

## **Yellow emissive and high fluorescence quantum yield carbon dots from perylene-3,4,9,10-tetracarboxylic dianhydride for anticounterfeiting applications**

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### **SUPPLEMENTARY FIGURES**

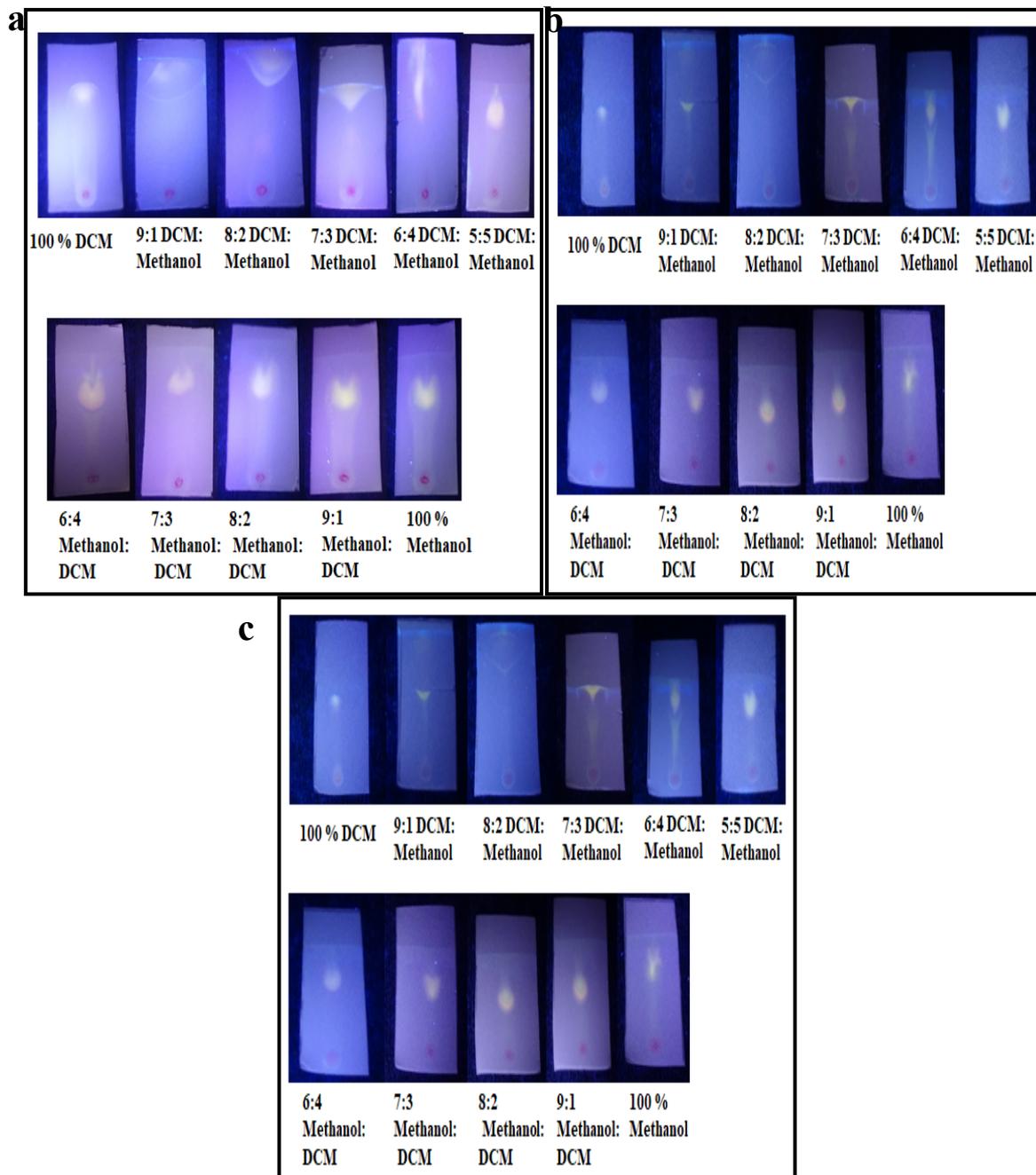
- SF1:** TLC separation observed for different elution system observed for (a) ML-1, (b) ML-3 and (c) ML-5 samples.
- SF2:** (a) Column chromatography separation for ML-1 with respect to increasing polarity of the solvent. The six eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).
- SF3:** (a) Column chromatography separation for ML-3 with respect to increasing polarity of the solvent. The four eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).
- SF4:** (a) Column chromatography separation for ML-5 with respect to increasing polarity of the solvent. The three eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).
