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Effect of ferroelectric nanoparticles in the alignment layer of twisted nematic liquid crystal display

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ABSTRACT

The alignment layer of a conventional twisted nematic liquid crystal device (TNLCD) has been modified by doping it with ferroelectric barium titanate ($BaTiO_3$) nanoparticles. The presence of uniformly dispersed ferroelectric nanoparticles in the alignment layer has enhanced the electro optical property of twisted nematic cell. The transmission-voltage characteristics show that the addition of $BaTiO_3$ nanoparticle has reduced the Frederik's threshold voltage and saturation voltage. The dispersion of nanoparticles in the alignment layer was studied using scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS). Nonlinear optical behaviour of the twisted nematic cell under different applied voltage is also investigated.

1. Introduction

Liquid crystal display (LCD) devices are of greater demand due to its simple structure, light weight and low current consumption. Research are being done in academic and industrial level for the better performance of the LCD devices. Among them twisted nematic liquid crystal (TNLC) have drawn a greater attraction due to its multiple application. The basic principle of all major LCD such as television, laptop, and watches works with the TNLC concept [1–6]. Nanotechnology is playing a major role in electronic devices. The introduction of nanotechnology in to liquid crystal devices has become a hot topic nowadays [7,8]. Surface area to volume ratio is very high in nanomaterials, which make the material more reactive and plays well in doped electronic devices. Many modifications of the existing technology has been found to be promising like reducing the response time of LCD and increasing the number of pixel per area, etc. The LCD has an alignment layer that shares the major part in the display property, the twisting nature is being done with the help of this polymeric alignment layer [9–12]. In this work we report the modification of the alignment layer with ferroelectric nanoparticles to reduce the switching voltage of the TNLCD [13]. Alignment layer is usually a polymer thin film with 200 nm thickness with a pretilt angle. The conventional alignment layer is replaced by a polymeric nanocomposite, with ferroelectric nanoparticle which can produce a remanent polarization and can improve the electrical property of the devices. A very low concentration of ferroelectric nanoparticles are introduced to the polymer alignment layer which shows a reduction in switching voltage. It has been reported that addition of small concentration of ferroelectric nanoparticle in to LC phase increases the sensitivity of liquid crystal molecule towards the external field by increasing the orientational order parameter of liquid crystal [10,14,15]. Ferroelectric particles at nano scale in the alignment layer produces much larger local electric fields, which can polarize the liquid crystal molecules and thus indirectly increase the intermolecular interaction, which will cause the lowering of switching voltage [16,17]. Nanoparticles are not added to liquid crystal hence device is not contaminated by ionic impurities which will improve the electro optical performance of LCD. Non-linear optical property of liquid crystal has been investigated, contact of nanoparticles with

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liquid crystal matrix has enhanced the non-linear absorption coefficient. Molecular orientation of the liquid crystal change on voltage application which will affect the optical property of the device and an enhancement in NLO behaviour [18–20].

2. Materials and methods

Indium tin oxide (ITO) coated glass plates (25 mm × 25 mm) was purchased from Sigma Aldrich, liquid crystal E7 was procured from Merck, Darmstadt with positive dielectric constant ($\Delta\varepsilon$). Barium titanate ($BaTiO_3$) nanoparticles of diameter 80–100 nm was obtained from Sigma Aldrich and used as it is. Polyimide varnish with high pretilt angle (8–10°) and UV curable glue and spacers (5 μm) were purchased from Nissan Chemicals Ltd. Japan. Cell were fabricated using a scrupulously cleaned and dried ITO plates, which are spin coated with polyimide at an rpm of 2000 with acceleration of 1000 for 60 sec, and cured in a vacuum oven for 90 min at 180 °C. The cured polyimide surface was uniaxially rubbed with a velvet cloth. The rubbing was done manually for five times and the rubbing strength was measured to be between in the range of 1.28–1.92 N/cm^2. The rubbing produces microscopic grooves on the surface of polyimide which helps to align liquid crystal molecules in unidirectional. Two rubbed ITO/polyimide glass plates were glued together with the help of a spacer keeping the rubbing direction orthogonal to each other. These cells were filled with liquid crystal E7 by the capillary action at 60 °C. This cell was considered as the reference cell. Another set of TN cells were fabricated by doping polyimide with barium titanate (BTO) nanopowder. The concentrations taken were below 2% (0.4%, 0.6%, 1%, 1.4%, and 1.6%). The BTO was dispersed in polyimide with bath sonication for 1 h followed by probe sonication for 5 min at 100 W. The TN cells were fabricated as mentioned in the previous procedure. The BTO doped polyimide coated ITO glass plates were characterised using field emission scanning electron microscopy (FESEM), Hitachi, SU 6600, Japan. The x-ray mapping was done using energy dispersive spectrometry (EDS), Horiba, Japan. Atomic force microscopy images were captured using Park XE 100 instrument in contact mode with a scanning rate of 1 Hz using silicon nitride cantilever. The transmittance -voltage (T-V) were measured with the help of an electro-optical setup using diode laser (532 nm) and photo detector with variable AC power source as shown in Fig. 1. Capacitance of the TN cell are measured using LCR meter.

