied before. In this work, voltage dependent some electrical properties as modulus, impedance and lost tangent of hexylcyanobiphenyl (6CB), octylcyanobiphenyl (8CB) and E7 coded mixture nematic liquid crystals is examined under 1 kHz frequency from 0-20V DC volts at room temperature.

MATERIAL AND METHOD

The 6CB and 8CB nematic liquid crystals used in the present study was obtained from Sigma-Aldrich company. The E7 coded eutectic mixture nematic liquid crystal was purchased from Faculty of Advanced Technologies and Chemistry Military University of Technology (Poland). Compose of four different nematic liquid crystals The E7 nematic liquid crystal was obtained by adding different proportions of four different nematic liquid crystals. The E7 liquid crystal compose of 5CB, 7CB, 8OCB and 7CT with proportions 51%,25%,16% and 8% respectively. The molecular structures of the nematic liquid crystals used in this study are shown in Figure 1.

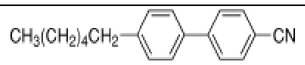
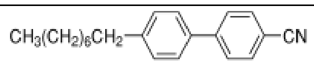
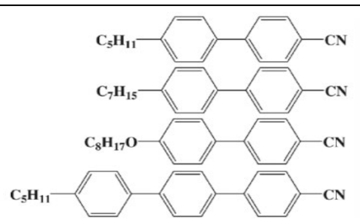
Name	Molecular structure
6CB	
8CB	
E7 Mixture	

Figure 1. The Molecular Structures of the 6CB, 8Cb and E7 Nematic Liquid Crystals

The planer alignment LC cells with cell gaps 8 µm and 1 cm^2 active area were purchased from Instec, Inc USA. To measurement the electrical properties of the 6CB, 8CB and E7 nematic liquid crystal samples were filled using capillarity method in indium tin oxide (ITO) cells.

Voltage dependence of the modulus, impedance and lost tangent of the 6CB, 8CB and E7 nematic liquid crystal samples were performed by HP 4194A Impedance Analyzer under 1 kHz frequency from 0-20V DC volts at room temperature.

RESULTS and DISCUSSION

The complex electric modulus can be a significantly powerful tool for analyzing dielectric behavior of some material. The complex electric modulus (M^*) is defined as the inverse of the complex dielectric constant (ε^*) and is represented as;

$$M^* = (\varepsilon^*)^{-1}$$
$$M' + iM'' = (\varepsilon' + i\varepsilon'')/(\varepsilon'^2 + \varepsilon''^2) \tag{1}$$

Where M' and M'' are the real and imaginary parts of the electric modulus; ε' and ε'' are the real and imaginary parts of the dielectric constant respectively.

The variation of the real electric modulus of the 6CB, 8CB and E7 samples depend on voltage is shown in Figure 2. The Figure 2 is obtained between 1-20V DC voltage range at 1 kHz frequency and the room temperature.

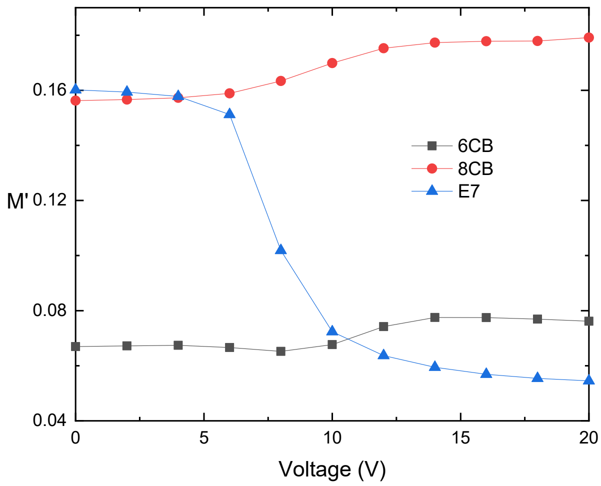


Figure 2. The Real Electric Modulus of The 6CB, 8CB and E7.

The real electric modulus of the 6CB and 8CB samples have a behavior as fixed at low voltages, then they increase with increase in voltage. The values of 8CB modulus are higher than 6CB modulus at all voltages. The values of E7 modulus are big at low voltages and they are small at high voltages. E7 modulus has a damping of around 7 volt.

The variation of the imaginary electric modulus of the 6CB, 8CB and E7 samples depend on voltage is shown in Figure 3. The Figure 3 is obtained between 0-20V voltage range at 1 kHz frequency and the room temperature. The imaginary electric modulus of the 6CB and 8CB samples have a behavior as fixed at low voltages, then they decrease with increase in voltage. The imaginary electric modulus value of 8CB liquid crystal is greater than 6CB and E7 modulus value at all voltages. The values of E7 modulus have a wavy behavior with increase in voltage.

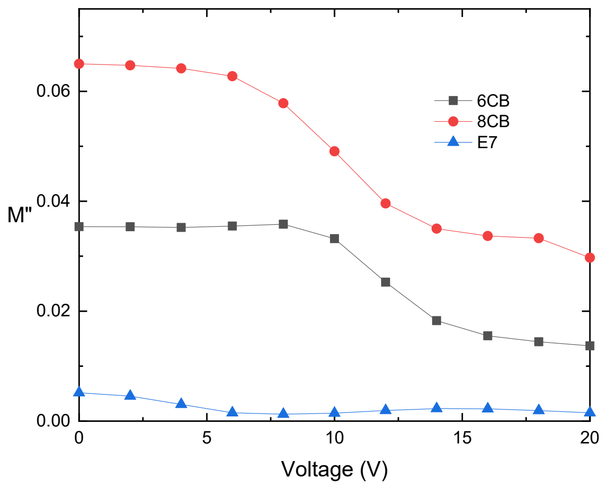


Figure 3. The Imaginary Electric Modulus of the 6CB, 8CB and E7.

