Journal of Molecular Liquids 219 (2016) 631–636

Contents lists available at ScienceDirect

Journal of Molecular Liquids

journal homepage: www.elsevier.com/locate/molliq

Effects of chirality on optical and electro-optic behavior of nematic liquid crystals doped with functionalized silver nanoparticles

Manju Middha [a], Rishi Kumar [a,b,*], K.K. Raina [a]

[a] School of Physics and Materials Science, Thapar University, Patiala 147004, India
[b] Department of Applied Physics, Maharaja Ranjit Singh State Technical University, Bathinda 151001, India

ARTICLE INFO

Article history:
Received 9 March 2016
Accepted 23 March 2016
Available online xxxx

Keywords:
Chiral molecular liquids
Nematic liquid crystals
Surface plasmons
Thermo-optical hysteresis

ABSTRACT

A comprehensive study based on the impact of chirality on the molecular organization in nematic liquid crystal matrix doped with dodecanethiol-capped silver nanoparticles (Ag NPs) was conducted. The temperature dependent morphological behavior was investigated by polarized optical microscopy. The thermo-optic and electro-optic switching behavior of the liquid crystalline helix was confirmed with an active chiral dopant. An improvement in the dielectric behavior in the frequency range of 50 Hz to 1 MHz was recorded by the induction of chirality in the matrix of the Ag NPs doped nematic medium confined in planar boundary conditions. A lowering of the threshold of Freedericksz transition and a nearly tenfold rise in dielectric constant with temperature was recorded. A pronounced surge in photoluminescence in addition to an irreversible memory was also observed in the chiral medium. Accredited with such prominent optical and electro-optical properties, silver nanoparticles doped chiral liquid crystals find a promising future as the materials of choice for optical sensors and electro-optic liquid crystal devices with memory.

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1. Introduction

Chirality in liquid crystals is a fascinating molecular phenomenon with a potential to induce new phases like Blue phase, Focal conic phase, TGB phase and many others with the helical ordering of molecules [1]. The pitch of the helix being sensitive to all sorts of external stimuli is the crux of the versatility in chiral phases. The nanoparticles induction in chiral media has resulted in a number of effects leading to improvisation and invention of new devices of display market and biomedical use. The appropriate dispersion of chiral dopant molecules in nematic liquid crystals (NLC) attunes them to design a material suitable for developing optical devices [2,3]. Owing to their tremendous applications and relatively simpler liquid crystal structure, nanoparticles doping was earlier limited to nematic liquid crystals only. Recently cholesteric liquid crystals (CLC) have been used for the doping of NPs. Doped CLCs showed improvements in optical response and driving voltage [4]. There are many reports [5–7] of effects like stabilization of the blue phase, enhancement in photoluminescence and the emergence of reversible and irreversible memory with doping of nanoparticles in chiral liquid crystals, some of which were rarely seen in nematics.

The pitch (sensitive to the external stimuli) dependent properties of chiral molecules combined with the shape and size dependent versatile properties of the nanoparticles have genuine prospects in the field of active plasmonics, fabrication of functional materials and dielectric spectroscopy [8–10].

Although a lot of work has been done in the past decade in the field of nanoparticles doping in nematic and ferroelectric liquid crystals, but a comparative study based on the effects of chirality in nanoparticle-doped achiral systems has been underexplored. Our purpose of carrying out the present study was to explore the prospective and potentiality of bringing helical symmetry in a nematic system characterized by uniaxial anisotropic molecules. It seemed fascinating about how in the presence of the incident electromagnetic field, the supramolecular structure would interact with the surface plasmons generated by the silver nanoparticles in comparison to the less orderly nematic molecular organization.

We, in the present case, have doped the same amount of dodecanethiol functionalized silver nanoparticles (Ag NPs) in the nematic as well as induced chiral nematic liquid crystals and compared their optical, morphological, electro-optic behavior by confining them in identical boundary conditions with antiparallel aligned liquid crystal cells of 5 μm thickness.

2. Experiment

We used ZLI-4151 [M/s E. Merck, UK] as the nematic liquid crystal and added 2.5 wt% of CB15 [M/s E. Merck, Darmstadt, Germany] as a chiral dopant to induce chirality. Dodecanethiol functionalized silver nanoparticles of size 5–15 nm obtained from Sigma-Aldrich were used as

* Corresponding author at: School of Physics and Materials Science, Thapar University, Patiala 147004, India.
E-mail addresses: manju.middha@gmail.com (M. Middha), rishikumar.phd@gmail.com (R. Kumar).