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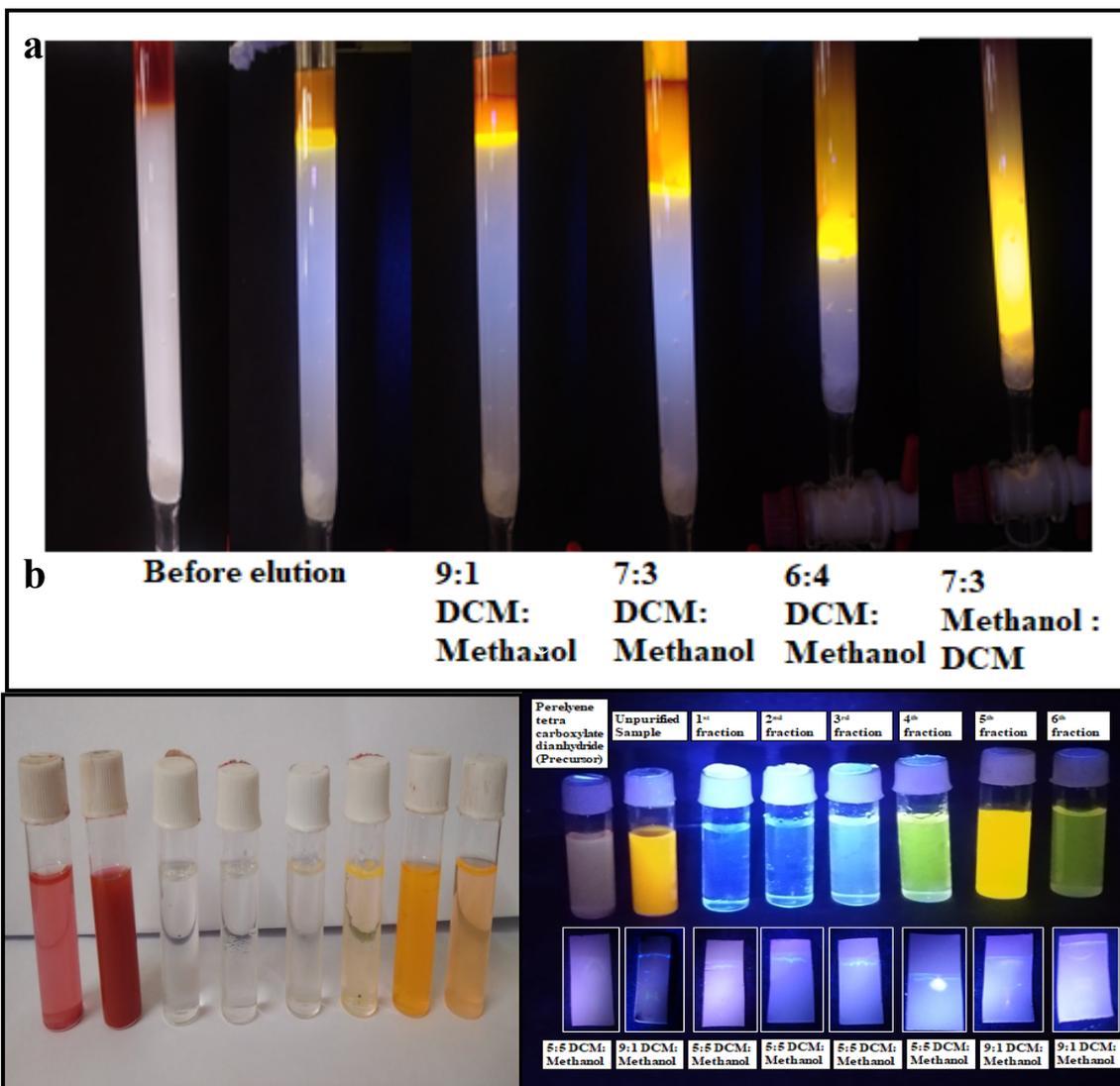
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- 1. ST1:** Retention time values corresponding to different fractions of ML-1 to ML-5 during column chromatography.
- 2. ST2:** Individual lifetime values for fourth fraction.
- 3. ST3:** Individual lifetime values for fifth fraction.
- 4. ST4:** Individual lifetime values for sixth fraction.
- 5. ST5:** Radiative ( $k_r$ ) and non-radiative rate ( $k_{nr}$ ) constant associated during fluorescence phenomenon.
- 6. ST6:** Values for  $2\theta$  and corresponding planes of diffraction of Graphite (2H) carbon.
- 7. ST7:** Raman shift values for PTCDA, NMP and fifth fraction acquired at 785 nm excitation.
- 8. ST8:** FT-IR peak values of PTCDA, NMP, ML-1 and fifth fraction.
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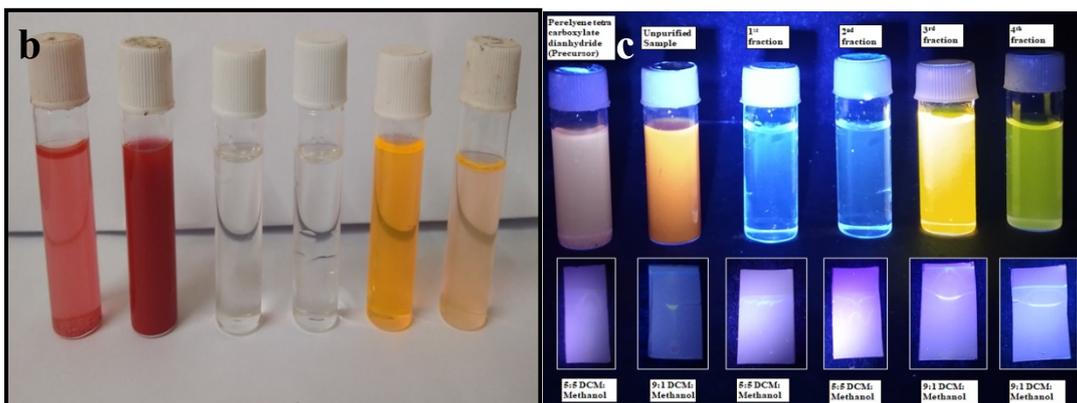
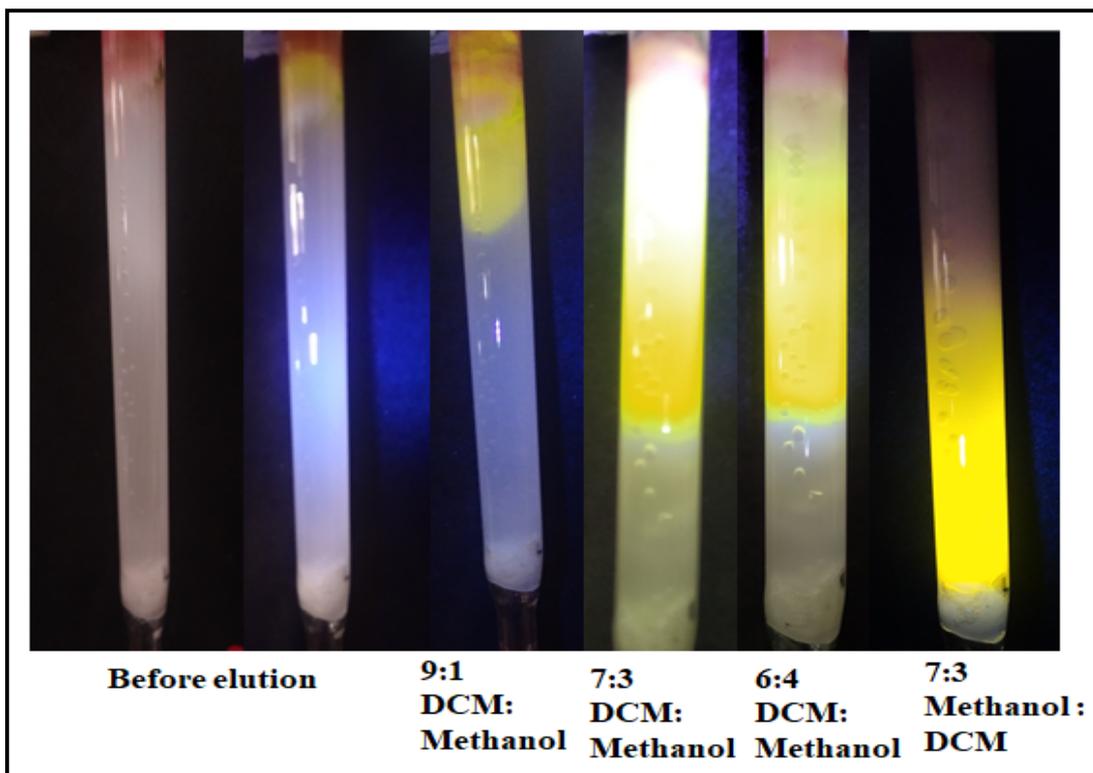


