Supporting Information

Cholesteric Liquid Crystal Microcapsules Exhibiting Triple Response and Dual-Mode Dynamic Regulation for Information Encryption

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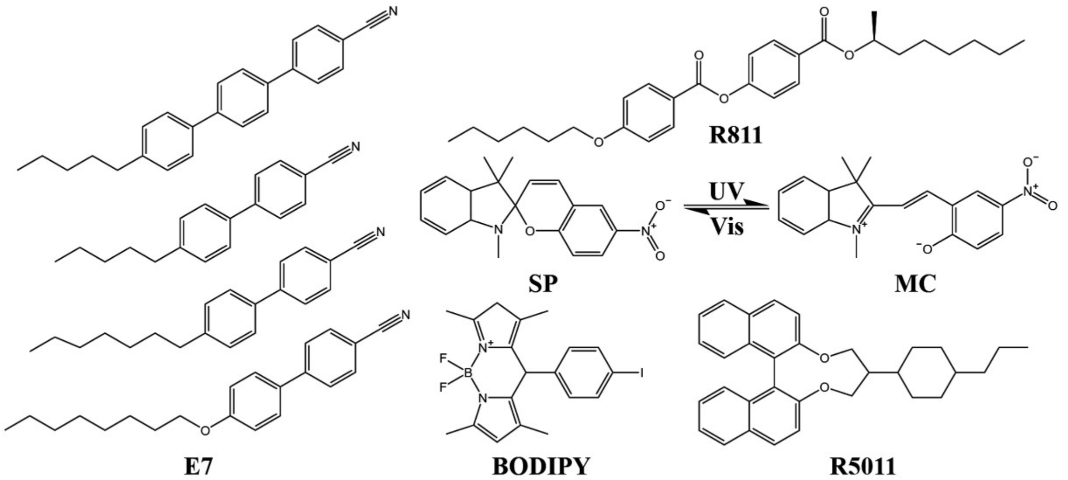

Fig. S1. Structural formulae of the main materials.

The core rationale for co-doping the two chiral dopants R811 and R5011 lies in their significant functional complementarity in terms of helical twisting power (HTP) and temperature-responsive behavior, which effectively addresses the inherent limitations of using a single dopant in thermochromic cholesteric liquid crystals (CLCs).

R811 exhibits excellent temperature sensitivity in its HTP, endowing CLCs with a broad temperature response range—this is critical for achieving wide-range thermochromism. However, when used alone, a relatively high doping concentration of R811 is required to tune the helical pitch into the visible wavelength region. In contrast, R5011 possesses an ultra-high HTP value, enabling the selective reflection wavelength of CLCs to quickly fall within the visible range with an extremely low doping concentration, thus exhibiting much higher doping efficiency.

Thus, this co-doping strategy fully integrates the advantages of both dopants. While retaining the broad temperature response range of the system and ensuring reliable dynamic regulation performance of thermochromism imparted by R811, the ultra-high HTP of R5011 significantly reduces the total doping concentration of chiral dopants. This not only minimizes material consumption but also avoids issues such as phase separation and reduced system compatibility caused by high concentrations of a single dopant. Consequently, the prepared thermochromic CLCs feature a broad temperature response range, which is more aligned with practical application requirements.

