Highly Reflective Cholesteric Liquid Crystal Films Based on Nematic Isolation Layers: Broadband Infrared Regulation and Polarization Anti-Counterfeiting Applications

Dengyue Zuo,[a] Mengqi Xie, [a] Jinghao Zhang, [a] Mengying Zhao, [a] Jianhui Qiao, [a] Zhou Yang, [a] Dong Wang, [a] Wanli He, [a] Hui Cao,* [a] and Yinjie Chen* [b]

a. School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing, China.
b. Beijing Engineering Research Center of Printed Electronics, Beijing Institute of Graphic Communication, Beijing, China.

* Corresponding author:
E-mail: caohui@mater.ustb.edu.cn
E-mail: chenyinjie@bigc.edu.cn

Table S1 Composition Ratio and Polymerization Conditions of Right-Handed PSCLC and Intermediate Layer Samples

Sample	SLC-1717/C6M/HCM-006/HCM-083 /I-651/UV-327	UV intensity (mW/cm^2)	Polymerization time(min)
A1	87.1/2.0/2.1/8.0/0.3/0.5	0.5	10
A2	85.1/4.0/2.1/8.0/0.3/0.5	0.5	10
A3	83.1/6.0/2.1/8.0/0.3/0.5	0.5	10
A4	81.1/8.0/2.1/8.0/0.3/0.5	0.5	10
A5	79.1/10.0/2.1/8.0/0.3/0.5	0.5	10
B1	85.5/4.0/2.1/8.0/0.3/0.1	0.5	10
B2	85.3/4.0/2.1/8.0/0.3/0.3	0.5	10
B3	85.1/4.0/2.1/8.0/0.3/0.5	0.5	10
B4	84.9/4.0/2.1/8.0/0.3/0.7	0.5	10
B5	84.7/4.0/2.1/8.0/0.3/0.9	0.5	10
C1	85.1/4.0/2.1/8.0/0.3/0.5	0.2	10
C2	85.1/4.0/2.1/8.0/0.3/0.5	0.5	10
C3	85.1/4.0/2.1/8.0/0.3/0.5	0.8	10
C4	85.1/4.0/2.1/8.0/0.3/0.5	1.1	10
C5	85.1/4.0/2.1/8.0/0.3/0.5	1.4	10
G	89.5/10.0/0/0/0.5/0	0.7	20
H	82.6/4.0/4.6/8.0/0.3/0.5	0.2/0.5/3.0	10

Table S2 Composition Ratio and Polymerization Conditions of Left-Handed PSCLC Samples

Sample	SLC-1717/C6M/S5011/I-651/UV-327	UV intensity (mW/cm^2)	Polymerization time(min)
D1	90.4/8.0/1.0/0.3/0.3	0.9	10
D2	88.4/10.0/1.0/0.3/0.3	0.9	10
D3	86.4/12.0/1.0/0.3/0.3	0.9	10
D4	84.4/14.0/1.0/0.3/0.3	0.9	10
D5	82.4/16.0/1.0/0.3/0.3	0.9	10
E1	86.6/12.0/1.0/0.3/0.1	0.9	10
E2	86.4/12.0/1.0/0.3/0.3	0.9	10
E3	86.2/12.0/1.0/0.3/0.5	0.9	10
E4	86.0/12.0/1.0/0.3/0.7	0.9	10
E5	85.8/12.0/1.0/0.3/0.9	0.9	10
F1	86.4/12.0/1.0/0.3/0.3	0.3	10
F2	86.4/12.0/1.0/0.3/0.3	0.6	10
F3	86.4/12.0/1.0/0.3/0.3	0.9	10
F4	86.4/12.0/1.0/0.3/0.3	1.2	10
F5	86.4/12.0/1.0/0.3/0.3	1.5	10
I	85.2/12.0/2.2/0.3/0.3	0.3/0.9	10
J	85.0/12.0/2.4/0.3/0.3	0.9/3.0	10

Table S3 Optimal Polymerization Conditions for the Right-and Left-Handed PSCLC System

Sample	SLC-1717/C6M/HCM-006/HCM-083/S5011 /I-651/UV-327	UV intensity (mW/cm^2)	Polymerization time(min)
M1			5
M2			10
M3	85.1/4.0/2.1/8.0/0/0.3/0.5	0.5	15
M4			20
M5			25
N1			8
N2			10
N3	86.4/12.0/0/0/1.0/0.3/0.3	0.9	12
N4			14
N5			16