**SF1:** TLC separation observed for different elution system observed for (a) ML-1, (b) ML-3 and (c) ML-5 samples.

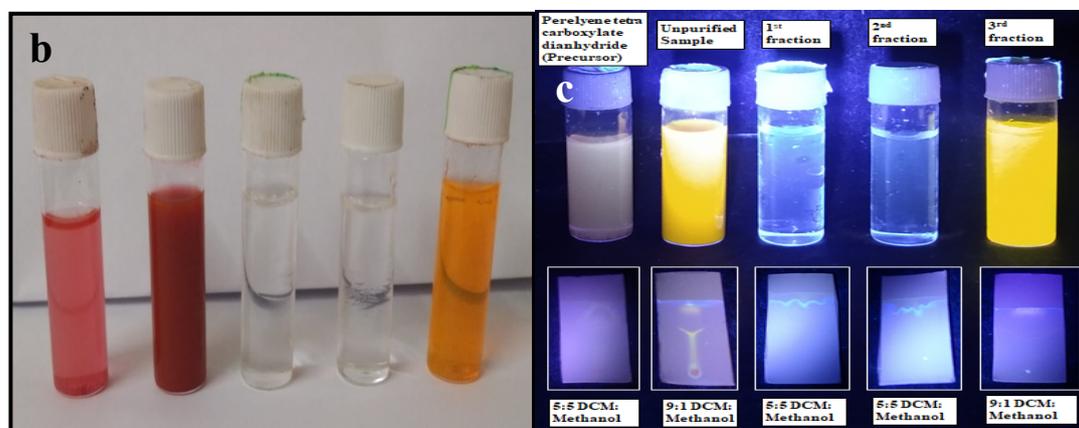
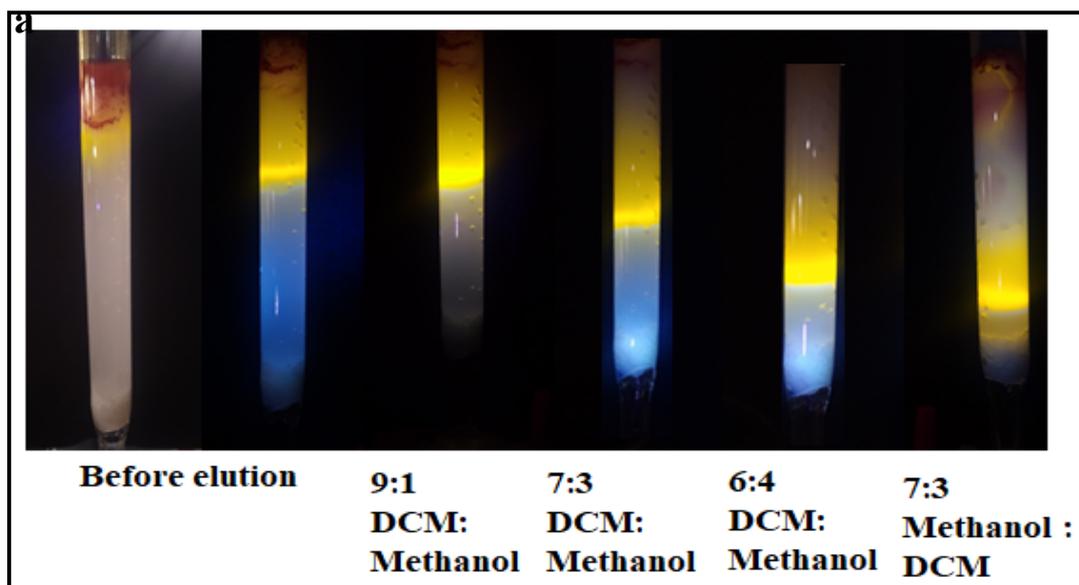


**SF2:** (a) Column chromatography separation for ML-1 with respect to increasing polarity of the solvent. The six eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).

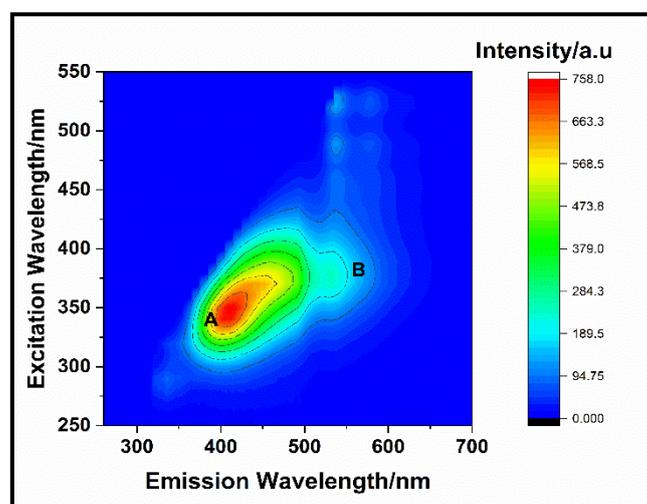
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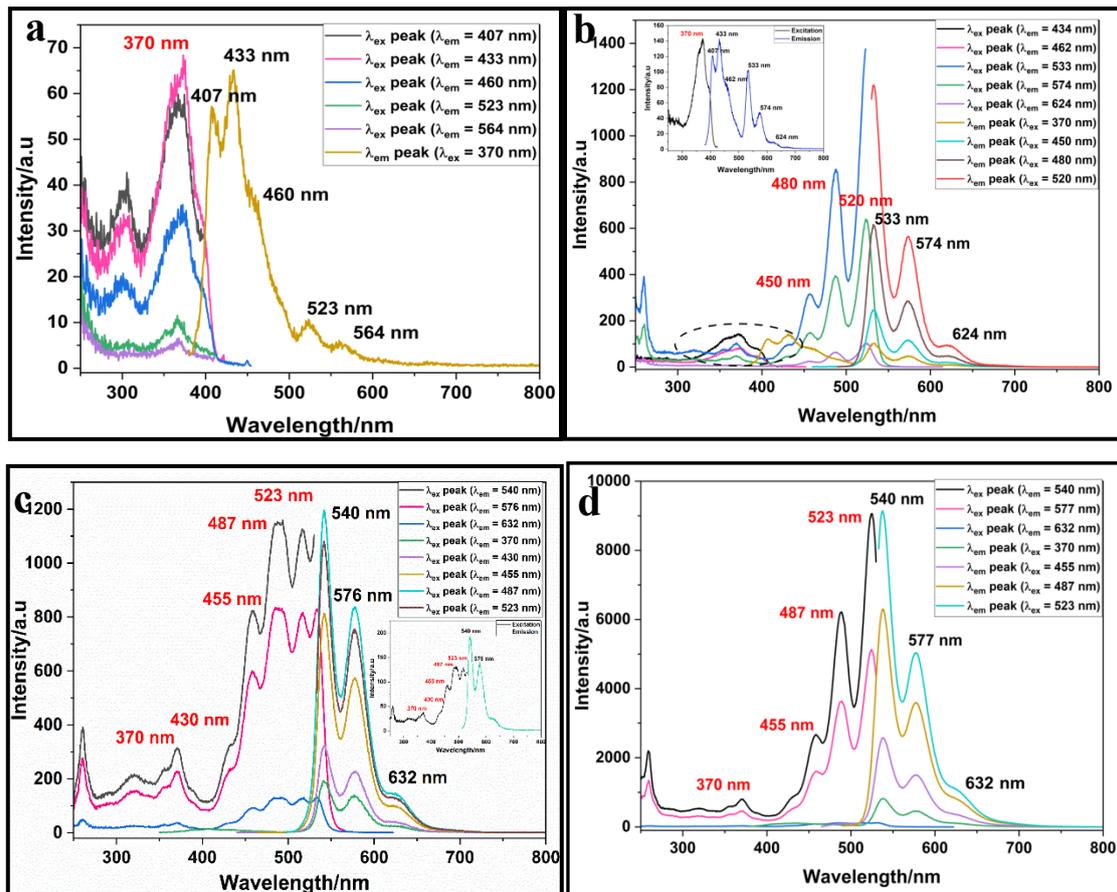
**SF3:** (a) Column chromatography separation for ML-3 with respect to increasing polarity of the solvent. The four eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).



