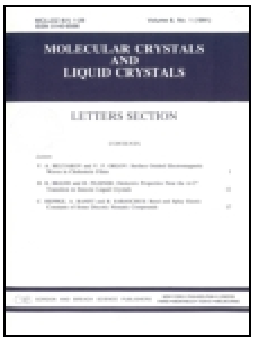

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Planar Alignment of Liquid Crystal in Silica-Based Photonic Structure

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The planar orientation of Nematic Liquid crystal (NLC) molecules on the surface of (111) plane of silica photonic structure has been investigated. Nano voids of silica photonic crystal has been obtained by vertical deposition technique on indium tin oxide-coated substrate. NLC was infiltrated into the channels of voids in the photonic structures. Optical texture studies under with and without electric field were applied to investigate the NLC orientation. It is observed that NLC molecules in the nano voids of silica photonic structure exhibit an excellent planar alignment. This obtained hybrid composite structure on infiltration of NLC will be a promising candidate for electro optic applications.

Keywords Nematic liquid crystal; photonic structure; planar alignment

1. Introduction

In recent decades, advances in technology have been made in reality with the development of fascinating materials, most notably liquid crystals (LCs) and photonic crystals (PhCs). LCs have seen a tremendous growth during the past decades [1–6] due to their potential applications in fast electrooptic devices. PhCs materials are also upcoming with characteristics to control the light through matter [7–9] with potential technical applications. PhCs are formed with the periodic arrangement of building blocks of a size of order optical wavelength, in one, two or three dimensions [10]. In literature, most of the research is focused on the PhCs to control the propagation of light [11–14], but least efforts have been reported for the alignment of LCs molecules.

In the present work, we reported the optical study on alignment of the LCs molecules on the silica-based photonic structure on indium tin oxide (ITO)-coated substrate. It is observed that the photonic structure is a good candidate for the orienting LCs molecules in the planar alignment.

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2. Experimental

Silica microspheres have been synthesized using well known Stöber method [15–18]. Three dimensional PhC was fabricated using self-assembly vertical deposition technique on ITO-coated substrate, which is discussed elsewhere [19–23]. The silica PhC film was sintered at 300°C for 2 hr. The film has a face centered cubic structure with interconnected periodic arrangement of voids [24]. The film was fixed to another ITO substrate for infiltrating nematic LC. The nematic liquid crystal (NLC) used in the present experiment was a biphenyl terphenyl LC mixture E8 (obtained from M/S BDH Ltd., UK). The phase sequence of this LC is given as [25].

$$\text{Crystal} \xrightarrow{12^\circ\text{C}} \text{Nematic} \xrightarrow{72^\circ\text{C}} \text{Isotropic}$$

This NLCs were infiltrated into the void of the sample by capillary action at the isotropic temperature of NLCs. The cells were sealed using epoxy adhesive (Fevitile). The cell thickness was 100 μm using mylar spacers. The schematic block diagram of fabricated device using NLC is shown in Fig. 1. Square wave of 1 KHz is applied to the cell using an arbitrary/function generator (Tektronix, ABG 3021B). Optical textures of NLC and PhCs infiltrated with NLCs were taken using Olympus Polarizing Microscope (BX51) fitted with color video camera (Sony).

3. Results and Discussion

Figure 2 shows topographic image of the silica PhC taken by atomic force microscope. From the AFM image, we can conclude that the all silica particles having spherical shape and diameter of order of 150 nm having hexagonal closed packed arrangement [17–18, 21].

The optical texture of LC without any surface treatment of substrate is shown in Fig. 3(a). It reflects that there is no alignment of the LC molecules and defects are present in the texture. Figure 3(b) shows the optical texture of the cell in which LC is infiltrated in the voids of the silica photonic structure. It reflects the homogeneous (planar)