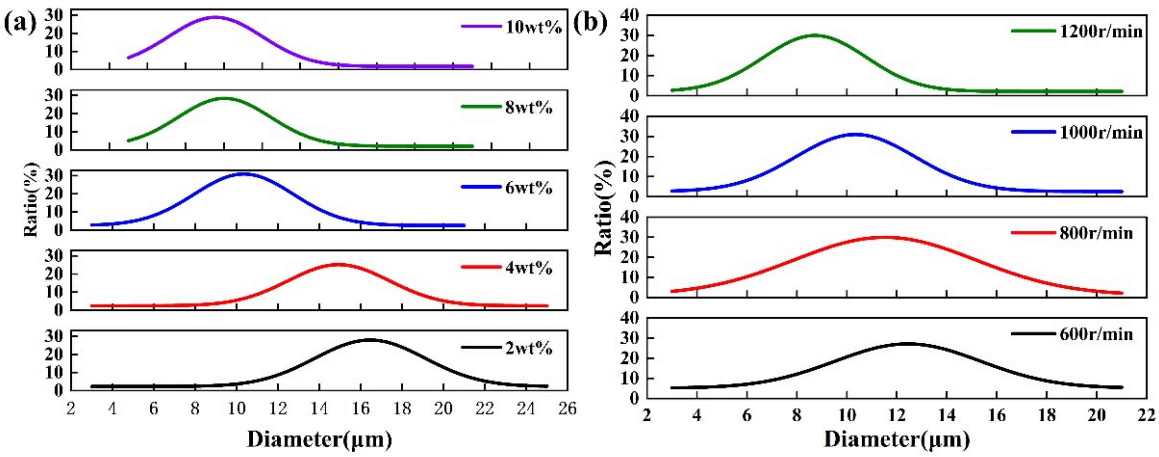

Fig. S2. Effect of PVA solution concentration (a) and stirring speed (b) on the particle size of CLCMs.

In this study, PVA-0588 with a degree of polymerization of 500, an alcoholysis degree of 88%, and a molecular weight of approximately 22000 g/mol was used as the emulsifier. Commercially available PVA grades such as PVA-0588, PVA-1788, and PVA-2488 show a successive increase in polymerization degree. PVA with a high polymerization degree can stabilize emulsions at relatively low concentrations due to its stronger steric hindrance effect and higher solution viscosity, but its effective concentration range for stable emulsification is rather narrow. In contrast, PVA with a low polymerization degree provides a wider concentration tuning window, which is more suitable for systematically investigating the influence of PVA concentration on the preparation of microcapsules. For this reason, PVA-0588 was selected for the relevant experiments in this work.

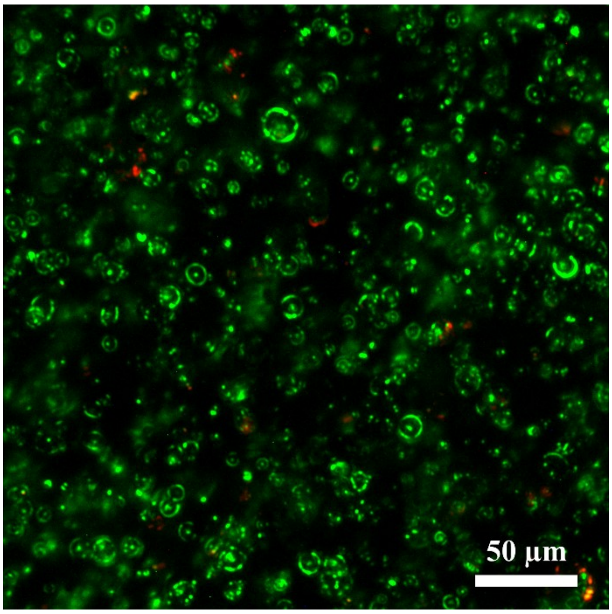

Fig. S3. POM image of dried CLCMF.

