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Versatile alignment layer method for new types of liquid crystal photonic devices

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Liquid crystal photonic devices are becoming increasingly popular. These devices often present a challenge when it comes to creating a robust alignment layer in pre-assembled cells. In this paper, we describe a method of infusing a dye into a microcavity to produce an effective photo-definable alignment layer. However, previous research on such alignment layers has shown that they have limited stability, particularly against subsequent light exposure. As such, we further describe a method of utilizing a pre-polymer, infused into the microcavity along with the liquid crystal, to provide photostability. We demonstrate that the polymer layer, formed under ultraviolet irradiation of liquid crystal cells, has been effectively localized to a thin region near the substrate surface and provides a significant improvement in the photostability of the liquid crystal alignment. This versatile alignment layer method, capable of being utilized in devices from the described microcavities to displays, offers significant promise for new photonics applications. © 2015 AIP Publishing LLC. [http://dx.doi.org/10.1063/1.4926737]

I. INTRODUCTION

Liquid crystals (LCs) have become increasingly common in photonics devices, including recent applications, such as ring resonators, lenses, and photonic crystal fibers (PCFs).¹ One particularly exciting new application of LCs to the field of photonics is their use in an uncooled thermal imager for high performance, large format, imaging arrays in the long wavelength infrared (LWIR) light.² In this application, LC microcavities are fabricated such that they are thermally isolated from an underlying substrate, as shown in Figure 1. The geometry of these microcavities, as well as the necessary processing steps utilized to fabricate them, makes the incorporation of a robust LC alignment layer through a single fill hole an incredibly challenging task.

In this paper, we describe a photo-definable azo-dye layer to provide the LC alignment. This alignment layer can be applied after almost all fabrication processing steps and can be utilized in any application requiring cell geometry with minimal fill-port access.

In general, photoalignment of LCs offers many advantages over rubbed alignment;³ these advantages include the elimination of the dirty mechanical rubbing step and the ability to easily create complex alignment patterning. Anchoring energies of these layers have also been measured to be on the same order of magnitude as the anchoring achieved through rubbed polyimide alignment.⁴ While photoalignment, as a general term, encompasses a variety of techniques, we use it here to describe, specifically, the use of polarized irradiation to impose a preferred molecular direction on an anisotropic dye deposited on the substrate surface.

Photoalignment has received a great deal of attention in LC photonics applications due to its ability to be utilized in non-standard geometries.¹ For instance, photoalignment has

been utilized in the creation of a tunable microresonator,⁵ however, the alignment layer in this case is applied through a standard spin-coating method. Great success has also been shown in the use of photoalignment for tunable PCFs.^{6–9} In this case, the application of the photoalignment layer via spin-coating is impossible; instead, the fiber is filled with the photoalignment solution through capillary action, then excess solution is removed through a pressure gradient. These methods offer a solution for the application of a photoalignment layer with either a completely open geometry or two open ends. However, neither is usable for a configuration with only one entry/exit port.

Another problem with these layers is their questionable stability, particularly against subsequent light exposure;^{3,10} this has kept photoalignment from being adopted for largescale applications. As such, researchers have sought ways to improve the stability of alignment generated with these layers, typically through the incorporation of a polymerizable material, with mixed results. For instance, one approach utilizes a photoalignment material which is also polymerizable.^{11–13} However, this method requires complex chemical synthesis and strict control of heat and light during processing. Additionally, while a number of tests have been used to verify thermal and photostability of these alignment layers, the anchoring energy and order parameter of these polymerizable dyes are questionable. In one case, Chigrinov et al. state that the order parameter they are able to achieve is quite low.¹³ As a modification of this approach, one can consider blending of azo dye with pre-polymer. However, this method is only tested for ferroelectric LCs, which requires quite specific anchoring conditions.¹⁴

Another strategy could be to utilize a spun-on reactive mesogen (RM) layer. Photoalignment layers have been used



FIG. 1. (a) Cartoon thermal pixel cross-section and (b) SEM photograph of a thermal pixel.²

FIG. 2. Example microcavity geometry: (a) side-view and (b) top-view.

as an alignment material for polymerizable LCs. Such a technique is easily used to align bulk LCs and has been shown to have high stability¹⁵ though anchoring energies are unknown. In addition, the requirement of spinning makes these layers unusable in microcavities or microcapillaries/ fibers.