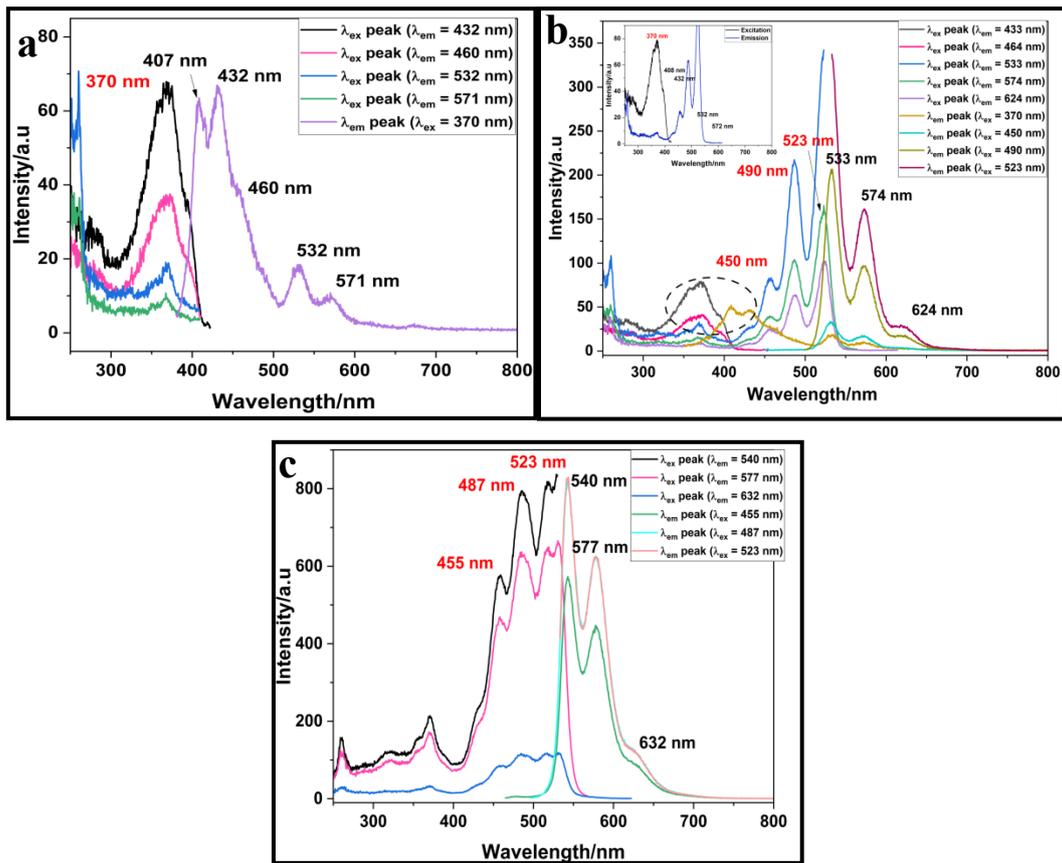
**SF4:** (a) Column chromatography separation for ML-5 with respect to increasing polarity of the solvent. The three eluted fractions placed beside precursor and ML sample viewed under (b) daylight and (c) UV light (inset displays TLC separations for different fractions).



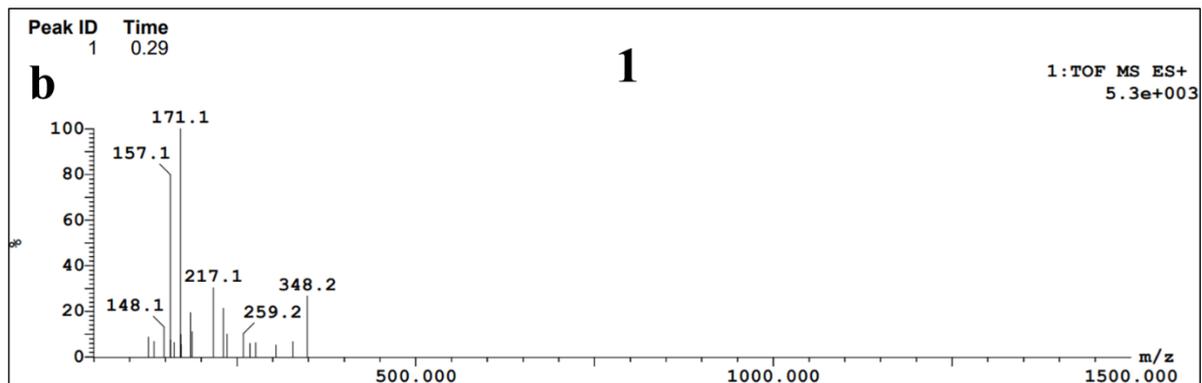
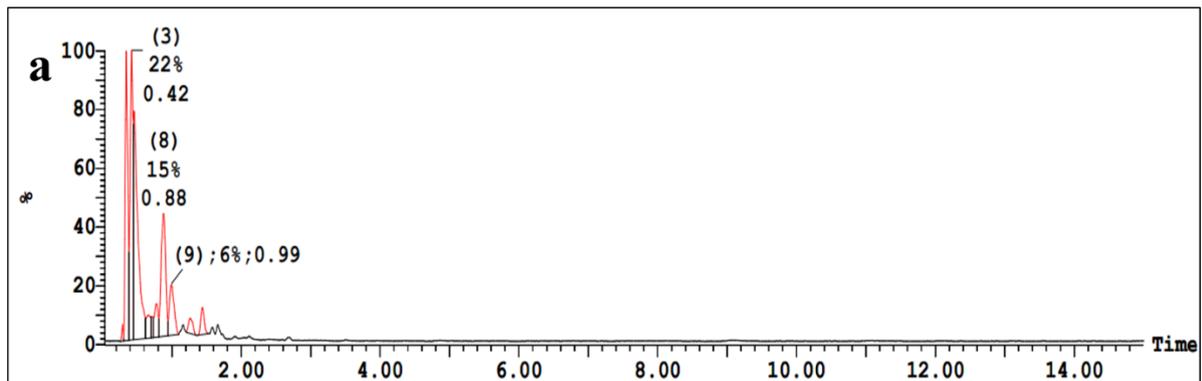
**SF5:** 3D photoluminescence spectra of NMP.