The Z scan technique was used for the nonlinear optical (NLO) characterization and schematic diagram of the experimental setup is shown in Fig. 2. The investigation was carried out by using the standard open aperture Z-scan technique established by Sheik Bahae et al. A Q switched, frequency doubled Nd: YAG laser with, 7ns pulse width, 10 Hz repetition rate and 532 nm wavelength was used as the excitation source for the analysis. Experiments were conducted at 20 μJ pulse energy which equals to a peak intensity of 0.554 GW/cm^2. The NLC cell was connected to an external AC voltage with the help of a function generator and which is scanned across the focus of a convex lens of 15 cm focal length using a computer controlled micrometer translation stage. A dual channel energy ratio meter (Rj-7620, Laser Probe Inc, USA) and two pyroelectric detectors (RjP-735) were used for the energy measurement.

3. Results and discussion

Fig. 3 (a) shows the SEM images of BTO nanoparticle with size ranges from 80 to 100 nm with spherical shapes. The SEM images of polyimide/BTO alignment layer is shown in Fig. 3(b) before rubbing. From the figure it is clear that the BTO nanoparticles were uniformly dispersed in the polyimide matrix. Fig. 3(c) shows the presence of BTO nanoparticle after rubbing with velvet cloth.

It can be observed that after repeated rubbing with velvet cloth microgrooves are formed on the nanocomposite film with deformation. The microgrooves formed during the rubbing process are also visible in the figure and the nanoparticles are still present in the film. Fig. 4 shows the atomic force microscopy images of BTO doped polyimide before and after rubbing with velvet cloth for five times. It can observe that the microgrooves are formed during the rubbing process where the polyimide undergoes deformation.

Fig. 5(a) shows the field emission scanning electron microscopy and its corresponding elemental mapping for barium (b), titanium (c) and oxygen (d). From the figure it is clear that the ferroelectric nanoparticles are uniformly distributed in the polymer matrix.

The effect of concentration of BTO nanoparticles on the optical transmittance of alignment layer was investigated. Fig. 6 shows the variation of transmittance with varying BTO concentration on the polyimide alignment layer. As expected the transmittance has reduced by 10% by the addition of 2% BTO but there is no considerable effect on transmittance before and after rubbing process. We have increased the BTO concentration up to 5% where the

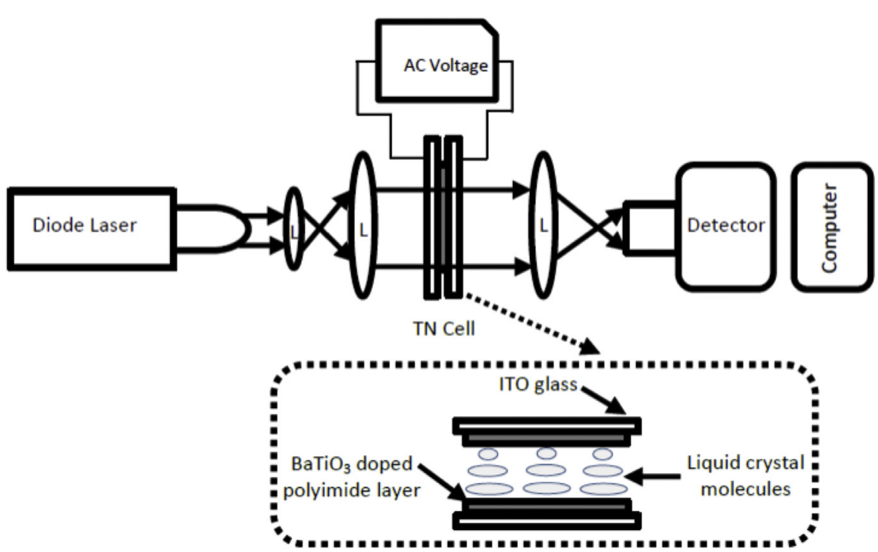

Fig. 1. Electro-optical setup for measuring the transmission-voltage characteristics of twisted nematic cells.