In this paper, we describe a technique for creating photoalignment layers by infiltrating a dissolved photo-definable dye into microcavities through a single micron-sized opening. Also, presented is a method to stabilize the photoalignment by infiltration into the microcavity of a RM that has been pre-mixed into a host LC. This method has been demonstrated previously on bulk samples as an effective method to generate customizable, patternable pretilt in liquid crystal cells.¹⁶ The layers generated by the method in this paper are thin and do not exhibit a large degree of light scattering.

II. PHOTOALIGNMENT IN MICROCAVITIES

The process of creating a stable azo dye photoalignment layer in confined microcavities begins with the application of the azo dye layer. An example of the test cavities used in these experiments is shown in Figure 2. Here, we define microcavity as any fully enclosed cell geometry in which all dimensions are on the order of microns. In this particular example, the microcavity is also defined as having only one available port through which solutions infuse. This cavity is structurally quite similar to those used in the thermal imager application described above.

A solution is prepared in which the azo dye Direct Yellow 4 (CAS No. 3051-11-4), commonly known as Brilliant Yellow (BY), is mixed with dimethylformamide (DMF), both of which have been obtained from Sigma Aldrich. Excellent photoaligning properties of BY layers in bulk cells have been earlier described.^{17,18} For these microcavities, we utilized a mixture of BY in DMF at 0.5% concentration by weight. The mixture was vortexed for 1 min to create a uniform dye solution. Microcavities were then submerged in this dye solution and allowed to soak for 15 min. Once removed from the dye solution, the top surfaces of the microcavities were cleaned by wiping with a fresh razor blade and the samples were immediately baked at 150 °C for

at least 15 min to evaporate solvent out of the microcavities. We conducted this process on two types of microcavity samples: one fabricated on a transmissive substrate and one fabricated on a reflective substrate.

BY has a somewhat wide absorption spectrum, shown in Figure 3, which allows for reorientation utilizing wavelengths ranging from the ultraviolet (UV) to blue light. In our case, we use a Royal Blue light-emitting diode (LED) purchased from Luxeon with a central wavelength of 447 nm. The intensity of the polarized light at the sample surface is approximately 50 mW/cm²; samples were irradiated for approximately 5 min. This irradiation aligns the dye on both substrate surfaces, resulting in planar alignment. LCs vacuum-filled in the isotropic state into the microcavities prepared in this way exhibit uniform dark and bright states, shown in Figure 4, for cavities that were designed to operate in transmissive or reflective mode.

A quantitative measure of alignment quality of the dye molecules is the order parameter of the dye layer following the polarized irradiation. This is determined by using a spectrophotometer to measure the absorption spectrum of the dye both parallel and perpendicular to the principle axis of the dye alignment. The maximum absorbances from these spectra, A_{\parallel} and A_{\perp} , respectively, are then utilized to calculate the two-dimensional order parameter as



FIG. 3. Unpolarized absorption spectrum of BY on glass substrate spun on using 1 wt. % BY in DMF taken prior to irradiation with polarized light.



FIG. 4. Bright (a) and (c) and dark (b) and (d) states of photoaligned LC cavities, between crossed polarizers which operate in either reflective (a) and (b) or transmissive (c) and (d) modes. Photoalignment layer prepared using 0.5 wt. % BY in DMF. Cavity diameter is $\sim 12 \,\mu$ m (top) or $\sim 20 \,\mu$ m (bottom). Bright and dark images for each taken with equal exposure.

$$S_{2D} = \frac{A_{||} - A_{\perp}}{A_{||} + A_{\perp}}.$$
 (1)

The value of this order parameter represents the degree to which the dye is aligned with values ranging from 0 to 1.0, 1.0 representing perfect order. These spectra could not be measured in the confined microcavities due to the fact that the alignment layers deposited in these microcavities are too thin. However, when we prepared photoalignment layers utilizing 1.0 wt. % BY in DMF applied to glass via spin-coating, the order parameters we achieved were in the range of 0.8, indicating very strong order of the dye molecules.

Although the photoalignment in the cavities is good, the stability of these layers is poor, as discussed previously. Section IV investigates the stability of the alignment layer with and without a RM.

