

Influence of Ferroelectric Nanoparticles on Liquid Crystal Polymer Nanocomposites and Studying their Electro-Optic Response

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Abstract: In this study, research the effect of ferroelectric nanoparticles ($\text{Sn}_2\text{P}_2\text{S}_6$) on electro-optical properties of liquid crystalline polymer (consisting of a polymer polysiloxane with a side chain). Using five different molecular weights of molecular weight ranging from (1.7×10^6 - 3.1×10^7) and the percentage of material nanoparticles $\text{Sn}_2\text{P}_2\text{S}_6$ added equal to all molecular weights, it has been noted that the voltages increase with increasing molecular weight and when less the value of the intensity we get the operating voltage. Measured the optic response times (τ^{on}) when current is switched on (under the electric field) and has also been measured when the electric current is switched off (τ^{off}) (the electrical field is removed) by calculating the time period between two stages under the effect of the electrical field. The performance of the electro optical cells has improved after add the ferroelectric nanoparticles ($\text{Sn}_2\text{P}_2\text{S}_6$) would reduce the contribution of the dipole moment of the cyano-group parallel to the molecular long axis of the mesogeic unit. The density of mesogenic unit the few on polymer chaine and lead to a increases of dielectric anisotropic $\Delta\epsilon$ and therefore, improved backbone mobility for the system. The variation of the threshold voltage is measure at constant ladders below (nematic-isotropic) transition temperature T_{IN} for series of polymers.

Key words: $\text{Sn}_2\text{P}_2\text{S}_6$ nanoparticles, polymer polysiloxane, electro-optic properties, mesogeic, ferroelectric, unit

INTRODUCTION

Liquid Crystal (LC) is a state of aggregation that is intermediate between the crystalline solid and the amorphous liquid (Sivaramakrishna, 1992). Side chain liquid crystal polymers are a composite from of macromolecule built up from 3 basic types of molecular unit. These are the polymer backbone, the mesogenic units and the coupling chains which link the mesogenic unit to the polymer chain. A large number of side chain polymers in which the nature of these three components and their interconnection are varied have been created and studied (McArdel, 1989; Plate and Shibave, 1987). Liquid crystalline polymers can be well ordered into main chain, side chain and combined. This arrangement is founded on the place of the polymer where the mesogenic is place in the main chain as side groups or both within the main chain and as side groups (McArdle, 1989). Important to understanding such materials is a quantitative knowledge of the interactions between those 3 normally incompatible components segregation. It is now clear that the relatively short length of coupling chains will result in some interaction between the mesogenic unit and the polymer backbone chains. A variety of nematic phases have been proposed (McArdel, 1990).

This design principle of side-chain liquid crystal polymers are now well established (Mitchell *et al.*, 2005). The word polymer is derived from the classical Greek words poly meaning “many” and meros meaning “parts”, simply stated, a polymer is a long chain molecule that is composed of a large of repeating units of equal structure (Fried, 2014). Polymers consist of large organic molecules (macromolecules) of repeating small structural units (monomers) connected together in a process called polymerization. The doping of Liquid Crystals Polymer (LCPs) with nanoparticles has become a common method of improving their optical, magnetic, electrical and physical properties (Goodby *et al.*, 2014). For example, ferroelectric nanoparticles have to decrease the threshold voltage, a shorter switching time and higher the birefringence of nematics (Herrington *et al.*, 2010; Reznikov *et al.*, 2003). A composite material is a mixture of two or more materials, each of which retains its own distinctive properties. Generally, the term composite is applied to materials that are created by mechanical bonding two or more different materials together. The resulting materials have characteristics that are not characteristics of the component in isolation (Iftekhar, 1999). The LC is considered as a continuum and molecular details are ignored. Here, the frank free energy density ascribes distortions of a presumed oriented sample. Three

types of distortions, twist, splay and bend can be identified. The response of the system is then decomposed into terms based on elastic constants. Lehmann found that some liquid crystals behaved differently from others and that a liquid crystal can be aligned if in contact with a solid surface. This finding is most important for today's LC technology (Leslie, 1992).

We shall measure a series of polysiloxane-based side-chain liquid crystal homopolymers in which different molecular weights. The state of orientational in these polymers is obtained using infrared spectroscopy.