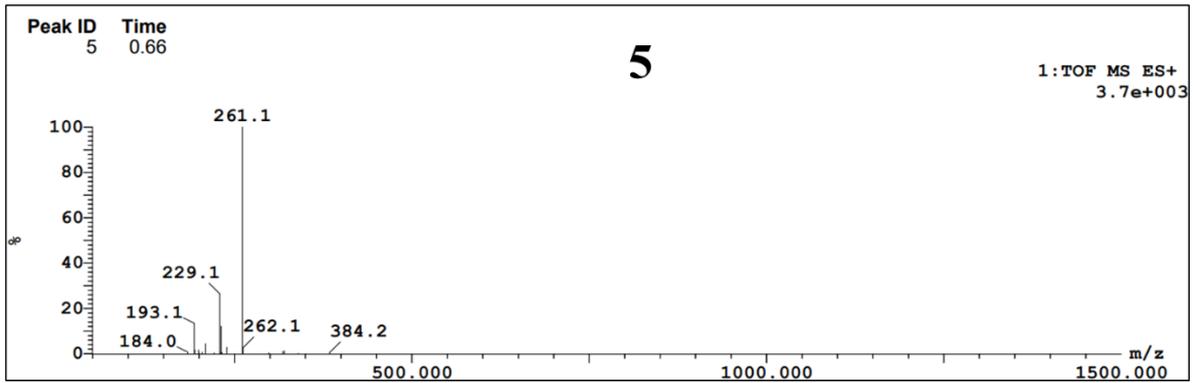
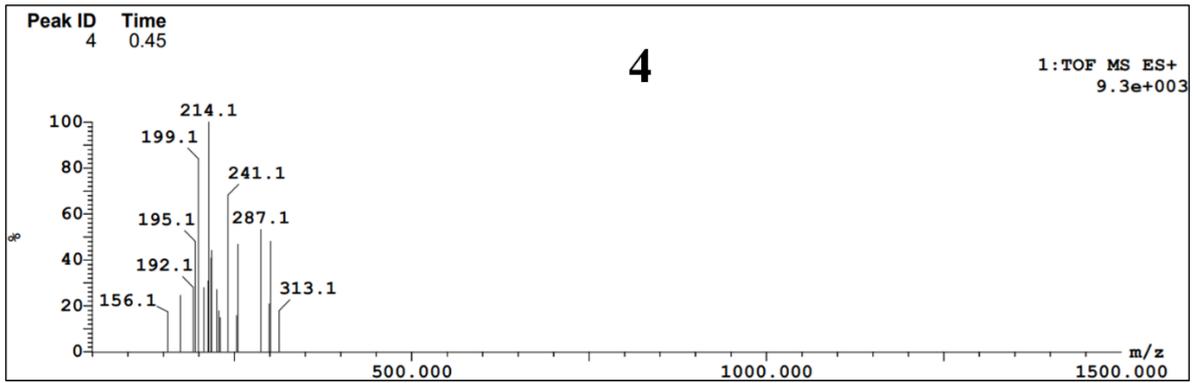
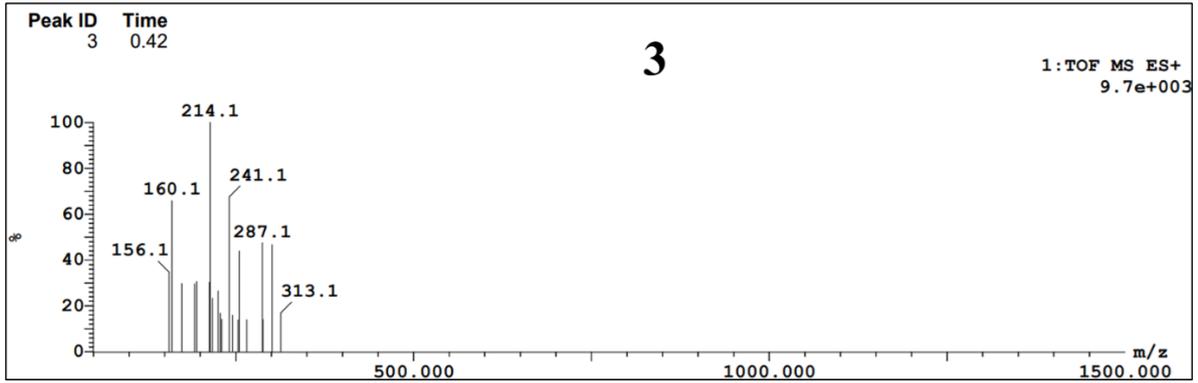
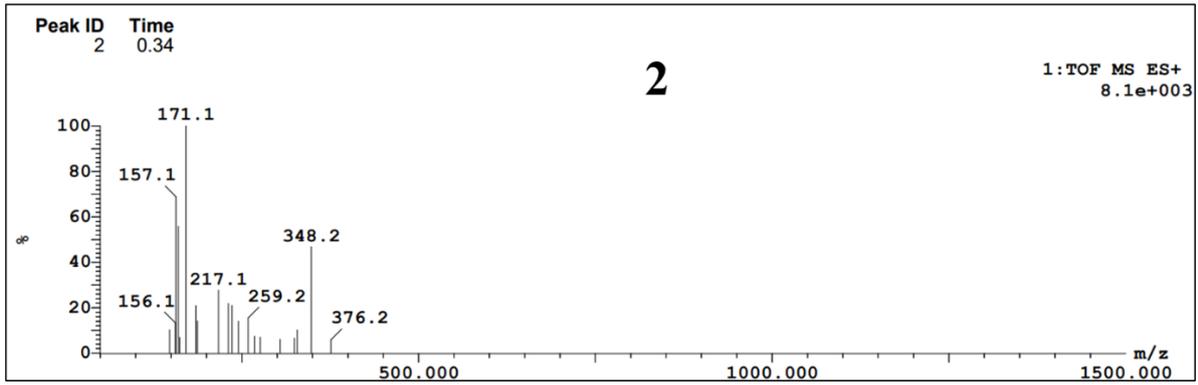


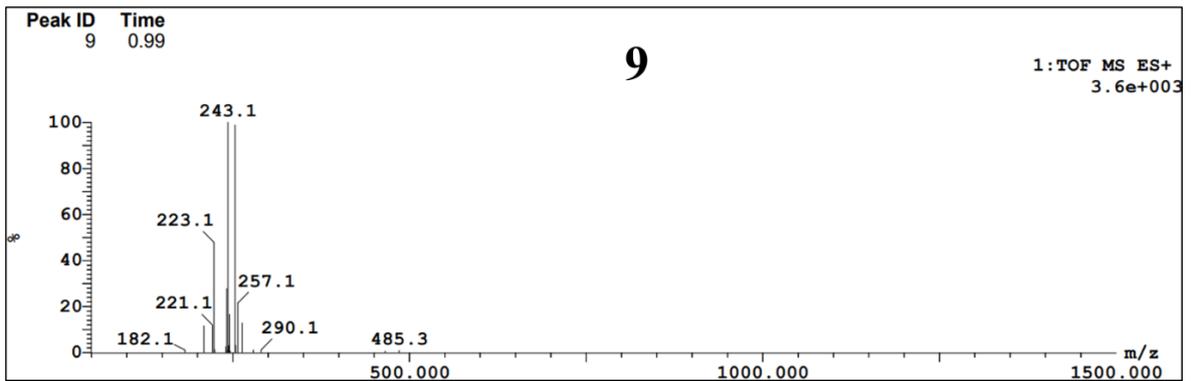
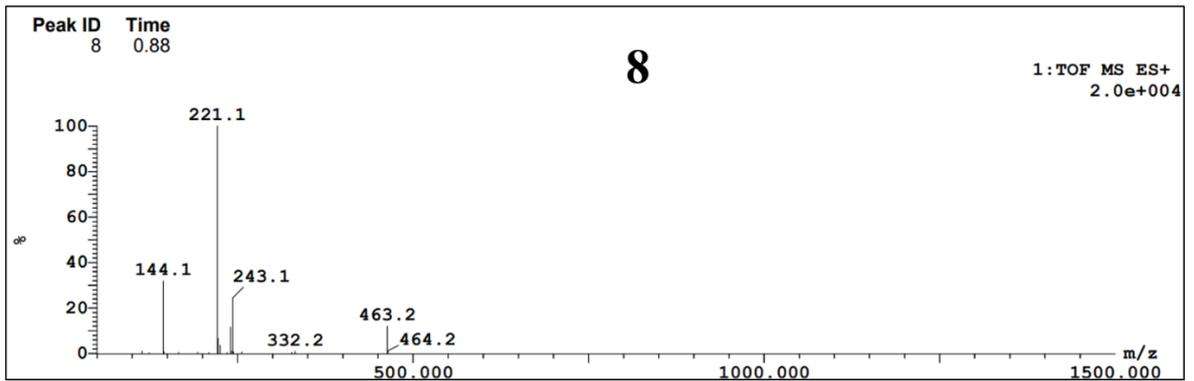
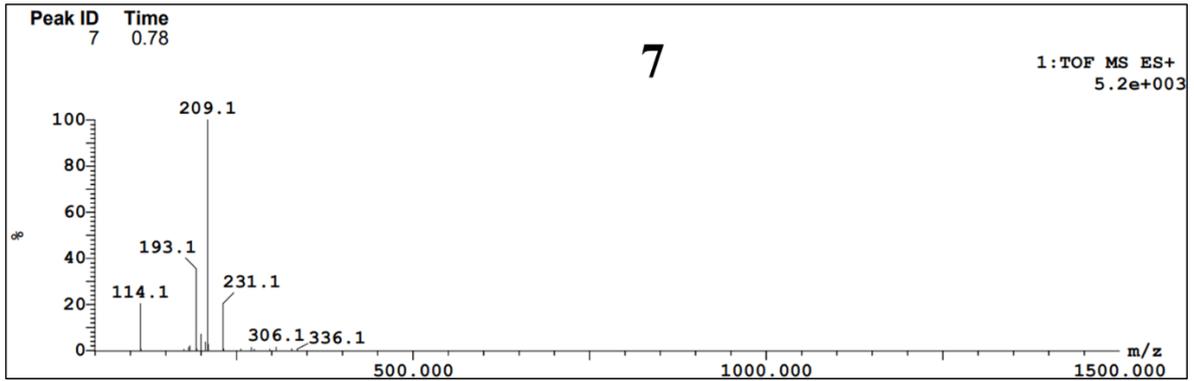
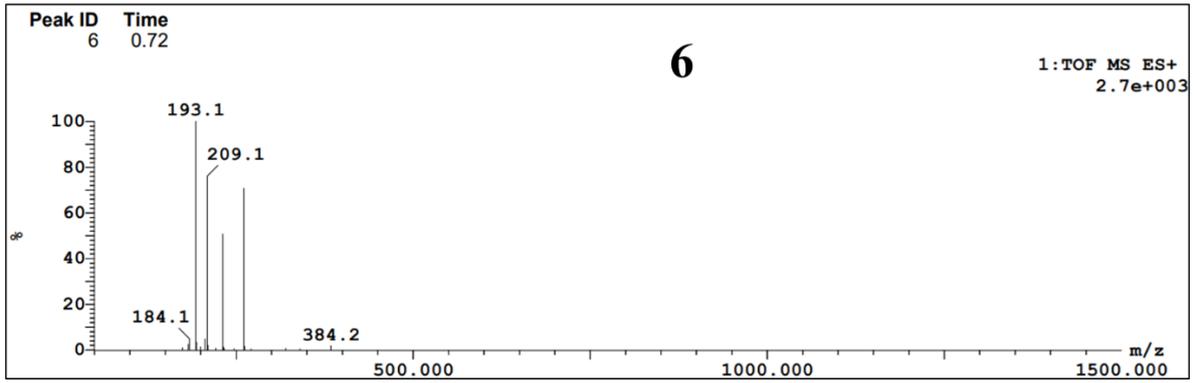
SF6: Photoluminescence spectra of (a) first, (b) second, (c) third and (d) fourth fractions corresponding to ML-3.