III. SURFACE LOCALIZATION OF REACTIVE MESOGEN

A. Illustrating surface-localization

Bulk cells (on the order of inches) were fabricated with RM84 and measured to estimate the conditions for creating a thin and stable alignment layer in microcavities. Confocal microscope images were taken using 0.08% weight concentration of Fluorescein Dimethacrylate, a dye which selectively associates with the RM in the test cells (the wavelength used was 460 nm, which is well absorbed by the dye). Using this method, we could assess the effect of mixing on the diffusion of RM to the cell surfaces. Figure 5 gives these confocal images with brighter areas indicating higher concentration of the dye (and, therefore, the RM). Figure 6 shows the intensity variation along a vertical cross-section of each image, showing the relative distribution of dye across the LC cell, showing that, for weak mixing, the RM will diffuse out of the LC and be localized at the surface rather symmetrically. However, both sonication and no mixing resulted in non-symmetric distribution of RM to the substrates

surfaces (worst in the case of no mixing) and a lower surface concentration of RM overall (reduction in the maximum measured dye intensity near the surfaces). Through control of mixing of the RM into the LC, the RM layer will be concentrated on the surface to provide stabilization of the photodefinable layer.

It should be noted that we have discovered a number of factors which can affect the degree of separation of the RM to the substrate surface, including the materials chosen (both the liquid crystal and the pre-polymer¹⁹), the exact mixing condition, and even the time between mixing/filling and polymerization. Even the substrate surfaces have been found to play a critical role in this separation. For the purposes of this paper, however, we focus only on a particular method of preparation which we determine as effective. The dependence of separation on these various factors is left for a following publication.

We can provide verification that the polymer network is concentrated near the surface with our specific preparation method by comparing measured data of transmission vs. voltage (TV) with the theoretical arguments developed previously using dielectric constant vs. voltage curves.

B. Simulated surface-localization

Dielectric constant vs. voltage curves have previously been utilized to develop a better understanding of the nature



FIG. 5. Monomers' distribution along the cell gap direction under different mixing conditions. Bright areas mean that the dye is more concentrated. 0.66% RM84, 0.08% dye.



FIG. 6. Monomers' distribution along the cell gap direction under different mixing conditions. Intensity measured along a random vertical cross-section of each image shown in Figure 5.

of a surface-localized polymer layer.²⁰ The key factor considered in that investigation was the network density gradient normal to the plane of the cell. The LC director configuration in the cell, given a particular applied voltage, was determined numerically by utilizing the free energy density of the system, given by

$$f_{d} = \frac{k_{11}}{2} (\nabla \cdot \hat{n})^{2} + \frac{k_{22}}{2} (\hat{n} \cdot \nabla \times \hat{n})^{2} + \frac{k_{33}}{2} (\hat{n} \times \nabla \times \hat{n})^{2} - \frac{W}{2} (\hat{n} \cdot \hat{n}_{o})^{2} - \frac{1}{2} (\vec{D} \cdot \vec{E})^{2}, \qquad (2)$$

where k_{11} , k_{22} , and k_{33} are the splay, twist, and bend elastic constants of the LC, respectively, **D** is the electric displacement, **E** is the electric field, **n** is the LC director at a particular point, **n**_o is the preferred direction of the director (at points along the polymer network), and W is the effective anchoring strength of the LC director in contact with the polymer (W = 0 in regions without polymer). The preferred director, **n**_o, is determined by the director orientation at the time of polymerization, where the orientation is imprinted onto the polymer network, illustrated in Figure 7. If the sample is polymerized (i.e., exposed to UV light) with no applied voltage, then the polymer network will lock in a planar orientation. However, if a voltage is applied during the polymerization process, then the tilted director configuration will be locked in, even after the voltage has been turned off. The effect of the polymer distribution through the cell was modeled by making the anchoring parameter, W, effectively proportional to a polymer distribution given by

$$X(z) = X_0(e^{-z/\xi} + e^{-(d-z)/\xi}),$$
(3)

where X_0 is considered as the polymer concentration at the substrate surface, d is the cell thickness, and ξ is the length scale for the decay of the concentration going away from the surface.

Figure 8 shows the effect of the values of X_0 and ξ on the dielectric constant vs. voltage curves where the polymer orientation, also equal to no, is determined by the director distribution in the cell with 10V root-mean-square (RMS) applied. Note that these plots show dielectric constant versus voltage-the dielectric constant was calculated directly based on the simulated director configuration with the dielectric properties of the polymer assumed to be equal to that of the liquid crystal. It can be seen that if the polymer is quite evenly distributed through the cell, the main effect is to see a shift in the threshold voltage of the device (the voltage below which no change in dielectric constant has occurred). However, if the polymer is more concentrated on the surface, the main effect is to see a shift in the saturation voltage of the device (the voltage above which the change in dielectric constant has saturated).