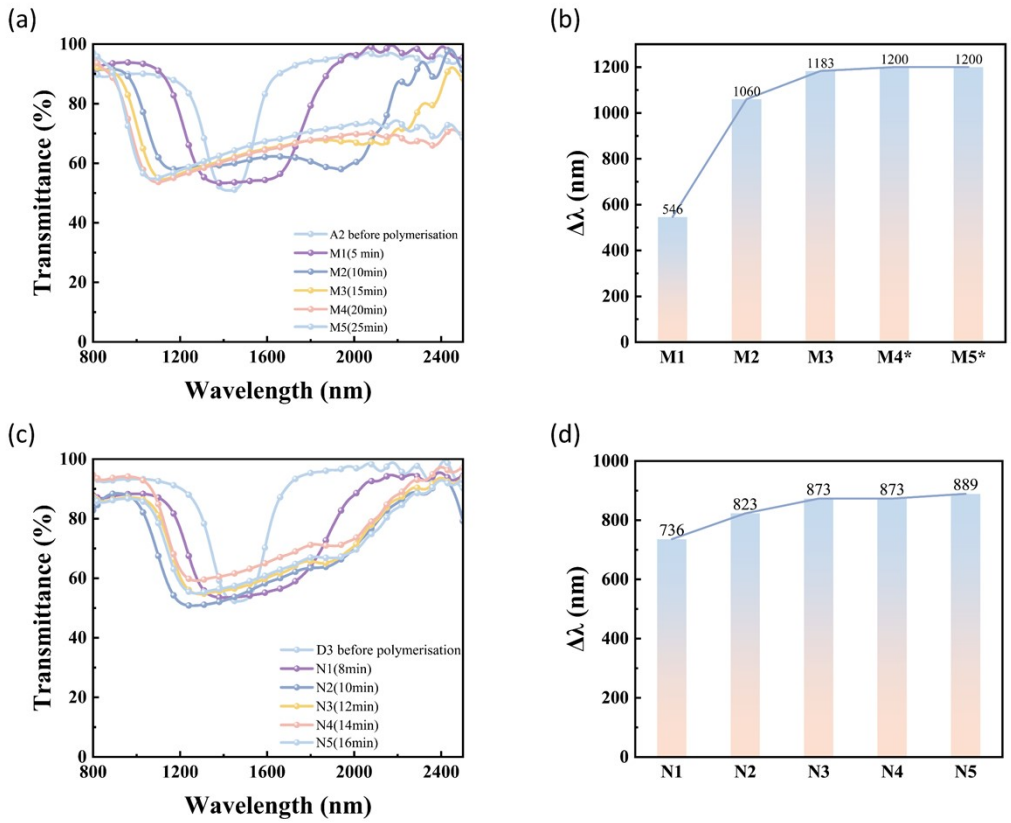

Fig. S1 Transmission spectra of A2 at different polymerization times (a) and the corresponding reflection bandwidths (b); transmission spectra of D3 at different polymerization times (c) and the corresponding reflection bandwidths (d).

Table S3 presents the investigation of the optimal polymerization time for left-handed and right-handed PSCLCs. For the right-handed PSCLC system, a reflection bandwidth of 1060 nm was achieved after polymerizing for 10 min. The reflection bands of samples M4 and M5 exceed the measurement range of the instrument, but the bandwidth of their reflection peaks is wider than that of M3, which is temporarily recorded as 1200 nm. Although the reflection band continued to broaden with extended polymerization time, the reflectance quality deteriorated. Therefore, the polymerization conditions were selected as 0.5 mW/cm² for 10 min. For the left-handed PSCLC system, the reflection bandwidth gradually increased with polymerization time and eventually reached a plateau; thus, the polymerization conditions were also chosen as 0.9 mW/cm² for 10 min. The corresponding UV transmission spectra and reflection bandwidths are shown in Fig. S1.