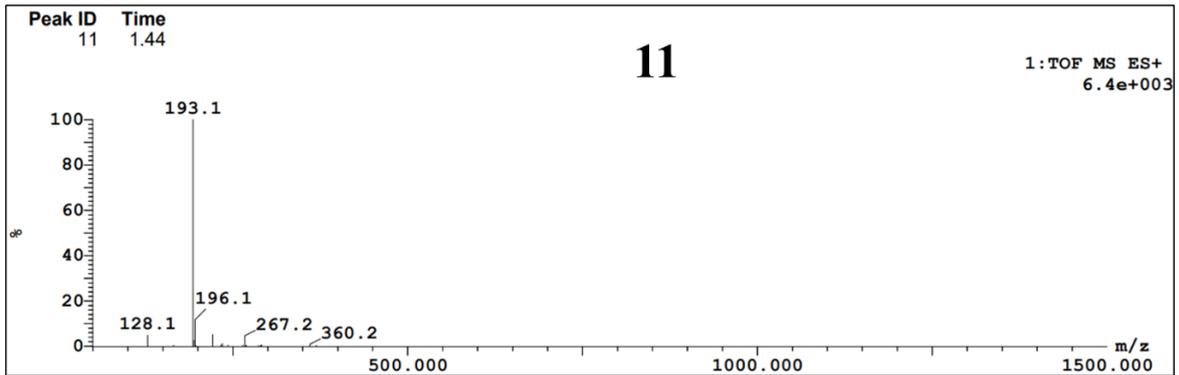
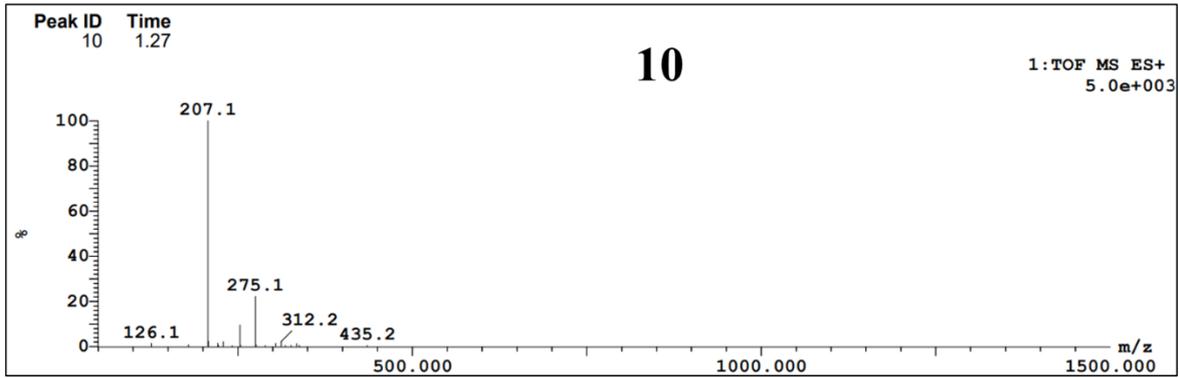


SF7: Photoluminescence spectra of (a) first, (b) second and (c) third fractions corresponding to ML-5.