On the other hand, when a simplified model was used in which it was assumed that the effect of the polymer was



FIG. 7. (a) Monomers are present in the liquid crystal sample which exists in some distribution across the cell normal, localized near the cell surfaces. (b) Applied voltage will reorient the liquid crystal. (c) UV illumination will crosslink the monomers, locking in the liquid crystal orientation during this stage. (d) After UV illumination, this liquid crystal orientation is locked in (where the polymer network exists), even after voltage is removed.

restricted to an infinitesimally thin layer (effectively a monolayer) at the surface and acts as an alignment layer with a pretilt (no polymer network exists in the liquid-crystal-filled region of the cell and the polymer interaction term is dropped), the effect on the dielectric constant vs. voltage curve was simulated as shown in Figure 9. Here, there is little effect on the curve where the polymer is cured at 0 V. The main effect is to lower the zero volt value of the capacitance for the case where the cell is cured at high voltage. The zero volt value of the capacitance will be related to the induced pretilt that results from the given value of the applied voltage, with higher voltages and/or higher polymer concentrations yielding values of the zero volt capacitance that are higher, approaching the saturation value with the effective pretilt of 90°.

Voltage (V)

ectric Constan

(a)

at OV

C. Measured surface-localization

Because we are interested in the optical properties of our samples, we utilize TV curves on cells prepared similarly to the referenced simulations discussed in Section III B. Phase vs. voltage for each sample will show similar behavior to the dielectric constant vs. voltage curves; a change in the zero volt phase will indicate an increase in the pretilt of the sample, while a change in the threshold voltage will indicate that the polymer network is not surface localized and exists in the bulk.

Five-micron thick cells with at least a $1 \text{ cm} \times 1 \text{ cm}$ active area were prepared with rubbed polyimide alignment the opposite direction). A diagram of this cell is shown in Figure 10. Before infiltrating the cells, RM257 was mixed with a photoinitiator Irgacure 651 in which the photoinitiator was at 10% concentration by weight. This was then added to the LC BL006 such that the RM257/photoinitiator was at 1.5% concentration by weight. This mixture was then heated to 125 °C and vortexed for 3 min to produce a uniform mixture. Cells were then infused with either the 1.5 wt. % RM257/BL006 mixture or pure BL006. The RM/LC cells were then stored overnight in dark conditions to allow for separation of the RM to the substrate surfaces. Next, these samples were polymerized using 20 minutes of exposure to 3.5 mW/cm^2 UV light ($\lambda = 365 \text{ nm}$) provided by a Mightex collimated UV LED light source. The cell was either polymerized at 0 V or 20 V (1 kHz AC).

layers on the substrate surfaces (each substrate was rubbed in

(b)

10

Voltage (V)

Once cells were polymerized, TV curves were obtained by placing the sample between two polarizers. TV curves were taken with both crossed and parallel polarizers; in both cases, the cell was oriented with the alignment at 45° to the input polarizer. A broadband Oriel fiber optic illuminator was used as a light source and an interference filter $(\lambda = 633 \text{ nm})$ was utilized to produce monochromatic light. To neglect transmission losses for phase calculations, the TV curve is adjusted so that the maximum and minimum transmissions through the cell (i.e., detected voltage) are taken to be equivalent to a transmission of 1 or 0, respectively.

To produce a plot more comparable to the dielectric constant vs. voltage curves, each set of TV curves was further converted into a phase retardation vs. voltage profile. This utilizes the fact that the transmitted intensity between crossed polarizers is given by

Top Substrate

≽

Rub Direction

Bottom Substrate

Rub Direction





Dielectric Constan





5µm



$$I_{\perp} = I_o \left(\sin \frac{\delta}{2} \right)^2, \tag{4}$$

with δ being the phase retardation of the LC sample. This transmitted intensity between parallel polarizers is similarly given by

$$I_{||} = I_o \left(\cos\frac{\delta}{2}\right)^2.$$
⁽⁵⁾

The phase retardation of the sample at a particular voltage, then, is given by the transmission ratio in these two plots, as

$$|\delta| = N\pi + 2 \tan^{-1} \sqrt{I_{\perp}/I_{\parallel}}, \quad N = 0, 2, 4, ...,$$
 (6)

or

$$|\delta| = (N+1)\pi - 2\tan^{-1}\sqrt{I_{\perp}/I_{\parallel}}, \quad N = 1, 3, 5, ...,$$
 (7)

where N is the peak number in the TV curve (counted up from the high-voltage end of the curve). When the cell is almost completely switched, N = 0.

