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Characterization and morphology of titania in 5cb liquid crystal

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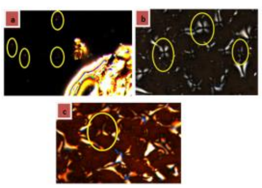
GRAPHICAL ABSTRACT



(a)5CB, (b) conc. 5 w/v% TiO_2/5CB (c) conc. 10 w/v% TiO_2/5CB at nematic-isotropic temperature

ABSTRACT

Nowadays, liquid crystals are widely used in electronic devices due to their unique properties. Conventionally, the alignment mode in liquid crystal displays (LCD) is parallel. There are still have unsettled issues such as low vision angle, low contrast, and image sticking of displays in the market. The performance characteristic of liquid crystals can be enhanced when doped with nanoparticles. In this study, 4-cyano-4'-pentyl biphenyl (5CB) was doped with titanium dioxide (TiO_2) to investigate the effect of nanoparticles to the properties of liquid crystals host. Two sets of concentrations of TiO_2, 5 and 10 w/v%, were characterized by Infrared (IR) and Raman spectroscopy as well as Polarized Optical Microscope (POM). The IR spectroscopy revealed the presence of functional groups in the compounds, which also indicates that both liquid crystal and nanoparticles are mixed physically since the IR spectra for both pure 5CB and doped with TiO_2 nanoparticles were the same. POM was captured the morphology and phase variance in different concentration of TiO_2/5CB. It shows the formation of Schlieren texture for both 5CB and doped with TiO_2 which signified the transition of nematic-isotropic phases, while Raman spectroscopy identified the fingerprint structure of 5CB and concentration of 10 w/v% TiO_2 in 5CB.

Keywords: Liquid crystal, 4-cyano-4'-pentabiphenyl (5CB), nanoparticles (NPs), titanium dioxide, hybrid materials.

1. INTRODUCTION

Liquid crystals (LCs) are an intermediate state of matter which properties are in between liquid and solid crystal [1]. There are many types of state that LCs can form, depending upon the amount of order in the material which can be employed with mechanical, magnetic or electric force. Liquid crystals are temperature dependent since they are hypersensitive towards the temperature. They will be form in solid if the temperature is too low and become liquid when the temperature is too high.

Nowadays, LC is important in our industry. Since LCs is materials with unique properties mainly due to the presence of partially ordered phases, the ability to form ordered domains is involved in many applications of LCs in electronic devices. The effect of doping of LC with nanoparticles (NPs) has been studied extensively. The performance characteristic of LCs such as electro-optical properties, memory effect and phase behaviour can be enhanced when doped with NPs. There are many types of NPs have been used in recent studied such as metallic, semiconducting, reffoelectric, carbon nano-tubes, dielectric and insulating to recognize LC nanocolloids [2,3].

LCD is one of the display technologies which allowed new development of mobile phones, hand-held games and portable computer [4]. The performance of LC devices is degraded due to the presence of impurity ions, for all modes used such as Twisted Nematic (TN), Hybrid Twisted Nematic (HTN), Super Twisted Nematic (STN), and Optically Compensated Bend (OCB) [5].

The conventional LCD used parallel alignment mode to achieve uniform alignment in liquid crystal. Unfortunately, they have a few weaknesses, such as narrow viewing angle, low contrast ratio and slow response time. Therefore, further studied was conducted to make vertical alignment mode in LCD since it can improve the defects and directly give good quality of LCDs. Recently, the LC-nanoparticles dispersion has been widely studied due to their intellectual and technical interest. The dielectric relaxation time constant of the LC-NPs suspension can be reduces when doping minute amounts of NPs into liquid crystal host. It also can reduce the response time of the LC cell effectively [6].

In this paper, the types of hybrid materials used were 4-cyano-4'-pentabiphenyl (5CB) liquid crystal and titanium dioxide (TiO_2) with concentrations 5 and 10 w/v%. Figure 1.1 shows the structure of 5CB.