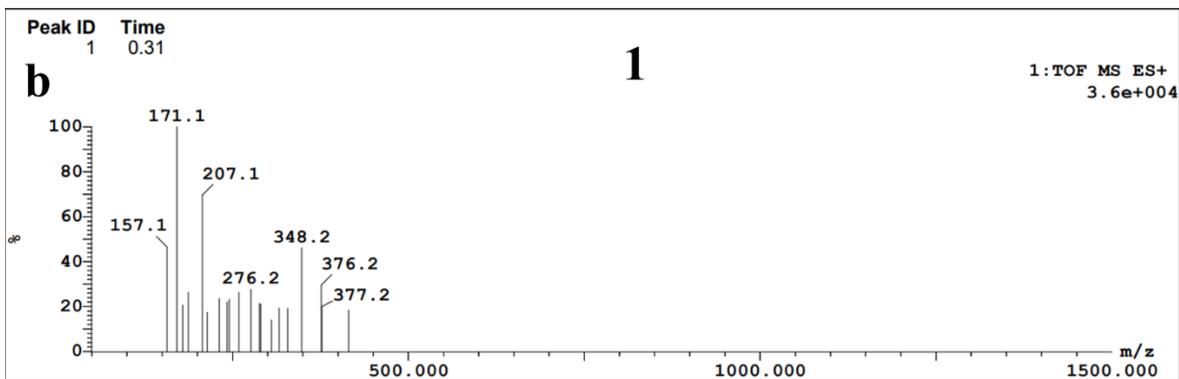
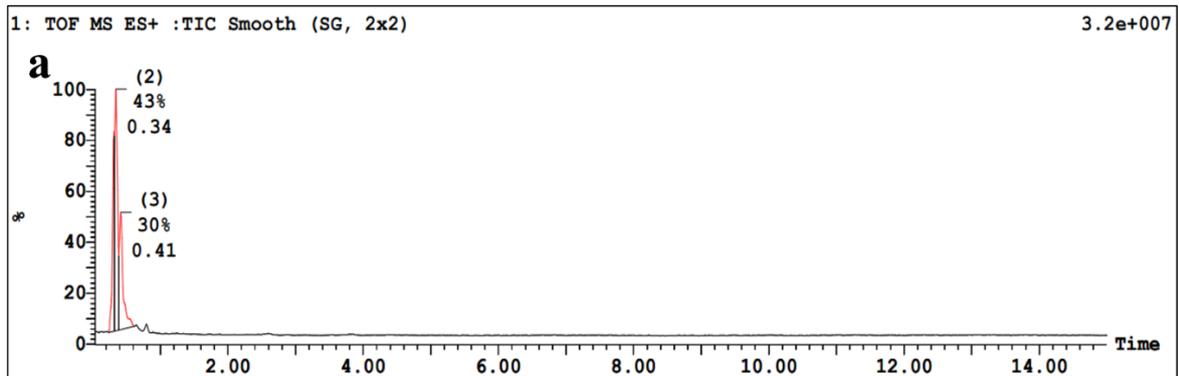


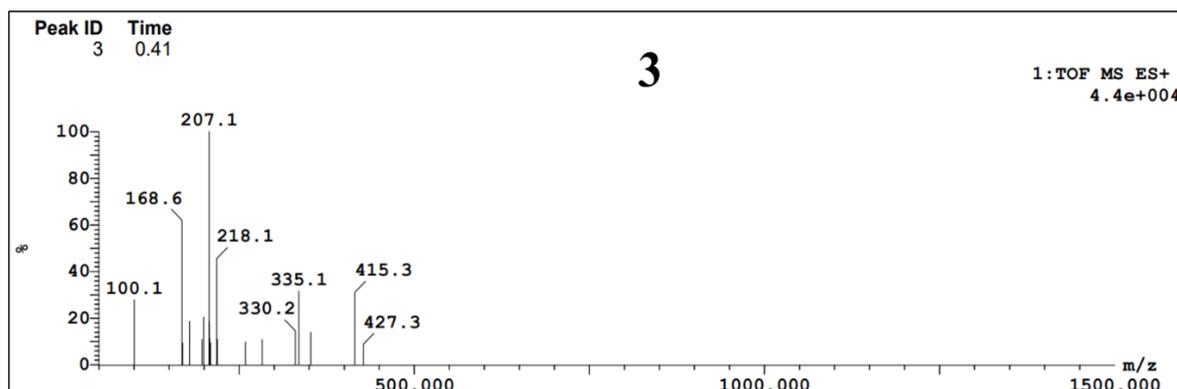
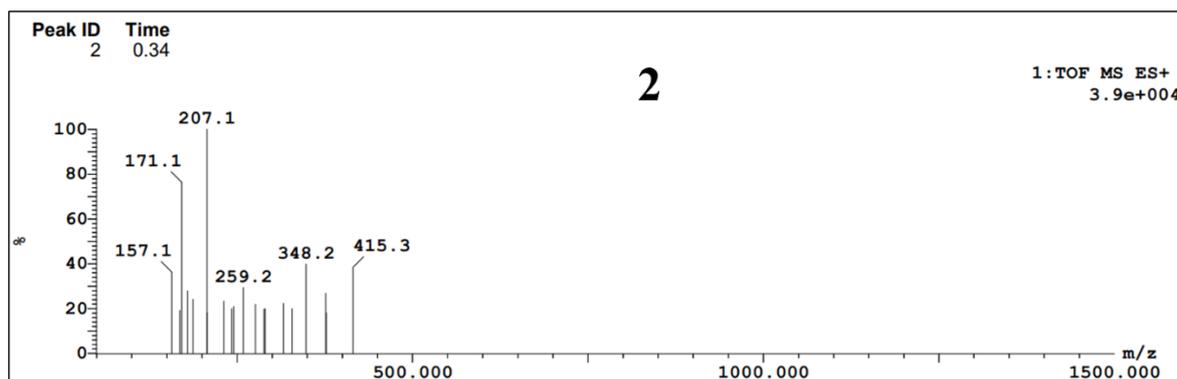




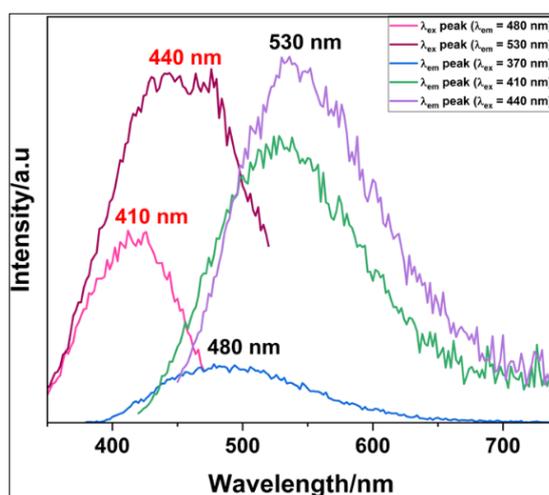


**SF8:** (a) Chromatogram of ML-1. (b) Mass spectra of different fractions (1-11) of ML-1 acquired during liquid chromatography.

