Electro-Optical Properties and Effect of BaTiO$_3$ of Polysiloxane

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Abstract: In this study a series of polysiloxane based side chain liquid crystal polymer in which the molecular weight is systematically varied are studied in this research use one molecules weight with adding ratios five of BaTiO$_3$ nanoparticles, the consequence of the composite structure for a side-chain liquid crystal polymer, the polymer backbone which made up of units with relatively low polarizabilities that optical signal is particularly sensitive to the former and not to the latter, unless variations in the chain orientation are coupled completely through the mesogenic side chains. The state of orientational order in these polymers is evaluated through the use of infra-red spectroscopy this is used together with the threshold voltage result for testing the theory as well as studying the effect of gold nanoparticles on the orientational order parameter (S), switching voltage and response times.

Key words: Barium titanate, nanoparticles, BaTio$_3$, polysiloxane, liquid crystal polymers, response

INTRODUCTION

The name "Liquid Crystals" during the past decade, coined and it has been used in many applications (Dunmur and Sluckin, 2011).

The discovery of liquid crystallinity by Fridrich Reinitzer (Dunmur and Sluckin, 2011; Collings and Hird, 1997). He observed material melted at 145.5°C into a cloudy fluid which upon further heating to 178.5°C became clear. He did not know what the matter was so, turned for help to the German Physicist Otto Lehmann. Who had developed a polarizing microscope (Brown and Wolken, 1979). Lehmann solved the Reinitzer's puzzle and confirmed that the cloudy liquid had a unique kind of order and in 1890 Lehmann coined the name "Liquid Crystals" (Al-Ammar, 2010).

Germans researchers Vorlander, Klepl and Emil Fischer started in order to get liquid crystal polymers contains long chains (Al-Ammar and AL-Maamori, 2014), already obtained long chains but did not realize their liquid crystalline character. Emil Fischer gave to Vorlander some samples prepared by his father Emi and vorlander found that they were liquid crystalline. Liquid crystalline polymers can be classified into main chain, side chain and combined. This classification is based on the place of the polymer where the mesogenic is inserted, i.e., within the main chain as side groups or both within the main chain and as side groups (Mitchell *et al.*, 2005) side chain liquid crystal polymers are a composite from of macromolecule built up from three basic types of molecular unit. These are the polymer backbone, the
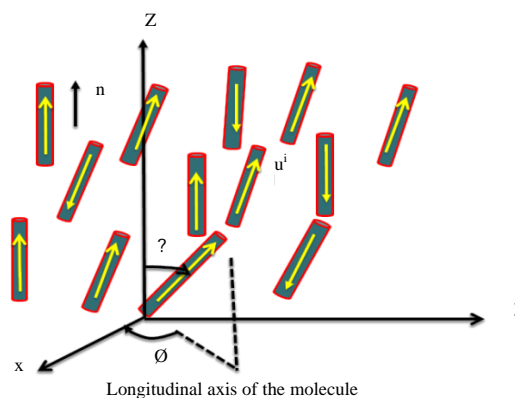

Fig. 1: Orientation (θ, $\emptyset$) relative to axes (x-z)

mesogenic units and the coupling chains which link the mesogenic unit to the polymer chain (Allen *et al.*, 1992) to quantify just how much is present in a material an order parameter (S) in defined. S describes the orientational order of liquid crystalline material, allowing for the individual orientational deviation of the molecules from the director which represents the average over the collection. Typically, S ranges from 0.3-0.9 depending on the temperature with a value of unity for perfect order traditionally (AL-Ghazali, 2015) (Fig. 1).

To measure the regularity in the liquid crystal molecules in relation to ($\hat{n}$) use orientational order parameters ($\hat{s}$) where Russian scientist Tsvetkovt 1942 San *et al.* enter this term and which can calculate using the following formula:

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$$\bar{S} = \left\langle \frac{3}{2} Cos^2 \theta - \frac{1}{2} \right\rangle$$

where, θ is the angle between the director and the long axis of molecule and brackets, denote to range all of the molecules in the sample, as shown Fig. 1 (AL-Ghazali, 2015; AL-Kizwini, 2015).