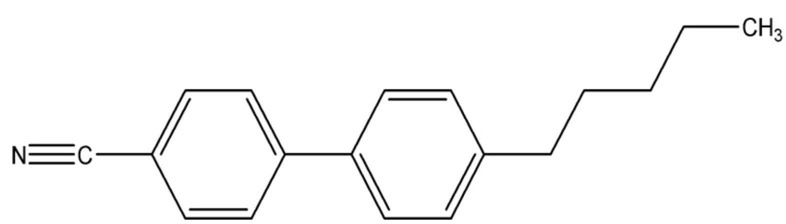


Figure 1.1 Chemical structure of 5CB

This work is important since it revealed the effect of nanoparticles to the properties of liquid crystals. Liquid crystal nanocolloids are mostly will give effect in terms of electro-optic and dielectric properties, memory effect, and screening effect. Besides that, when doping with small amount of NPs into the LC host can reduces the dialectric relaxation time constant of the LC-NPs suspension as well as reduces the response time of LC cell. This work also important due to determination of texture for liquid crystal nanocolloids and identify the presence of fingerprints spectrum. The aim of doing this study were to prepare LC nanocolloid by using 5CB and TiO_2 and to investigate the effect of NPs with LC by using IR and Raman spectroscopy, and as well as POM.

2. EXPERIMENTAL

2.1 Synthesis of liquid crystal nanocolloid

The technique to synthesize liquid crystal nanocolloid is by using self-assembly technique. 4-cyano-4'-pentylbiphenyl or known as 5CB was purchased from Sigma Aldrich Co. (USA). The suspension of 5CB doped with titania at various concentrations which were 5 and 10 w/v%.

2.2 Characterization of titania colloidal liquid crystal

Titania colloidal liquid crystal was characterized by using Attenuated Total Reflectance-Infrared (ATR-IR), brand Perkin Elmer. The texture of 5CB and doped with TiO_2 were capture by using LEICA Polarized Optical Microscope (POM). For nematic, nematic-isotropic and isotropic phases, the images were captured at 25.0°C, 35.0°C and 50.0°C respectively with holding time 1 minute for each temperature. The types of brand used for Raman spectrometer is HORIBA. Raman spectrometer used to identify the fingerprint present in the samples.

3. RESULTS AND DISCUSSION

3.1. Infrared Spectroscopy (IR)

The TiO_2 was doped in 5CB with concentrations 5 w/v% and 10 w/v%. Before the mixture being conducted by using polarizing optical microscope and Raman spectroscopy, it was investigated by using infrared spectroscopy, to find out physical mixing or changes of chemical bonds. The compound is mixed physically if only 5CB spectrum is present in the IR spectrum while mixed chemically if both TiO_2 and 5CB functional groups presents in the IR spectrum.

All light can be classified as electromagnetic radiation which consists of alternating magnetic and electric field [7]. It can be described classically by a continuous sinusoidal wave like motion of the electric and magnetic field. IR spectroscopy will be considered the electric field and neglect the magnetic component.

There were six peaks in the IR spectrum for 5CB. The C-H stretching occurs at 2955.81, 2927.87 and 2856.79 cm^{-1} while for C≡N, the frequency occur at 2226.16 cm^{-1}. At 1605.94 and 1493.59 cm^{-1} are both for C=C aromatic [8].

Figure 3.1 shows the IR spectra for 5CB, concentration 5 w/v% TiO_2 in 5CB and concentration 10 w/v% TiO_2 in 5CB. Since the IR spectrum for pure 5CB and doped with TiO_2 are same, it is proved that 5CB and TiO_2 are physically mixed and the chemical bonds did not have interrupted. The IR spectrum only shows the functional group that present in 5CB.