http://dx.doi.org/10.1016/j.molliq.2016.03.087
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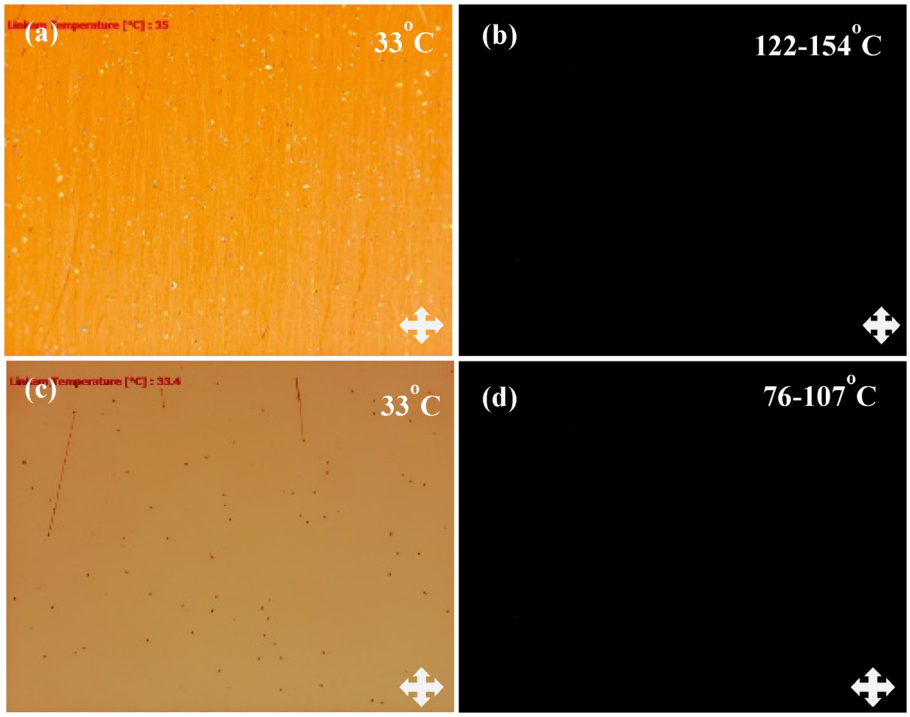

Fig. 1. Phase transition of Ag NP-doped (a, b) nematic and (c, d) chiral LCs to isotropic while heating cycle.

dopants in the host nematic and the chiral nematic matrices. We prepared the doped composites by homogeneously dispersing 0.002 wt% of Ag NPs into nematic as well as chiral nematic mixtures. The pure and Ag NP-doped LC mixtures were filled in antiparallel aligned LC cells of thickness 5 μm, obtained from M/s Linkam (UK), via capillary action at their isotropic temperature.

Electrical connections were applied to the conducting indium tin oxide (ITO) -coated glass substrates using indium solder. Thermal studies were carried out in Linkam temperature controller and hot stage models T95-HS and THMS-2028, respectively. The electro-optic behavior of the material was recorded by applying electric field pulse to the sample cells through the SciTech function generator (Model-ST 4060). The microphotographs of optical textures were taken using Carl Zeiss polarizing optical microscope (Model-Scope. A1) fitted with camera AxioCam 1Cc 1. PL excitation and emission spectra of the filled LC sample cells were recorded with a fluorescence spectrophotometer equipped with a xenon flash lamp (Model-Agilent Carry Eclipse G9800A, Mulgrave, (Melbourne, Australia) in the fluorescence mode.

3. Results and discussion

3.1. Thermo-optical studies

Polarizing optical microscope with crossed polarizers at 100× magnification attached to a temperature controlled hot stage was used to record micro textures of the sample cells while increasing their temperature till isotropic and then cooling down to room temperature at a rate of 1 °C/min. The Ag NPs ferment the obvious colour changes in both the nematic as well as chiral matrices. The phase transition from chiral to isotropic occurs at a slightly (4 °C) lower temperature than nematic to isotropic in the undoped samples. The difference increases to 47 °C with Ag NP doping (Fig. 1(a–d)). The occurrence of the phase transition at a lower temperature in doped CLC as compared

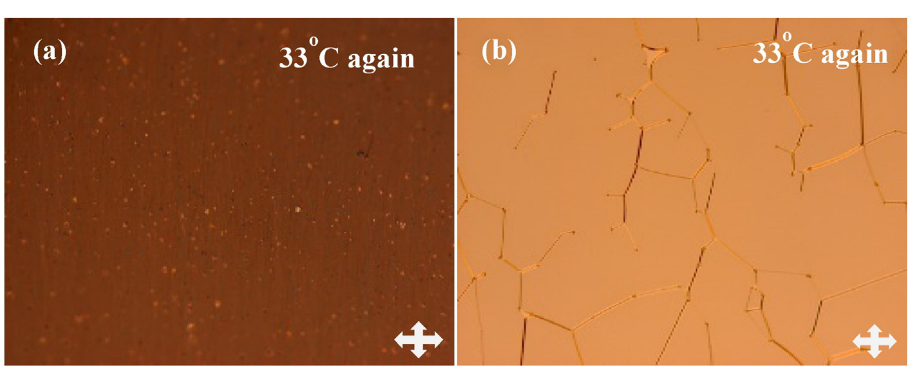

Fig. 2. Microtextures depicting phase transitions of Ag NP-doped (a) nematic and the emergence of thermo-optical memory in (b) chiral LCs while cooling.

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