The imaginary part of the dielectric constant is known as the loss tangent and calculated by the equation;

$$\varepsilon'' = \varepsilon' tan\delta \quad (2)$$

where $\delta = 90 - \phi$ and ϕ is the phase angle. Variation the loss tangent($tan\delta$) of the 6CB, 8CB and E7 samples with voltage are given in Figure 4.

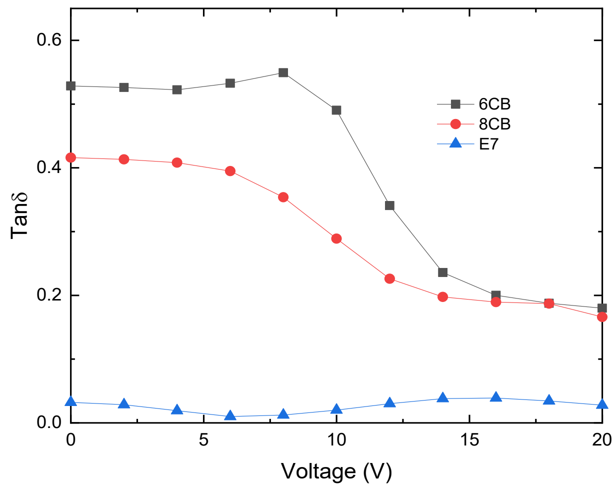


Figure 4. The Loss Tangent of the 6CB, 8CB and E7.

The loss tangent of the 6CB and 8CB samples have a behavior as fixed at low voltages, then they decrease with increase in voltage. The loss tangent value of 8CB liquid crystal is greater than 6CB and E7 modulus value at all voltages. The values of E7 loss tangent are low and having a wavy behavior with increase in voltage.

The variation of the impedance of the 6CB, 8CB and E7 samples depend on voltage is shown in Figure 5. The Figure 5 is obtained between 1- 20V voltage range at 1 kHz frequency and room temperature. Absolute impedance of 6CB sample has wavy behavior ranging from 108-116 kΩ. Absolute impedance of 8CB sample increases with increase in voltage from 250-270 kΩ. The impedance value of the E7 liquid crystal is zero for all voltages at 1kHz frequency.

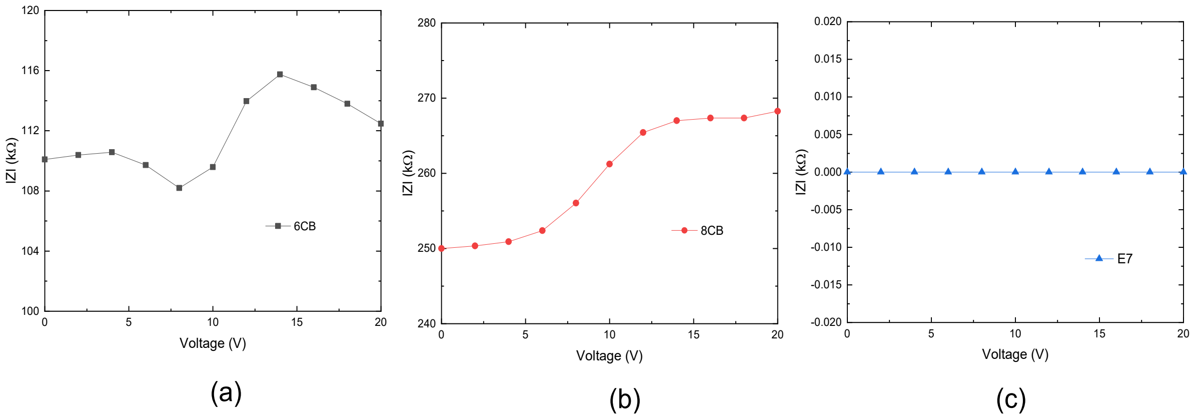


Figure 5. The Variation of Impedance with Voltage at 1kHz Frequency a) 6CB, b) 8CB and c) E7.

CONCLUSION

The nematic liquid crystals are used display systems and many technological applications. Voltage dependence of the real and imaginary modulus, impedance and lost tangent of hexylcyanobiphenyl (6CB), octylcyanobiphenyl (8CB) and E7 coded nematic liquid crystals as have been investigated under 1 kHz frequency from 0-20V DC volts at room temperature. The 6CB and 8CB real electric modulus have a behavior as fixed at low voltages, then they increase with increase in voltage. The 8CB modulus are higher than 6CB modulus at all voltages. The modulus of E7 is high at low voltages and getting decrease with increasing voltages. The imaginary electric modulus of the 6CB and 8CB samples have a behavior as fixed at low voltages, then they decrease with increase in voltage. The 8CB imaginary electric modulus value is greater than 6CB and E7 modulus value at all voltages. The E7 modulus have a wavy behavior. The loss tangent of the 6CB and 8CB samples have a behavior as fixed at low voltages, then they decrease with increase in voltage. The 8CB loss tangent value is greater than 6CB and E7 modulus value at all voltages. The E7 loss tangent are low and having a wavy behavior. 6CB absolute impedance has wavy behavior ranging from 108-116 kΩ. 8CB absolute impedance increases with increase in voltage from 250-270 kΩ.

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