3.2. Polarized Optical Microscope (POM)

The morphology and phase variance of 4-cyano-4'-pentyl biphenyl or 5CB, and different concentration of TiO_2 nanopaticles in 5CB is revealed by using polarizing optical microscope (POM) by using heating and cooling process. The choose of TiO2 nanoparticles as guest dopant is due to its ability to used in applications such as catalysts, photocatalysts, pigments, and photovoltaic devices. Besides that, the electro-optic performance of LC system can be enhanced by the addition of TiO_2 nanoparticles. The trend of morphology has been studied by using 5CB, concentration 5 w/v% TiO_2 with 5CB, and 10 w/v% TiO_2 with 5CB. The range of temperature used to capture the image is between 25.0°C and 50.0°C.

Figure 3.2 shows the 5CB and doped with NPs at nematic phase. At ambient temperature, the nematic LC exhibits uniform colour throughout cell confirmed that the homogeneous alignment of the nematic molecules. When the insertion of NPs at 5 w/v%, some bright patches in the nematic matrix. These bright patches cover more regions when the concentration of NPs increased to 10 w/v%. The agglomeration of NPs starts when the doping of 5 w/v% of NPs and further change the orientation of the nematic molecules in the region of their surface which results in bright patches.

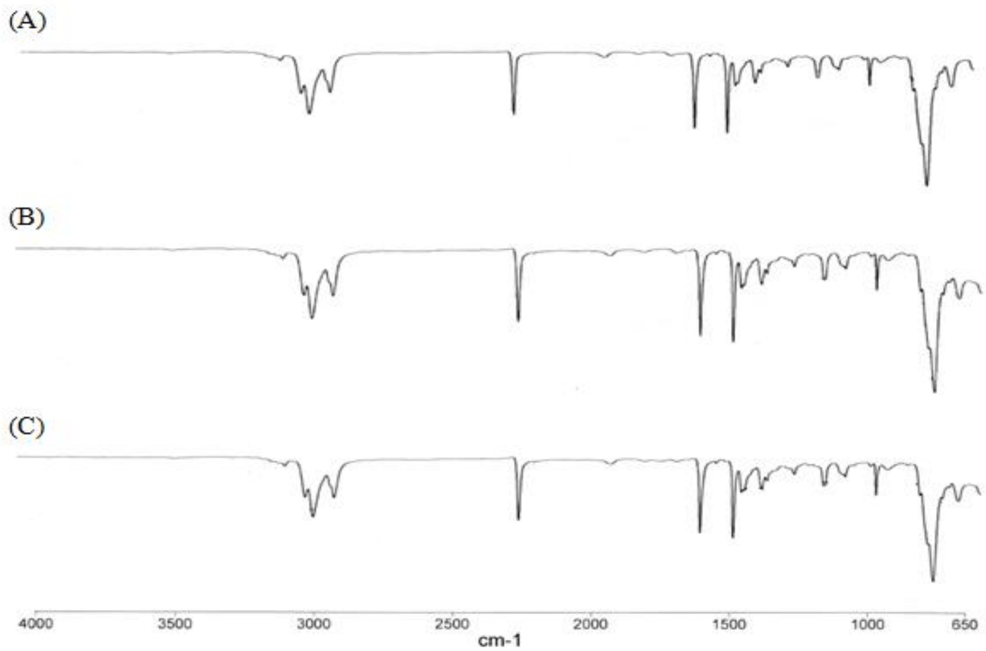


Figure 3.1 IR spectra for (A) 5CB, (B) concentration 5 w/v% TiO_2 in 5CB, (C) concentration 10 w/v% TiO_2 in 5CB