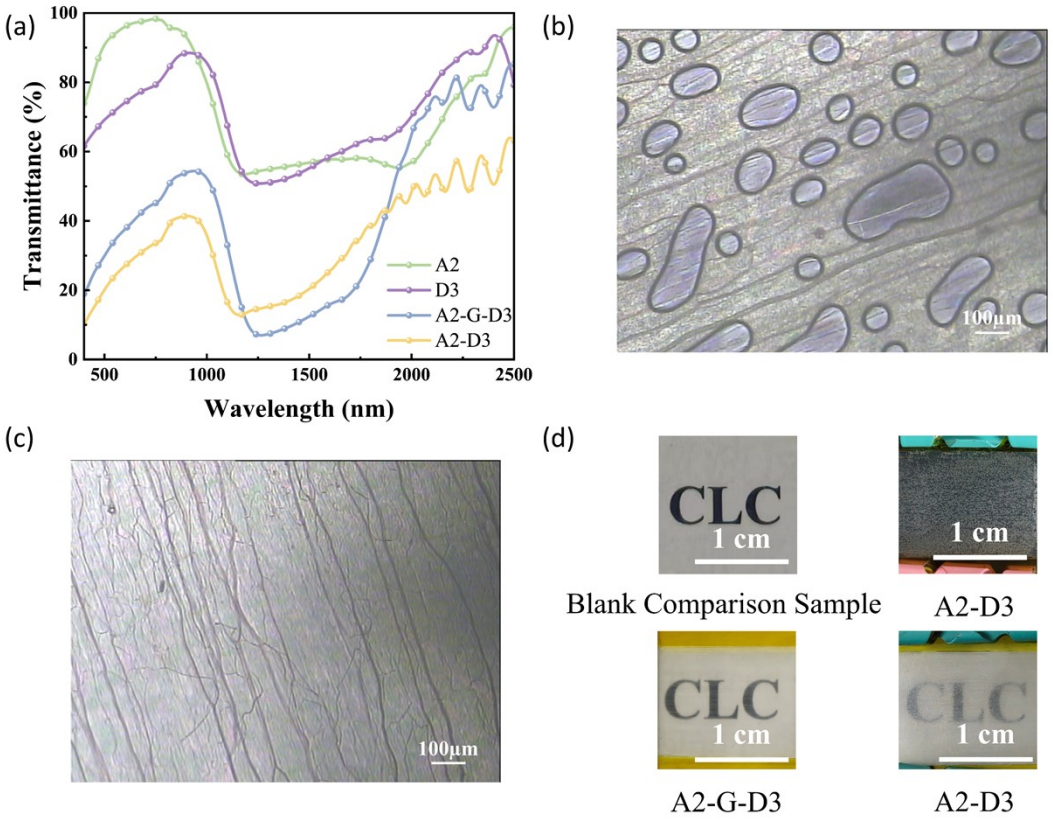

Fig. S2 (a)Transmission spectra of A2, D3, A2-G-D3, and A2-D3; (b) Polarized optical micrographs of A2-D3; (c) Polarized optical micrographs of A2-G-D3; (d) Digital photographs of the blank comparison sample, A2-D3, and A2-G-D3.

We provide the transmission spectrum, polarized micrographs, and digital photographs of the PSCLC film A2-D3 fabricated by direct stacking of left- and right-handed reflective PSCLC. The transmission spectrum of A2-D3 reveals that although its reflectance is higher than 50%, both the reflectance magnitude and reflection bandwidth are inferior to those of A2-G-D3 infiltrated with polymer-stabilized nematic liquid crystal layer. Both the digital photograph and polarized optical micrograph of A2-D3 clearly reveal the presence of numerous air bubbles between the two film layers, resulting in a dramatic decline in transmittance in the visible region. Consequently, the optical performance of A2-D3 obtained by directly stacking left- and right-handed reflective PSCLCs is considerably poorer than that of polymer nematic liquid crystal-infiltrated A2-G-D3.

Table S4 The temperature changes and statistical errors of the Blank Comparison Sample, A2, D3, and A2-G-D3

Time	Blank Comparison Sample		A2		D3		A2-G-D3	
	Average	S.D.	Average	S.D.	Average	S.D.	Average	S.D.
0	23.1	0	23.1	0	23.1	0	23.1	0
2	23.93333	0.15275	23.5	0.1	23.63333	0.05774	23.26667	0.05774
4	24.7	0.17321	24.13333	0.05774	24.23333	0.05774	23.56667	0.15275
6	25.56667	0.15275	24.66667	0.11547	24.76667	0.11547	23.9	0.1
8	26.3	0.1	25.16667	0.05774	25.26667	0.05774	24.2	0.1
10	27.03333	0.15275	25.53333	0.05774	25.73333	0.20817	24.56667	0.11547
12	27.46667	0.20817	25.83333	0.05774	26.13333	0.11547	24.76667	0.11547
14	28	0.26458	26.03333	0.11547	26.36667	0.20817	24.96667	0.05774
16	28.53333	0.25166	26.2	0.1	26.53333	0.25166	25.13333	0.05774
18	28.86667	0.20817	26.26667	0.05774	26.76667	0.25166	25.2	0.1
20	29.16667	0.20817	26.33333	0.11547	26.9	0.2	25.2	0.1
22	29.46667	0.20817	26.4	0.1	27.03333	0.15275	25.3	0.1
24	29.56667	0.20817	26.5	0.1	27.13333	0.15275	25.33333	0.05774
26	29.73333	0.32146	26.53333	0.11547	27.16667	0.15275	25.4	0.1
28	29.83333	0.32146	26.56667	0.05774	27.23333	0.15275	25.43333	0.05774
30	29.9	0.26458	26.66667	0.05774	27.3	0.1	25.5	0.1