MATERIALS AND METHODS

Experimental set-up:
- MK 1000
- Hcs 402
- ALCT

The MK 1000 series temperature controller offers precision, accuracy and stability for temperature measurement and control. When coupled with heating/cooling equipment from instc, the MK 1000 can provide temperature control which is accyrate to 0.001°C. Two operation modes, keypad operation using the front panel of the controller or software control however pc as well as adjustable ramp (rate of heating/cooling) to user set temperature point. Programmable operation command set. Precisely controls temperature to 0.001°C option save temperature data to the computer. RTD thermistor or thermocouple, LC cell holders for many types of LC cells (AI-Ammar and Mitchell, 1992).

Temperature control system which includes MK 1000 controller, nitrogen container nitrogen pump (LN2-p) and hot-cooling stage. It features large viewing aperture dual pane window for better thermal isolation integrated aperture window defrost system gas purge sample chamber Inner lid for improved sample temperature uniformity vertical and horizontal mounting optional precision X-Y micropositionar for sample positioning submission software, wintemp, allows remote control from computer (Mitchell *et al.*, 1991).

ALCT liquid crystal measuring subsystem which includes ALCT-EO1 (referred as ALCT after), test cell holder, photo detector head and connecting cables. using this system with well-prepared LC test cell and proper method, user can measure mixture (Akram, 1993).

Liquid crystal mixture physical parameters:
- Dielectric constants, $\varepsilon\|$, $\varepsilon\perp$, $\Delta\varepsilon$
- Elastic constants, k 11 and k 33
- Threshold Voltage, Vth
- Polarization current, IP
- Viscosity γ_1

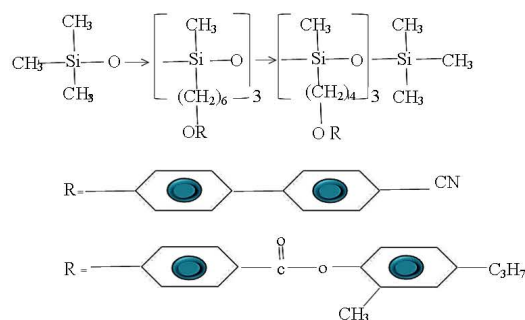Fig. 2: Picture of a device

Fig. 3: Structure of the polymer poly-siloxanes

Optical performance of LCD devices:

- Voltage-transmittance curve
- Switching speed, rise, falling time

Application software, WinLC, provides user an integrated tools to configure measurement setup, data collection, analysis and visualization

Optical test bench subsystem which includes white LCD light source, polarizer, rotatable hot-cooling stage holder analyzer and photo detector holder. This test bench allows user to (Fig. 2):

- Arrange polarizer and analyzer perpendicular and parallel to each other
- Test cell in side of the hot-cooling stage can be rotated in full 360° range
- Light source, polarizer and analyzer are installed in sealed dark sections to prevent the contamination of optical components
- Light sealable working chamber shields a way the room lighting (Drexler, 1989; AI-Ammar *et al.*, 1993)

Chemical structures: It is used in this research (Fig. 3)