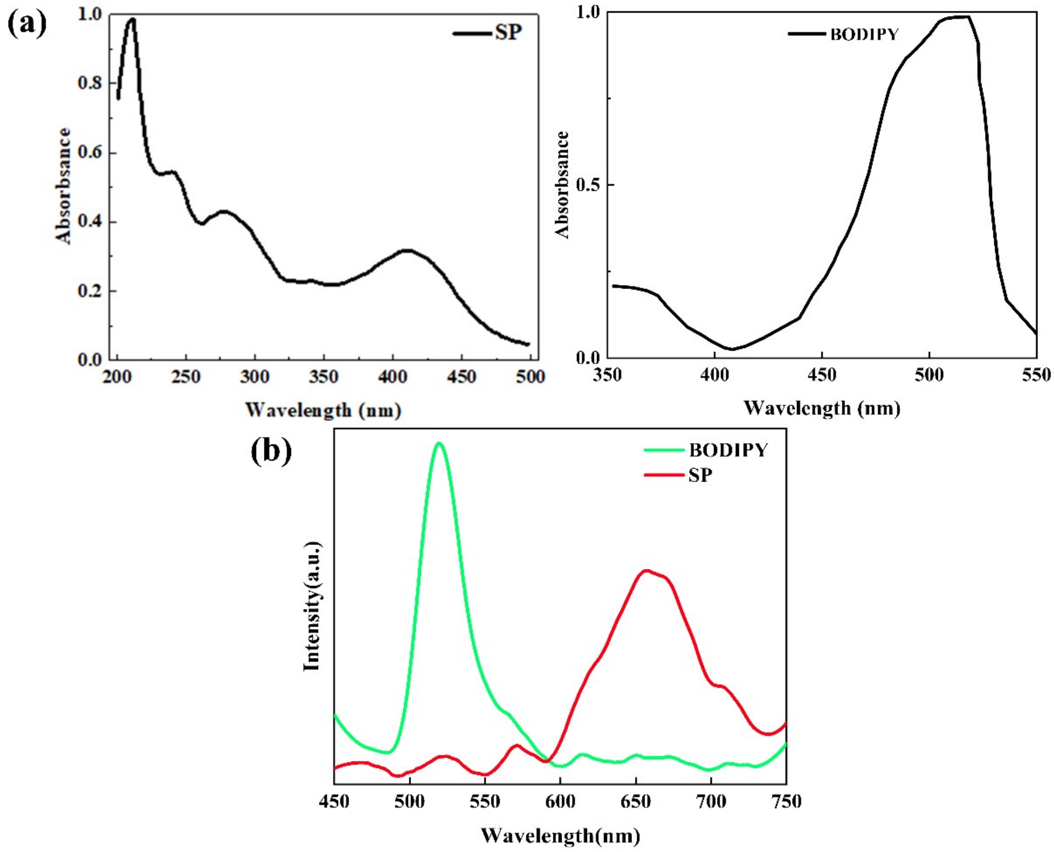

Fig. S4. Fluorescence absorption spectra (a) and emission spectra (b) of SP and BODIPY.

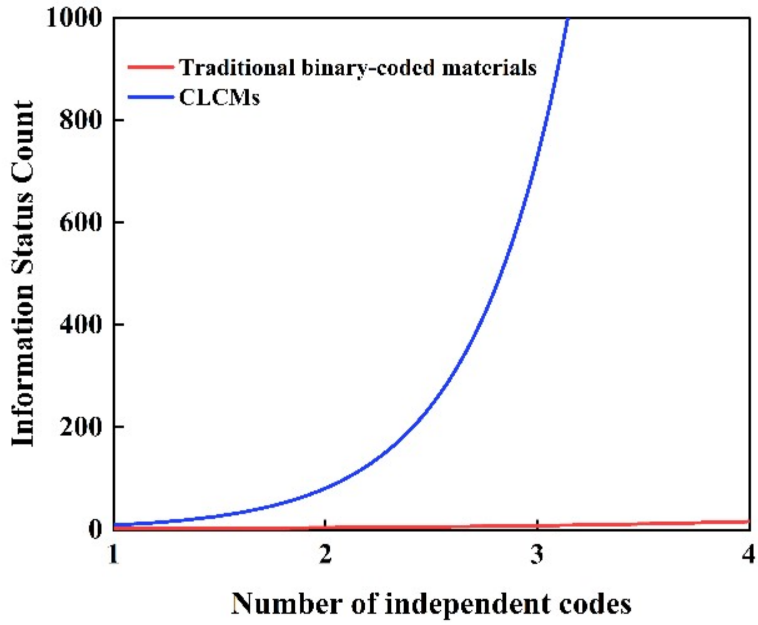

Fig. S5. Number of information states in series with CLCMs versus multiple traditional binary-encoded materials