In the infrared thermal insulation experiment, three independent replicate experiments were conducted for each sample. The mean values and standard deviations (S.D.) of the measured temperatures at different times are presented in Table S4.

Table S5 Composition ratios of right-handed PSCLC samples

Sample	SLC-1717/C6M/HCM-006/HCM-083 /I-651/UV-327	UV intensity (mW/cm^2)	Polymerization time(min)
A2	87.1/4.0/2.1/8.0/0.3/0.5	0.5	10
A6	84.2/4.0/3.0/8.0/0.3/0.5	0.5	10
A7	83.7/4.0/3.5/8.0/0.3/0.5	0.5	10
A8	83.2/4.0/4.0/8.0/0.3/0.5	0.5	10
H	82.6/4.0/4.6/8.0/0.3/0.5	0.5	10

Table S6 Composition ratios of left-handed PSCLC samples.

Sample	SLC-1717/C6M/S5011/I-651/UV-327	UV intensity (mW/cm^2)	Polymerization time(min)
D3	86.4/12.0/1.0/0.3/0.3	0.9	10
D6	86.0/12.0/1.4/0.3/0.3	0.9	10
D7	85.6/12.0/1.8/0.3/0.3	0.9	10
D8	85.5/12.0/1.9/0.3/0.3	0.9	10
I	85.2/12.0/2.2/0.3/0.3	0.9	10
J	85.0/12.0/2.4/0.3/0.3	0.9	10

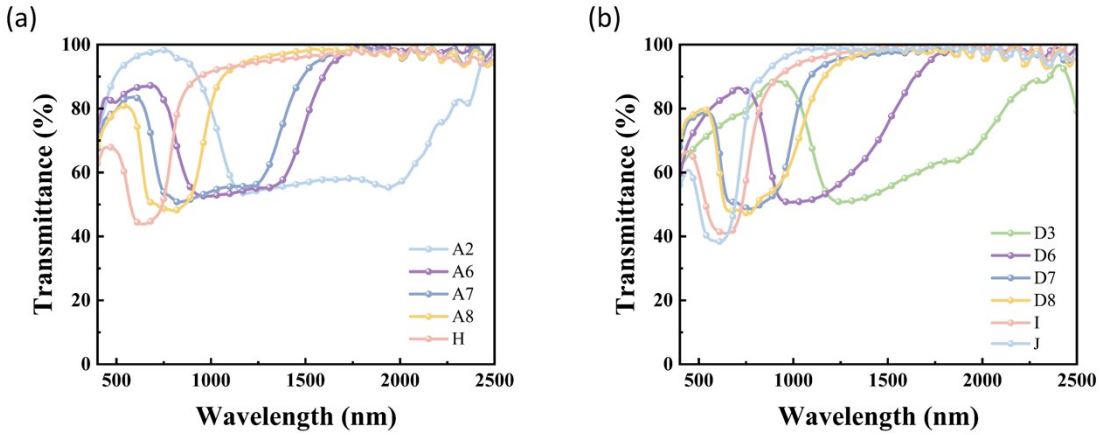

Fig. S3 (a) Transmission spectra of samples with different HCM-006 concentrations; (b) Transmission spectra of samples with different S5011 concentrations.

Figure S3(a) shows the transmission spectra of the right-handed system after varying the chiral compound concentration; the corresponding sample compositions are listed in Table S5. Varying the chiral compound concentration affects not only the position of the reflection peak but also the reflection bandwidth of the system. According to the formula $P=[(HTP)\cdot c]^{-1}$, an increase in the

chiral compound concentration reduces the helical pitch of the system, leading to a blue shift of the reflection peak. Concurrently, the increased amount of chiral dopant diminishes the concentration gradient formed during photopolymerization-induced molecular diffusion, thereby resulting in a narrower reflection bandwidth. Similarly, in the left-handed system, increasing the S5011 concentration also induces a blue shift of the reflection peak and a reduction in the reflection bandwidth.