Figure 11 shows the phase retardation vs. voltage for the prepared cells. In this case, the sample polymerized at 0 V shows no significant differences from the cell filled with pure LC—neither the threshold voltage nor the saturation voltage is noticeably different. This indicates that the RM layer is sufficiently thin so as to have no affect on the bulk LC. In the case of the sample polymerized at 20 V, though, the zero volt retardation has dropped and the threshold voltage has also decreased, indicating that the pretilt of the cell has increased. These results are very similar to the case of an infinitesimally thin RM layer, shown in Figure 8, indicating that our RM layer is quite thin.

IV. PHOTOSTABILITY TESTING

To test the ability of our polymer layer to stabilize the alignment generated using a photoalignment layer, additional $7 \mu m$ cells were constructed in which one substrate was coated with a rubbed polyimide alignment layer and the other was coated with a spun-on BY photoalignment layer. The BY was applied to the glass by mixing the dye at 2% concentration by weight into DMF, then vortexing for 1 min



FIG. 11. Phase profiles for 5 μ m planar cells filled with pure LC or LC with 1.5 wt. % RM257, which was polymerized at either 0 V or 20 V.

to create a uniform solution. The glass was cleaned via ultrasonic and UV/O₃ cleaning just prior to the application of the dye solution, which was passed through a 1 μ m filter as it was applied. The entire substrate was coated and the sample was spun at 1500 rpm for 30 s to create an even dye layer coating. The substrate was then baked for 120 °C for 40 min to evaporate any remaining solvent.

Test samples, once assembled, were exposed to 50 mW/cm^2 polarized blue light for 7 min using the same exposure setup described for microcavities. This exposure was incident on the back of the photoaligned substrate and with the polarization direction aligned with the rubbed polyimide alignment direction. This exposure results in an approximately 90° twist with the photoalignment direction perpendicular to the rubbed alignment.

This twisted cell configuration provides for fast visual determination of the degradation of alignment. When the cell is initially fabricated, the anchoring energies of the rubbedpolyimide and of the photoalignment layer are both sufficiently strong, so the twisted LC director configuration is observed. If the photoalignment layer is rewritten to a new



FIG. 12. Sample filled with pure BL006 (a) before exposure or after (b) 50 min, (c) 100 min, (d) 150 min, and (e) 200 min of exposure to $\sim 20 \text{ mW/cm}^2$ polarized blue light oriented at 45° to the photoalignment axis. Before exposure images are shown between crossed (left) and parallel (right) polarizers. After exposure images are shown between parallel (left) and crossed (center) polarizers as well as polarizers oriented at 45° (right).²¹ Reprinted with permission from V. Finnemeyer, D. Bryant, and P. Bos, in SID Symposium Digest of Technical Papers, 67.1, 2015. Copyright 2015 from J. of SID.



FIG. 13. Samples filled with 1.5 wt. % RM257 in BL006 shown between parallel (left) or crossed (right) polarizers. (a) Before and (b) after exposures to polarized blue light of $\sim 20 \text{ mW/cm}^2$ for 21 days and (c) before and (d) after exposures to unpolarized blue light of $\sim 120 \text{ mW/cm}^2$ for 21 days.²¹ Reprinted with permission from V. Finnemeyer, D. Bryant, and P. Bos, in SID Symposium Digest of Technical Papers, 67.1, 2015. Copyright 2015 from J. of SID.

angle, then the twist angle through the cell will change. If the photoalignment layer is degraded, the rubbed polyimide alignment direction will dominate and the cell will lose its twisted director configuration completely. The director field in the cell will then be co-planar and aligned with the axis determined by the polyimide. When viewed between crossed polarizers, twisted regions will appear bright, while nontwisted planar regions will appear dark. When viewed between parallel polarizers, non-twisted planar regions will appear bright, while twisted regions will appear dark.

The samples were filled with either pure BL006 or the same 1.5 wt. % RM257/BL006 mixture as utilized in Section III, with storage and polymerization at 0 V occurring as previously described. For photostability testing, samples were exposed to the same blue LED used to align them. In one case, samples were exposed to 20 mW/cm^2 polarized light at 45° to the original photoexposure direction; this approximates the highest level of illumination expected on the thermal pixels. In another case, samples were exposed to unpolarized light of 120 mW/cm^2 . In this case, unpolarized light was used so as to simulate flux $5 \times$ higher than utilized in the thermal pixel application.