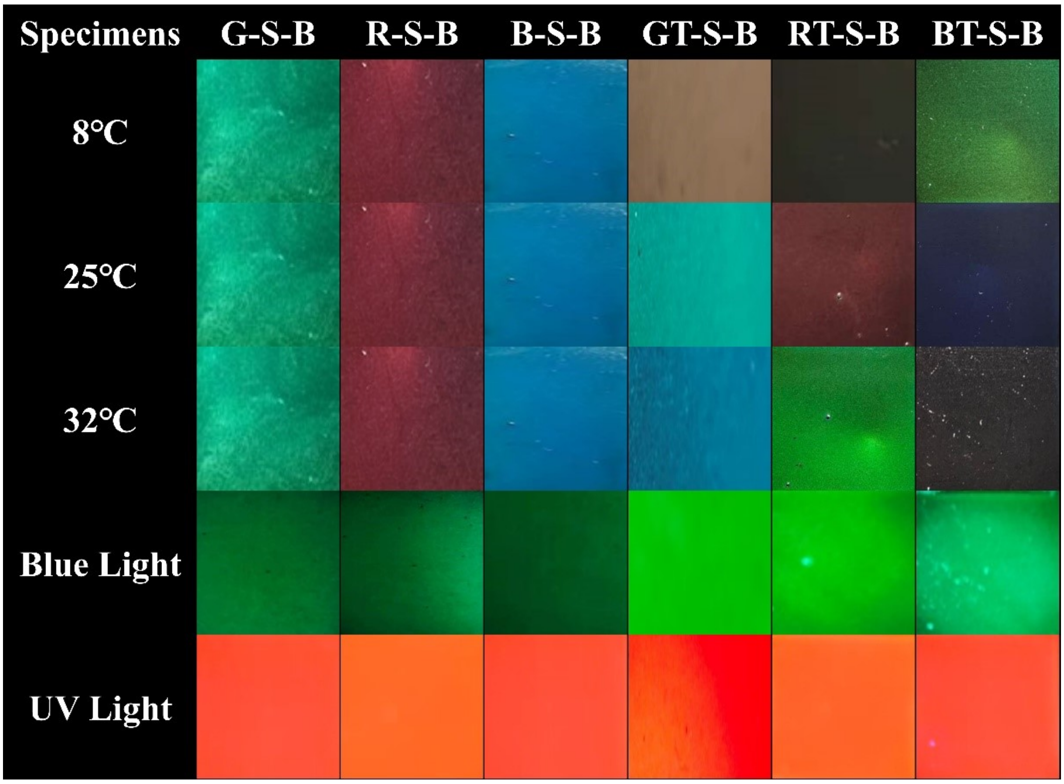

Fig. S6. Stimulus-response behavior of different CLCMs used for information encryption coding.

Table S1. Material Proportions (wt.%) for CLCMs with Different Response Behaviors

	E7	R5011	R811	SP	BODIPY	MMA
G-S-B	97.5	2.5		2	0.1	100
R-S-B	97.9	2.1		2	0.1	100
B-S-B	97	3.0		2	0.1	100
GT-S-B	78.98	1.02	20	2	0.1	100
RT-S-B	79.4	0.6	20	2	0.1	100
BT-S-B	78.3	1.7	20	2	0.1	100

Table S2. Parametric indicators of various cryptographic materials reported in the literature.

Category	Number of optical modes	Stimulus-response count	Visible structural color count	Visible fluorescence number	Optical state number	Ref.
Hydrogel	2	2	4	1	4	[29]
	2	1	3	1	3	[35]
Photon Capsule	1	1	-	3	3	[36]
Photonic crystal	1	3	5	-	5	[37]
	2	1	1	1	1	[38]
	2	3	4	1	4	[39]
CLCMs	2	1	3	1	3	[30]
	1	1	6	-	6	[34]
	1	2	5	-	5	[40]
	2	2	1	1	1	[41]
	2	1	1	1	1	[42]
	2	1	1	1	1	[43]
Triple-mode CLCM	2	3	3	3	9	**This work**

Table S3. ASCII characters corresponding to decoding results

S	ASCII characters	S	ASCII characters	S	ASCII characters
32	(space)	64	@	96	`
33	!	65	A	97	a
34	"	66	B	98	b
35	#	67	C	99	c
36	$	68	D	100	d
37	%	69	E	101	e
38	&	70	F	102	f
39	'	71	G	103	g
40	(	72	H	104	h
41	)	73	I	105	i
42	*	74	J	106	j
43	+	75	K	107	k
44	,	76	L	108	l
45	-	77	M	109	m
46	.	78	N	110	n
47	/	79	O	111	o
48	0	80	P	112	p
49	1	81	Q	113	q
50	2	82	R	114	r
51	3	83	S	115	s
52	4	84	T	116	t
53	5	85	U	117	u
54	6	86	V	118	v
55	7	87	W	119	w
56	8	88	X	120	x
57	9	89	Y	121	y
58	:	90	Z	122	z
59	;	91	[	123	{
60	<	92	\	124	|
61	=	93	]	125	}
62	>	94	^	126	~
63	?	95	_		