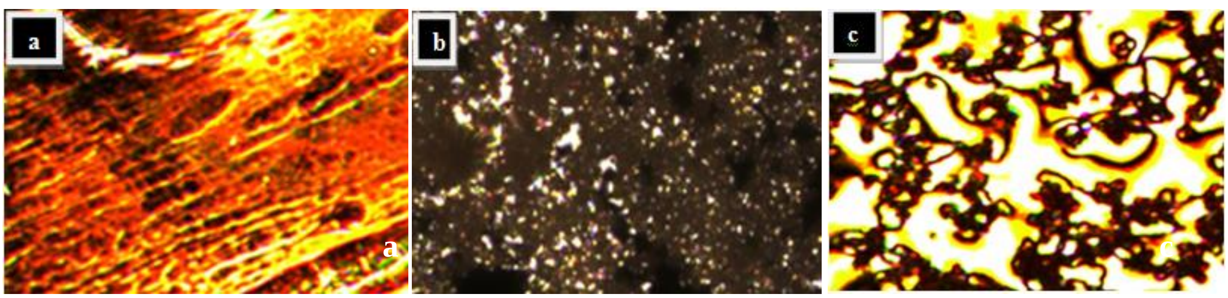


Figure 3.2 Nematic phase (a) 5CB (b) concentration 5 w/v% TiO_2 in 5CB (c) concentration 10 w/v% TiO_2 in 5CB

Figure 3.3 shows the 5CB and doped with NPs at nematic-isotropic phase. The samples were continuously heated to nematic-isotropic phase transition where around temperature at 35.0°C [9,10]. At this stage, the transition occurs rapidly as well as during the cooling process. The nematic-isotropic phase became domain. There were Schlieren texture formed for 5CB, concentration 5 w/v% and 10 w/v% of TiO_2 with 5CB. The yellow circles indicated Schlieren texture. The texture can be categorized by using point of singularities from which two ($s = \pm {}^{1}/_{2}$) or four dark ($s = \pm 1$) brushes radiate [11]. The dark regions of the texture indicates the disclination of the texture which would occurred when the orientations of local directors whether it is parallel to the polarizer or analyzer. The Schlieren texture formed at the earlier stage of cooling process.

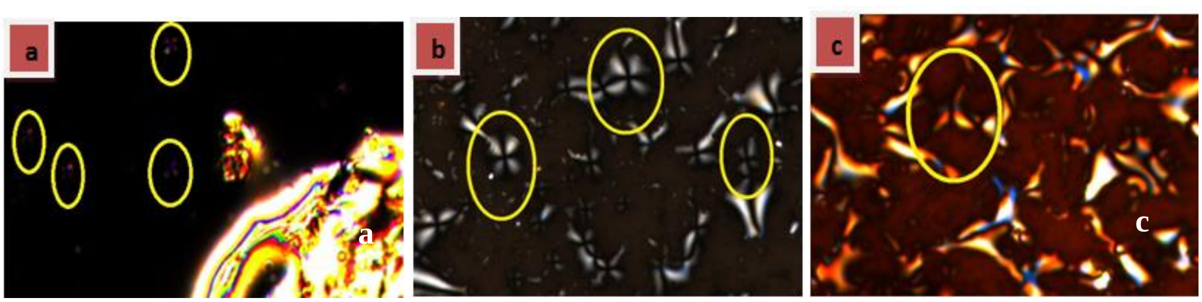


Figure 3.3 Nematic-isotropic phase (a) 5CB (b) concentration 5 w/v% TiO_2 in 5CB (c) concentration 10 w/v% TiO_2 in 5CB

Figure 3.4 shows the 5CB and doped with NPs at isotropic phase. At this temperature, the isotropic transition became domain. 5CB shows dark region at this stage due to the incident light that could not be rotated by the isotropic medium across the crossed polarizers. For the insertion of 5CB with nanoparticles, the regions are not totally dark due to the presence of the nanoparticles.

Figure 3.4 Isotropic phase (a) 5CB (b) concentration 5 w/v% TiO_2 in 5CB (c) concentration 10 w/v% TiO_2 in 5CB

After reached the isotropic phase, the samples were continued by cooling process. The temperature was cooled to nematic phase. During the cooling process, there was formation of Schlieren texture at the earlier stage of cooling process. The isotropic-nematic transition is domain. When continuously cooling, the nematic phase is reached.