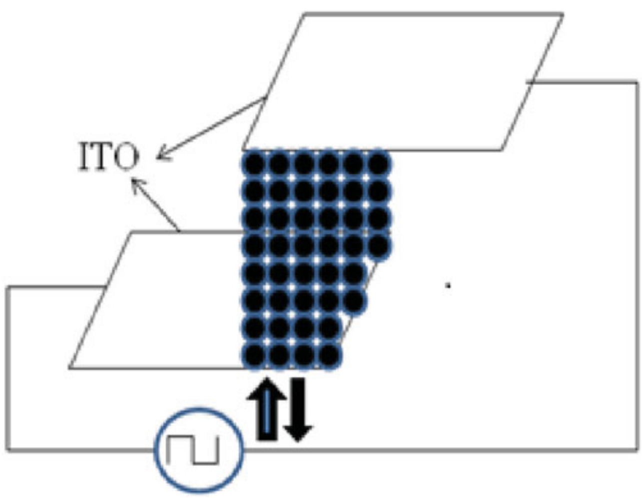

Figure 1. Systematic diagram of fabricated cell using nematic liquid crystal.

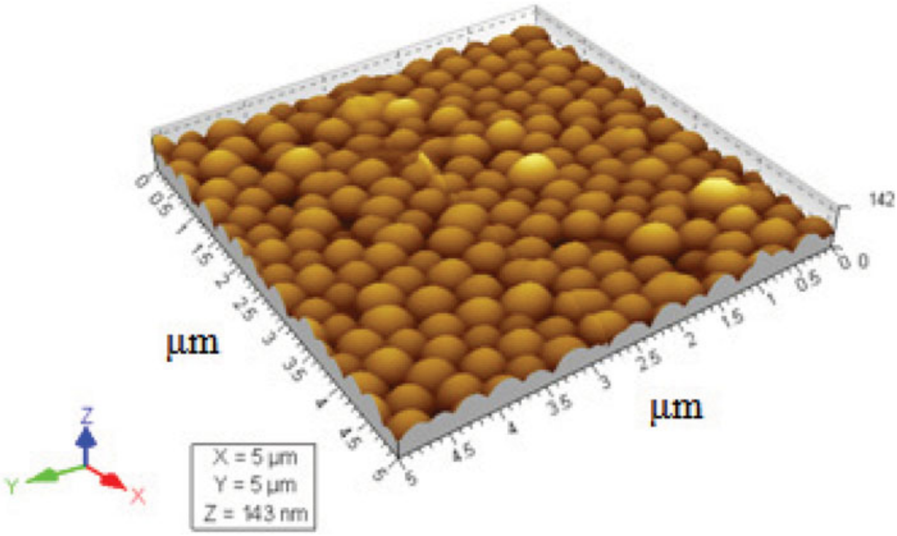

Figure 2. AFM image of silica photonic crystal.

alignment of the LC molecules on the infiltration in the photonic structure containing silica microspheres.

We demonstrated this through schematic diagram, in which the orientation of the LC molecules near and in between the upper and lower solid boundary of ITO substrates without any treatment as shown in Fig. 4(a). It shows that, the LC molecules are orienting in all possible direction which results thread like texture and is clearly seen in Fig. 3(a). Figure 4(b) presents the orientation of LC molecules in the voids of the photonic structure as well as near the substrate surface.

The surface of silica microspheres carries negative charges (as shown in Fig. 4(b)). These negatively charged silica microspheres will interact with LC molecules through Van der Waals interaction which encourage the planar orientation of the LC molecules in the voids as well as near the solid boundary of the substrates as shown in Fig. 4(b). Planar orientation of the LC molecules is also encouraged by the anisotropic surface properties of the developed photonic structures on the substrate. The planar alignment of the LC molecules is confirmed by optical texture under crossed polarizer is shown in Fig. 3(b). It is also noticed that optical texture shows periodic variation in the transmitted intensity

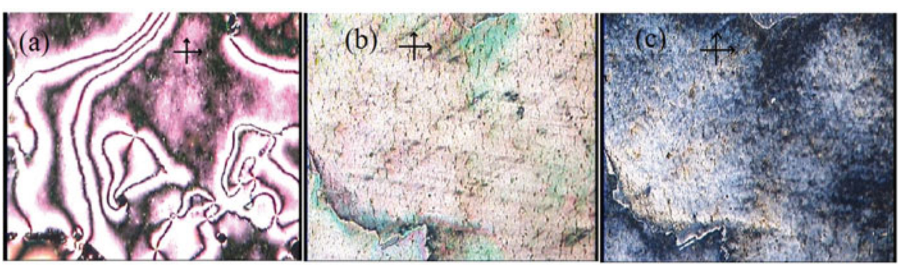

Figure 3. Optical textures of (a) NLC and infiltrated silica photonic crystal with NLC at (b) 0 V and (c) 9 V at magnification 10× under crossed polarizers.