RESULTS AND DISCUSSION

For getting on the switching voltage must be the transmitted light intensity decrement with increasing of the required voltage, so, it can be determined to complete switching and using one molecular weight with different addition from $BaTio_3$. The required voltage is increased with increasing of molecular weight MW this is due to viscosity and the degree of entanglement between the molecules are high. The same behavior was observed for the poly siloxane liquid crystal, although, there are some differences in the required voltage. The voltage for the complete orientation are identified, applied to the cell and calculates the required time to the occurrence of complete orientation. Where Fig. 4 show switch on-time on as function of the time for which the field is switched off before the measurement. Using the system and the method described in research, we have implemented a cyclic experiment in which we use the values of to determine when a steady state is reach. As mentioned in research the approach allows both and to be evaluated in order to achieve complete switching we typically applied (147-250) V (peak to peak) at a frequency of 500 Hz. The variation of the transmitted light intensity as a function of the applied voltage and the required voltage for each material in this research for complete switching. By reducing the temperature TNI the saturation states showed in these figures shifted, The required voltage for complete switching was increased in this case. The same behavior was observed for the materials in research although the materials in this research show larger differences between the required voltages for each material compared with the materials in research. Reproducible switching effect were observed at temperatures close to the nematic-isotropic transition temperature where the viscosity of the polymer is relatively low and measurement were made in the range of TNI-TNI -4 for matrials No. 1 and 2 and no response to the applied field had been observed for these materials in the smectic phase but measurements were made for the materials No. 3.4 and 5 in the range of TNI-TNI-5 at the same time reproducible swiching effects were observed in the smectic phase No. 3 show as a function of the time for respectively, each set of experiment were made at constant temperature. The experimental rrangement used for the static electro properties is similarly used for the dynamic electro-optic effects. Fields with a frequency of 500 Hz were employed for measurements. The static electro-optic properties are important because they contain important experiments between the threshold voltage Uc and curvature elastic constants Kii and their relationship to composition and temperature for the liquid
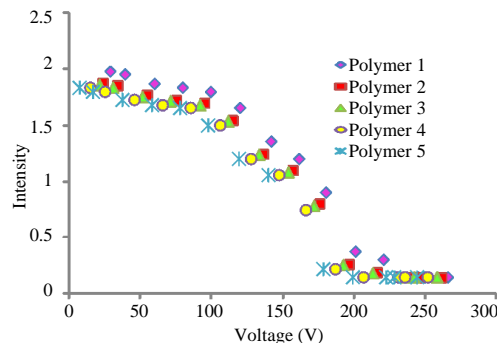

Fig. 4: Variation of the normalized intensity with voltage for polymer (1-5)

crystal copolymers. The results obtained for the material in this study are presented in Fig. 3. There is a marked reduction in the threshold voltage for both increasing temperature and reducing the molecular weight. In this series of polymers, Fig. 10 makes a direct comparison of the threshold voltage obtained in the nematic phase at a constant step below TNI for the series of polymers prepared. It is clear that there is an increase in the threshold voltage with increasing molecular weight. Indeed if the effect of the end-groups of the polymer chains are taken into account then the trend will be even more marked. It is emphasized that any dynamic effects arising from changing viscosity have been eliminated in the procedures outlined above. A few contributions have dealt with measuring the threshold voltage for polysiloxane polymers. Unfortunately, molecular weight data were not given, however, the threshold voltages reported are broadly similar to those found here. The marked increase of the threshold voltage with temperature follows similar dependence observed of the materials in which the mesogenic density along the polymer backbone is changed. It is noticeable that there is no sudden step in the threshold voltage at the transition from nematic to smectic phases for polymers 3. From a smectic phases the value of K11 is usually similar to that observed for the nematic phase, since, layer deformation is a relatively facile process. In the present study, using infrared dichroism to analyze the orientation ordering of the liquid crystalline side-chain polymers on prealigned cells also using the different molecular weights to obtain information about the orientation order of the head part, by observing the bands corresponding to the vibrations of the relevant functional groups where the major vibration absorption band C = N occur in the 2235 cm^{-1} region. The dependence of temperature with different molecular weight MW .Where of these liquid crystals. It is evident that the polymers with the highest MW exhibit
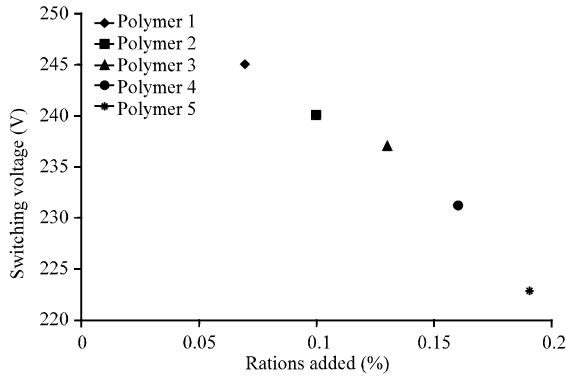
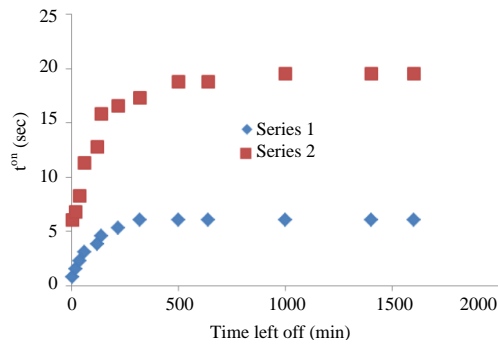Fig. 5: Switching voltages as a function of BaTiO$_3$ additives ratios of polymers