3.3. Raman spectroscopy

Raman spectroscopy is a spectroscopy technique, where used to observe the vibrational, rotational, or other low-frequency modes in a system. It also used to determine the fingerprint where the molecules can be identified. In this experiment, the excitation wavelength used was 532nm. The samples used were 5 CB and concentration of 10 w/v% TiO_2 in 5CB.

There were five intense vibration bands that present in the spectrum for 5CB [12]. For 1179.14 cm^{-1}, the vibration band intensity was medium. The band shows that there was C-C stretching present in the compound. For 1281.52 cm^{-1} and 1522.28 cm^{-1}, the vibrational band is approved the presence of C-H deformation in the outer phenyls and the aromatic of C-C stretching, which is asymmetric, respectively. At 1602.63 cm^{-1}, there was a strong intense band occurred which represent the C-C stretching of aromatic ring, symmetry and at 2222.68 cm^{-1}, it also an intense band occurred represent the formation of C≡N stretching. Since all the Raman shift represents the bonds exists in 5CB, it is confirmed the sample is 5CB.

For concentration of 10 w/v% of TiO_2 in 5CB, there were the formation of peaks that represent the formations of 5CB and TiO_2 NPs. The four peaks at 141.08, 392.97, 513.92 and 634.49, it confirm that the major form of TiO_2. For peaks at 1179.14, 1283.06, 1604.08, and 2224.01 cm^{-1} represents the formation of 5CB, where indicating the formation of C-C stretching, C-H deformation in the outer phenyls, C-C stretch of aromatic ring, and C≡N stretching, respectively. Since the entire Raman shift represents the types of bonds in the sample, it confirmed the sample has both 5CB and TiO_2 NPs. Figure 3.5 shows the Raman shift for pure 5CB and 10 w/v% TiO_2/5CB.

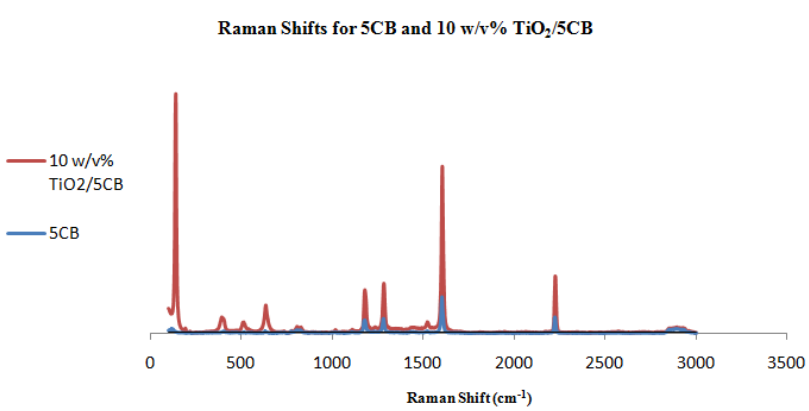


Figure 3.5 Raman shift for pure 5CB and 10 w/v% TiO_2/5CB

4. CONCLUSION

The uses of LCs in electronic devices give significance benefits. This is due to the presence of partially ordered phases, indirectly, the ability to form ordered domains is involved in many applications of LCs in electronic devices. The aim of this study is to prepare LC nanocolloid by using 5CB and TiO_2 and to investigate the effect of NPs to the properties of LCs host. By using IR spectroscopy, the functional groups in pure 5CB and doped with 5CB had been revealed. From the IR spectra, it indicates that both LC and NPs were mixed physically due to the formation of peaks on spectra for both pure 5CB and doped with NPs were the same and the chemical bonds are not interrupted. POM had been used to capture the morphology and phase variance in different concentration of TiO_2/5CB. From the results, there were the formation of Schlieren texture for both 5 CB and doped with NPs at the nematic-isotropic transition, while for Raman spectroscopy, the fingerprint structure of 5CB and concentration of 10 w/v% of TiO_2 in 5CB had been identified.

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