MATERIALS AND METHODS

The procedures followed for the construction of electro-optic cells with predefined director orientation in these investigations were similar to those developed for low molecular weight liquid crystal. Blazers Z20 tin oxide-coated glass slides were used for all electro-optic cells constructed in this research. This was easily cut and was sufficiently flat to allow the fabrication of cells with parallel plate separation to within a few seconds of arc. The glass was cut into plate of approximately 6 cm² area and etched using HCL acid with zinc metal powder as a catalyst to give a 2 cm² electrode surface. Each glass plate was then washed hand-by-hand in soap and water and cleaned in an ultrasonic bath for 30 min at 65°C. The plates were then rinsed in distilled water and dried in an oven for 20 min at 60°C. This treatment produced plates sufficiently clean for the surface treatment procedure which is the subject of the next section. In this research one technique was used to achieve uniform planer alignment of the liquid crystal director.

The cell electrodes were coated with a thin layer of polyimide precursor (consisting of a 5% solution of Rodehftal 322 (Rh one Poulenc chemical Ltd.) in dimethyl formamide), using a spin-coater running at 4,500 r.p.m these coated slides were heated in an oven for 30 min at 80°C. They were then rubbed at room temperature in a single direction with a cloth using controlled repeatable procedure, heated again for 30 min at 130°C. Finally, it will be putted for one hour at 200°C in the oven.

Experimental set-up: The most important 3 devices were used in this research for electro-optic measurement are:

- MK1000
- HCS402
- ALCT

The MK 1000 series temperature controller offers precision, accuracy and stability for temperature

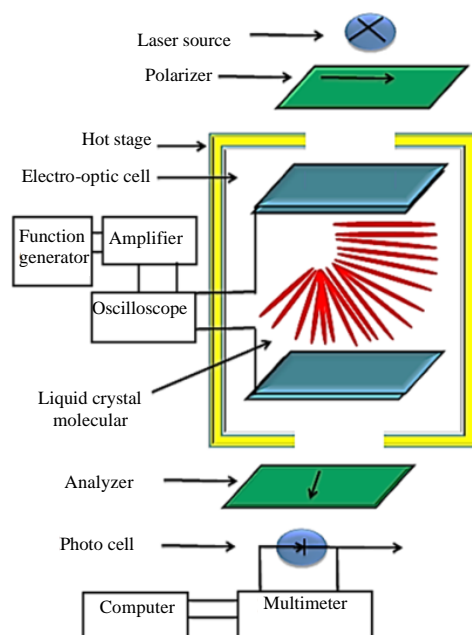


Fig. 1: Scheme of the work system

measurement and control. When coupled with heating/cooling equipment from instec, the MK 1000 can provide temperature control which is accurate 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 (Fig. 1-3).

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.

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.

Liquid crystal mixture physical parameters:

- Dielectric constants, $\epsilon_{||}$, ϵ_{\perp} , $\Delta\epsilon$
- Elastic constants, K11 and K33



Fig. 2: Picture of a device with optical test bench subsystem

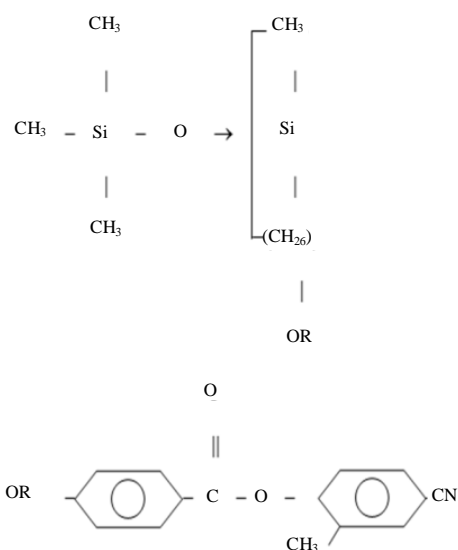


Fig. 3: Materials chemical structures

- Threshold voltage, V_{th}
- Polarization current, IP
- Viscosity γ_l

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:

- 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

RESULTS AND DISCUSSION

Figure 4 defined by which voltages necessary to make a complete switching and from these figures it can be seen is the variation of the transmitted light intensity as a function of the applied voltage and the required voltage for each material. 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. The required voltage is increased with increasing of molecular weight Mw this is due to viscosity η 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 voltages for the complete orientation are identified, applied to the cell and calculates the required time to the occurrence of complete orientation. Figure 5-9 show switch on-time on as a function of the time for which the field is switched off before the off measurement. Using the system and the method described in research, we have implemented a cyclic experiment in which we use the values of τ^{on} to determine when a steady state is reach. As mentioned in research the approach allows both τ^{on} and τ^{off} to be evaluated. In order to achieve complete switching we typically applied (143-240) 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. The measurement were made in the range of TNI-TNI-4 for materials No. 1 and 2 and no response to the applied field had been observed for these materials

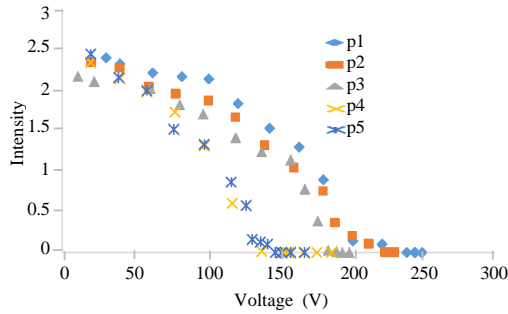


Fig. 4: Variation of the normalized intensity with voltage for polymer 1-5

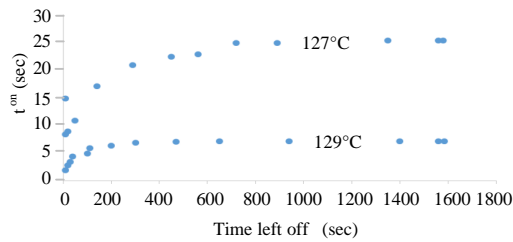


Fig. 5: Switching-on (τ^{on}) and time left off (τ^{off}) a constant temperature below TNI for polymer 1

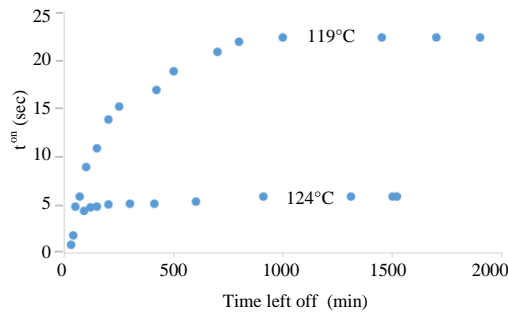


Fig. 6: Switching-on (τ^{on}) and time left off (τ^{off}) at constant temperature below TNI for polymer 2

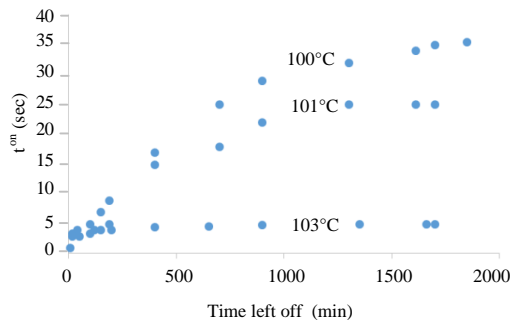


Fig. 7: Switching-on (τ^{on}) and time left off (τ^{off}) at constant temperature below TNI for polymer 3

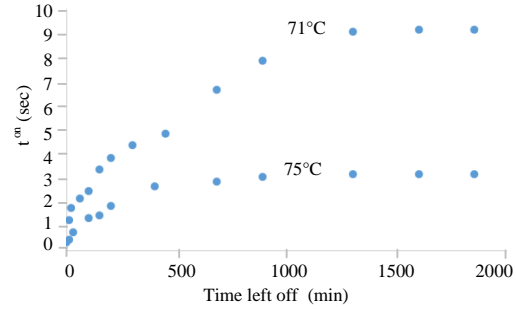


Fig. 8: Switching-on (τ^{on}) and time left off (τ^{off}) at constant temperature below TNI for polymer 4