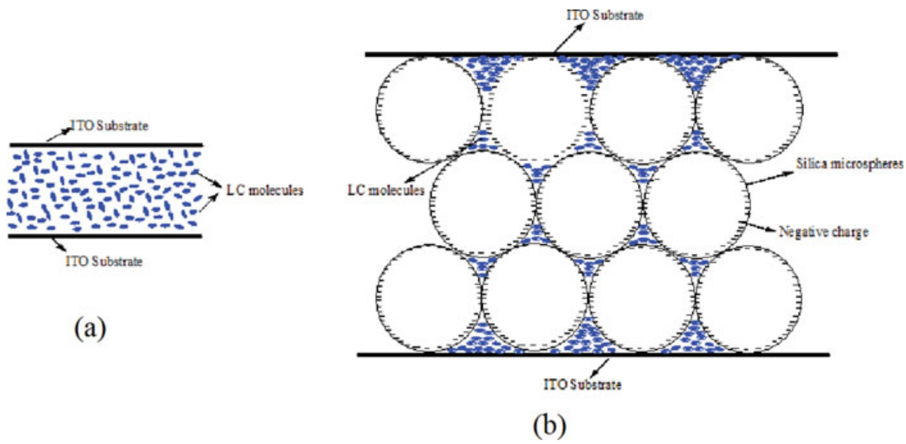

Figure 4. Orientation of LC molecules (a) without and (b) with photonic structure.

through cell by rotating it by an angle of 90º, normal to the incident light under crossed polarizers. This reflects good planar alignment of LC with the photonic structure on a substrate.

Figure 5 represents the position of the director (***n***) (which shows the average orientation of LC molecules) near the interface in term of polar (θ) and azimuthal (φ) angles. The ***n*** lies in the plane of the interface surface, i.e., $\theta = 0^{\circ}$. It is also oriented uniformly over the interface surface with constant φ angle for planar orientation.

The degree of order is represented by order parameter (s) is given as [26]

$$s = \frac{1}{2}\left\langle 3\cos^2\theta - 1\right\rangle,$$

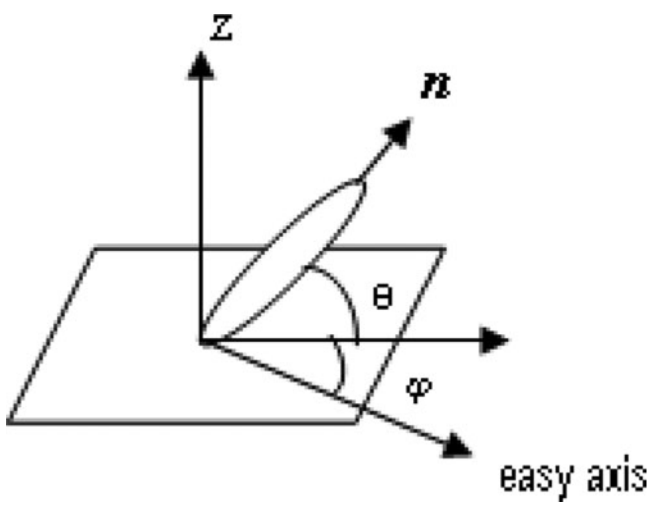

Figure 5. Orientation of the director at the interface surface in term of polar and azimuthal angles.

where brackets represent an average orientation of all molecules in the LC. The value of *s* lies in between 0 and 1. For uniform planar alignment this value approaches to unity. There may be light scattering at the contact surface due to the mismatch of refractive indexes between LC molecules and silica microspheres. In the present study, we have not considered this effect.

On the application of electric field the optical texture starts appearing black due to orientating themselves in the direction of applied field across the cell, the LC molecules oriented normal to the surface of substrate resulting Freedericksz transition [25] are clearly seen in Fig. 3(c) at 8 V. Therefore, we can conclude that silica photonic structure may be suitable candidate for attaining planar alignment because of their ease fabrication, good thermal as well as chemical stability.