Samples containing pure BL006 showed a complete loss of their original photoalignment direction in the low intensity polarized exposure (Figure 12). The alignment has been rewritten within the first 50 min of exposure. Between polarizers oriented at 45° (the newly written twist angle of the cell), the sample exhibits a somewhat dark twist state. However, as the sample is exposed for longer, even this alignment is lost, with the sample failing to twist light at all. The photoalignment layer has been completely degraded and the intended alignment of the sample has been lost.



FIG. 14. TV curves of 5 μ m samples with rubbed polyimide alignment on one substrate and BY photoalignment on the other substrate, aligned in a 90° twisted configuration. Curve taken between crossed polarizers with sample aligned with polarizers as shown in embedded diagram. Sample is either unexposed (pure BL006) or exposed to 120 mW/cm² unpolarized blue light for 3 weeks (1.5 wt. % RM257 in BL006).

Samples with pure BL006 also showed a rapid degradation of their photoalignment layer in the high intensity unpolarized case. These samples exhibited planar alignment after less than 20 min of exposure to this condition.

On the other hand, samples which contained the RMstabilization layer exhibited a high degree of stability. In both the low intensity polarized condition and the high intensity unpolarized condition, samples maintained their 90° twisted alignment for 3 weeks with no sign of degradation in their alignment (Figure 13).

We have also considered the electro-optic response of these samples. In this case, a sample filled with pure BL006 which had not been exposed, as well as the sample filled with 1.5 wt. % RM257 in BL006 which had been exposed to \sim 120 mW/cm² unpolarized light for 3 weeks, was utilized. Samples were placed between crossed polarizers with the entrance and exit LC director aligned with the entrance and exit polarizers, respectively. TV curves for the samples taken in this configuration are shown in Figure 14. There is no significant difference in the electro-optic response of these two cells indicating that not only does the RM layer have no effect on this response but also that this TV response remains stable against extended light exposure.

V. DEMONSTRATING RM-STABILIZED PHOTOALIGNMENT IN MICROCAVITIES

Finally, we bring together the previous results by demonstrating RM-stabilized photoalignment in microcavities. A microcavity sample on transmissive substrate was prepared



FIG. 15. Bright (a) and dark (b) states of RM-stabilized photoaligned LC microcavities on transmissive substrate, between crossed polarizers. Image magnification 50×. Cavity diameter is ~20 μ m. Bright and dark images for each taken with equal exposure.

[This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to] IP 95.135.59.110 On: Wed, 22 Jul 2015 20:40:21 as described in Section II, with the only exception being that the LC in this case was mixed with 3 wt. % RM257 (with 10 wt. % Irgacure 651) in BL006 which had been vortexed for 3 min just prior to filling. Note that the concentration of the RM was increased to 3 wt. % in this case due to the fact that the microcavity samples have a thickness of 2 μ m rather than the 5 μ m thick cells utilized in Section III. Samples were then stored and polymerized at 0 V as described in Section III. Figure 15 shows this sample on the microscope between crossed polarizers at 50× in both the bright state and the dark state. Again, this sample exhibits uniform alignment. Using these images to calculate the intensity of a cavity in both its bright and dark states results in a contrast ratio of 24:1—we anticipate better contrast once the process is optimized.

VI. CONCLUSION

We have introduced a technique to generate stable alignment utilizing a photodefinable dye and a surface-localized polymer layer. This alignment technique is especially useful in uniquely challenging geometry of microcavities created for a recently proposed LC thermal imager. We have shown that we are able to infuse the photoalignment layer into these fully fabricated microcavities.

We further introduced the polymer-stabilization layer into the microcavities by mixing it with the LCs at low weight concentration. We have demonstrated that a polymer layer introduced into a cell in this manner is able to naturally localize in a thin region near the substrate surfaces. We have also shown that this layer significantly improves the robustness of the alignment against subsequent light exposure, regardless of any degradation of the underlying photoalignment layer. The alignment process described in this paper offers the versatility necessary to expand the field of LC photonic devices. In future work, we plan to verify the stability of the alignment of the stabilized microcavities. We are also investigating anchoring energies of both the photoalignment layers and the RMstabilized alignment.

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