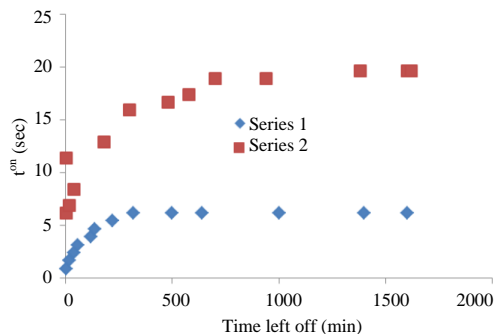Fig. 6: Switching-on (t^{on}) and time left off (t^{off}) at constant temperature below TNI for polymer 1

Fig. 7: Switching-on (t^{on}) and time left off (t^{off}) at constant temperature below TNI for polymer 2

Fig. 8: Switching-on (t^{on}) and time left off (t^{off}) at constant temperature below TNI for polymer 3

Fig. 9: Switching-on (t^{on}) as a function of the ratios added for polymer poly-siloxanes

Fig. 10: Switching-off (t^{off}) as a function of BaTiO$_3$ additives ratios using the method exponential decay of the transmitted light signal

the lowest reflect an incomplete monodomain formation due high viscosity, there was no experimental evidence to suggest that the measurements were anything other than true steady state values (Fig. 4-10).

In this study, research on the impact of the BaTiO$_3$ nanoparticles on electro-optical properties of liquid crystals polymer polysiloxan with side chain charity different molecular weight and while adding BaTiO$_3$
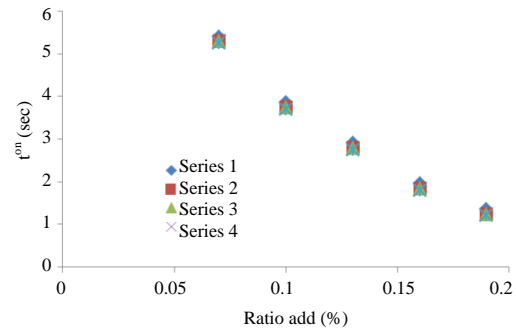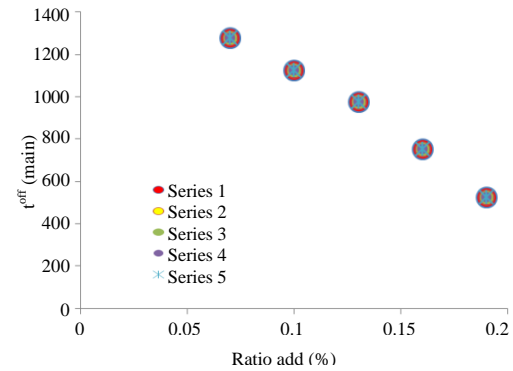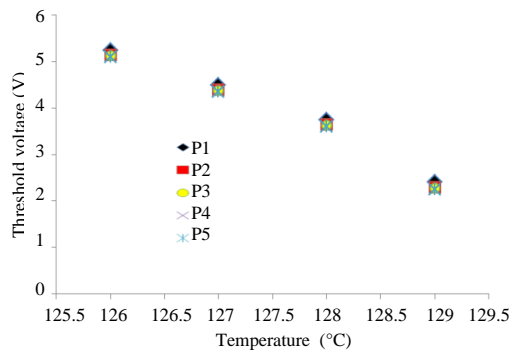
nanoparticles which is equal (0.07) to the polymer polysiloxane by side chain will research to increase the viscosity of the polymer as well as the researches of these nanoparticles added to increase connectivity polymer shed while an electric field and working to reduce the degree phase transition of polymer, this leads to reduce the switching times 9.