4. Summary

Morphological study of silica photonic structure using atomic force microscopy confirms the hexagonal closed packed arrangement of silica microspheres. Optical texture study of the infiltrated silica PhC with NLCs reveals that silica photonic structure on the substrate is a good candidate for attaining planar alignment of NLCs molecules due to Van der Waals interaction among themselves. The fabrication of this hybrid structure is easy and has better thermal as well as chemical stability.

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References

[1] Golovin, A. B., Xiang, J., Park, H-S., Tortora, L., Nastishin, Y. A., et al. (2011). *Materials*, *4*, 390.
[2] Gathania, A. K., Singh, B., & Raina, K. K. (2004). *Jpn. J. Appl. Phys.*, *43*, 8168.
[3] Gathania, A. K., Ahuja, J. K., Singh, B., & Raina, K. K. (2000). *Ind. J. Eng. Mater. Sci.*, *7*, 429.
[4] Gathania, A. K. (2008). *Liquid Cryst.*, *35*, 773.
[5] Gathania, A. K., Singh, B., & Raina, K. K. (1999). *Ind. J. Pure Appl. Phys.*, *37*, 657.
[6] Gathania, A. K., Singh, B., & Raina, K. K. (1999). *J. Phys.: Condensed Matter Phys.*, *11*, 3813.
[7] Yablonovitch, E. (1987). *Phys. Rev. Lett.*, *58*, 2059.
[8] John, S. (1987). *Phys. Rev. Lett.*, *58*, 2486.
[9] Skoda, K. "Optical Properties of Photonic Crystals," Springer (2001). ISBN 3-540-41199-2.
[10] Joannopoulos, J. D., Meade, R. D., & Winn, J. N. (1995). *Photonic Crystals: Molding the Flow of Light*, Princeton University Press: Princeton.
[11] Chiappini, A., Chiasera, A., Berneschi, S., Armellini, C., Carpentiero, A., et al. (2011). *J. Sol-Gel. Sci. Technol.*, *60*, 408.
[12] Fang, M., Volotinen, T. T., Kulkarni, S. K., Belova, L., & Rao, K. V. (2011). *J. Nanophotonics*, *5*, 053514.
[13] Moroz, A. (2000). *Eur. Phys. Lett.*, *50*, 466.
[14] Deng, T. S., Zhang, J. Y., Zhu, K. T., Zhang, Q. F., & Wu, J. L. (2010). *Opt. Mater.*, *32*, 946.
[15] Stober, W., Fink, A., & Bohn, E. (1968). *J. Coll. Inter. Sci.*, *26*, 62.

[16] Dhiman, N., Sharma, A., & Gathania, A. K. (2010). *ISST Indian J. Appl. Phys.*, *1*, 53.

[17] Gathania, A. K., Dhiman, N., Sharma, A., & Singh, B. P. (2011). *Colloids and Surfaces A: Physicochemical and Eng. Asp.*, *378*, 34.

[18] Dhiman, N., Singh, B. P., & Gathania, A. K. (2012). *Colloids Surf. A: Physicochem. Eng. Asp.*, *409*, 69.

[19] Wu, C. Y., Lai, N. D., & Hsu, C. C. (2008). *J. Korean Phys. Soc.*, *52*, 1585.

[20] Meijer, J-M., Hagemans, F., Rossi, L., Byelov, D. V., Castillo, S. I. R., et al. (2012). *Langmuir*, *28*, 7631.

[21] Gathania, A. K., Dhiman, N., Sharma, A., & Singh, B. P. (2011). *Proceedings of the International Conference on Smart Nano-micro Materials and Devices SPIE, 8204*. 82043N1, SPIE Smart Nano + Micro Materials and Devices, Melbourne.

[22] Dhiman, N., Sharma, A., Singh, B. P., & Gathania, A. K. (2014). *AIP Conf. Proc.*, *1591*, 1696.

[23] Sharma, A., Dhiman, N., Singh, B. P., & Gathania, A. K. (2014). *J. Mol. Struct.*, 1074, 522.

[24] Ma, X., Li, B., & Chaudhari, B. S. (2007). *App. Surf. Sc.*, *253*., 3933.

[25] Gathania, A. K., & Raina, K. K. (2003). *Can. J. Phys.*, *81*(12), 1427.

[26] Chandrasekhar, S. (1993). *Liquid Crystals*, New York: Cambridge University Press.