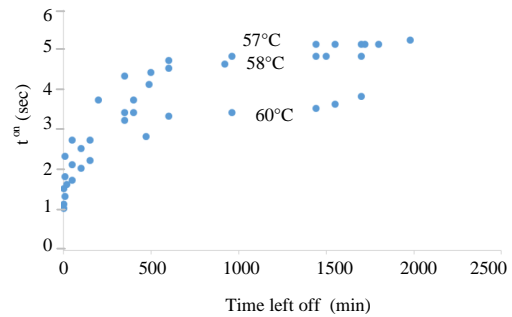


Fig. 9: Switching-on (τ^{on}) and time left off (τ^{off}) at constant temperature below TNI for polymer 5

in the smectic phase but measurements were made for the materials No. 3-5 in the range of TNI to TNI -5 at the same time reproducible switching effects were observed in the smectic phase No. 3 show δ_{on} as a function of the time for, respectively, each set of experiment were made at constant temperature. The experimental arrangement 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 electric-optic properties are important because they contain important experiments between the threshold voltage U_c and curvature elastic constants K_{ii} and their relationship to composition and temperature for the liquid crystal copolymers. The results obtained for the material in this study are presented in Fig. 10. There is a marked reduction in the threshold voltage for both increasing temperature and reducing the molecular weight. In this series of polymers, Fig. 11 makes a direct comparison of the threshold voltages 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

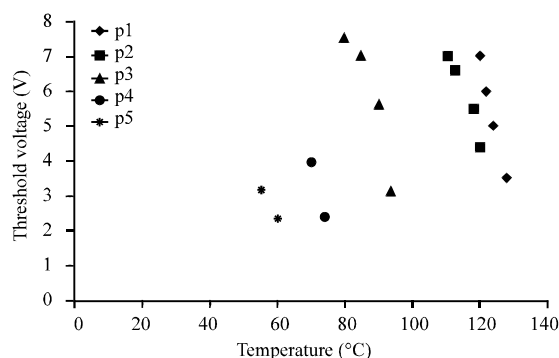


Fig. 10: Plots of the measured threshold voltages as a function of temperature

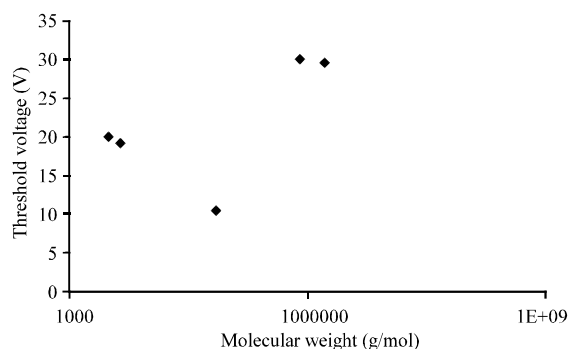


Fig. 11: A plots of the measured threshold voltages as a function of the molecular weight

arising from changing viscosity have been eliminated in the procedures outlined above. A few contributions have dealt with measuring the threshold voltage for polysiloxan 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.

This study has focused on the electro-optic properties of a series of polymers with differing molecular weight based on the polysiloxane backbone when adding $\text{Sn}_2\text{P}_2\text{S}_6$ nanoparticles which is equal 0.07) to the polymer polysiloxane with side chain. Nanoparticles will work to increase the viscosity of the polymer as well as the works of these nanoparticles added to increase connectivity

polymer shed when an electric field and working to reduce the degree phase transition of polymer, this leads to reduce the switching times (τ^{on} , τ^{off})

Variation of the degree of polymerization in this series of polysiloxan based side chain liquid crystal polymers has impact upon the phase behavior, the order parameter and upon the electro-optic properties. it is found that decreasing the molecular weight lower, the phase transition temperature for high molecular weight polymers (Material No.1-3) a smectic phase is observed with very narrow nematic range, however, at low molecular weight (Material No. 4 and 5) only the nematic phase is observed. Complementary to the reduction of the phase transition temperature with decreasing the molecular weight of the polymers there is a marked 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.

CONCLUSION

Finally redeeming range Syano was chosen because of the interest in electrical characteristics of the polymer could make it particularly suitable for applications and in any case add $\text{Sn}_2\text{P}_2\text{S}_6$ possible particles increase the density mesogen units which are connected with a series polymer to increase the contribution of dual-electrode parallel group Syano molecules torque along the axis mesogen group this in turn increases the dielectric anisotropy $\Delta\epsilon$.

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