CONCLUSION

Lastly redeeming range Syano was chosen because of the interest in electrical characteristics of the polymer could variety it particularly suitable for applications and in any case add $BaTiO_3$ possible particles increase the density mesogen units which are linked with a series polymer to increase the contribution of dual-electrode parallel group Syano molecules rotation along the axis mesogen Group this in turn increases the dielectric anisotropy $\Delta\varepsilon$. It is found that decreasing the molecular weight lower, the phase transition temperature for high molecular weight polymers (materials No.1-3) a smectic phase is observed with very narrow nematic range though at low molecular weight (material No.4 and 5) only the nematic phase is observed. corresponding to the reduction of the phase transition temperature with decreasing the molecular weight of the polymers there is a market lowering of the glass transition temperature of value of the glass transition is found to increase as the molecular weight of the polymer is increased.

REFERENCES

AI-Ammar, K.H. and G.R. Mitchell, 1992. Electro-optical properties of liquid crystal copolymers and their relationship to structural order. Polym., 33: 11-21.

AL-Ghazali, A.N., 2015. Influence of the non-polar group on the properties of Polysiloxane side chain liquid crystal polymer. Master Thesis, University of Babylon, Hillah, Iraq.

Akram, A.M., 1993. Plastics Chemistry. University of Mosul, Mosul, Iraq,.

Al-Ammar, K. and Z. Al-Maamori, 2014. Effect of molecular weight on the static electro-optic properties of Polysiloxane liquid crystal Polemers. J. Babylon Univ. Pure Appl. Sci., 22: 1820-1828.

Al-Ammar, K., 2010. Switching properties in Siloxane-based Liquid-crystal elastomer. J. Kufa Phys., 2: 1-7.

Al-Ammar, K.H., M.J. Whitcombe and G.R. Mitchell, 1993. The effect of the molecular weight on the electro-optic properties of methacrylate-based side-chain liquid crystal polymers. Polym., 34: 2060-2064.

Al-Kizwini, S.F., 2015. Effect of gold nanoparticles on electro-optical properties of Polysiloxane liquid crystal polymer. Master Thesis, University of Babylon, Hillah, Iraq.

Allen, G., S.L. Aggarwal and S. Russo, 1992. Comprehensive Polymer Science. Pergamon Press, Oxford, England, UK., ISBN:9780080370712, Pages: 690.

Brown, G.H. and J.J. Wolken, 1979. Liquid Crystals and Biological Structures. 3rd Edn., Academic Press, Cambridge, Massachusetts, ISBN:9780121368500, Pages: 187.

Collings, P.J. and M. Hird, 1997. Introduction to Liquid Crystals: Chemistry and Physics. CRC Press, Boca Raton, Florida, USA., ISBN:9780203211199, Pages: 314.

Drexler, K.E., 1989. Engines of Creation: The Coming Era of nanotechnology. Anchor Press, New York, USA., ISBN:9780385199728, Pages: 298.

Dunmur, D. and T. Sluckin, 2011. Soap and Flat-Screen TVs: A History of Liquid Crystals. University of Oxford, Oxford, England, UK., ISBN:978-0-19-954940-5, Pages: 325.

Mitchell, G.R., F.J. Davis, W. Guo and R. Cywinski, 1991. Coupling between mesogenic units and polymer backbone in side-chain liquid crystal polymers and elastomers. Polymer, 32: 1347-1353.

Mitchell, G.R., S. Saengsuwan and S. Bualek-Limcharoen, 2005. Evaluation of ereferred orientation in multi component polymer systems using X-ray scattering perocedures. Proyress Colloid Polym. Sci., 130: 149-159.