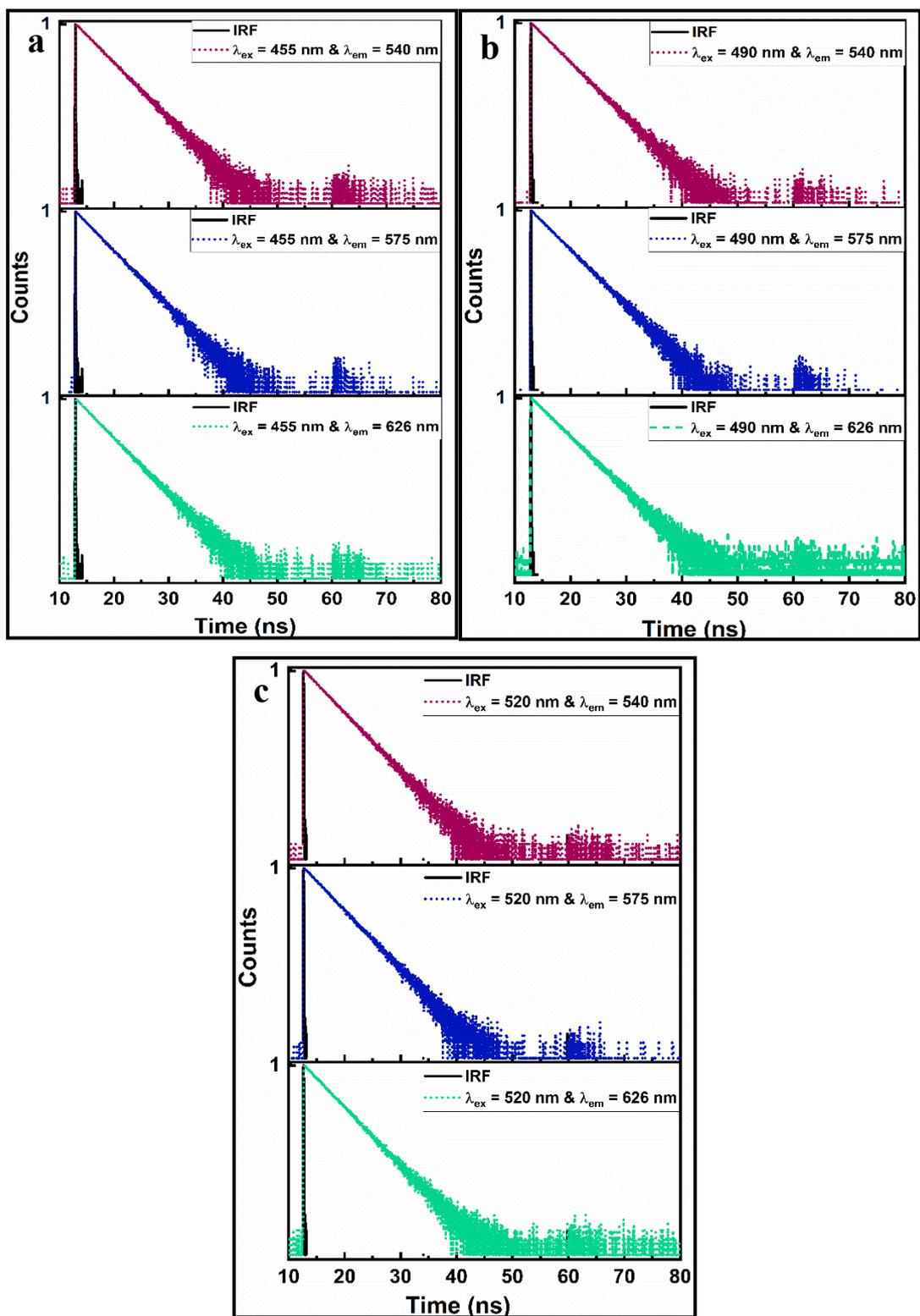




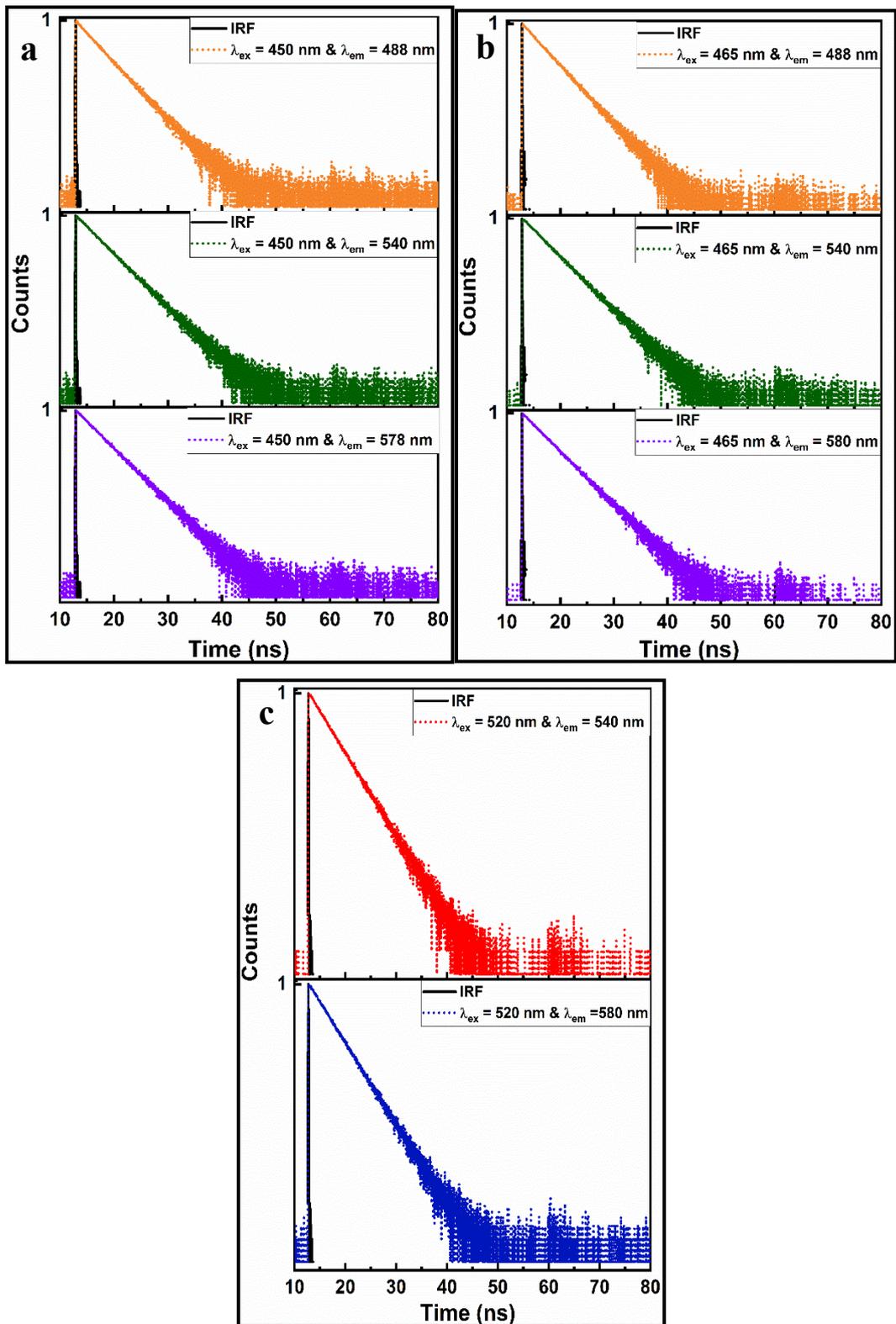
**SF9:** (a) Chromatogram of solvothermal product of NMP. (b) Mass spectra of different fractions (1-3) acquired during liquid chromatography of solvothermal product of NMP.



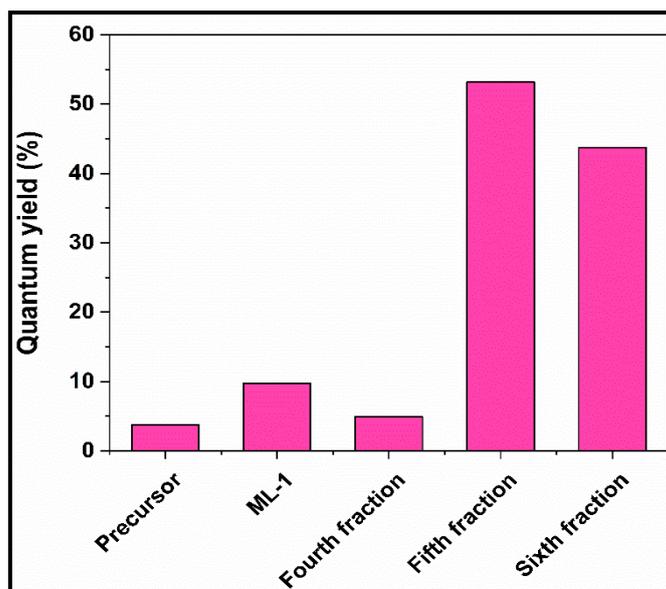
**SF10:** Photoluminescence spectrum of solvothermal product of NMP measured at different excitations.



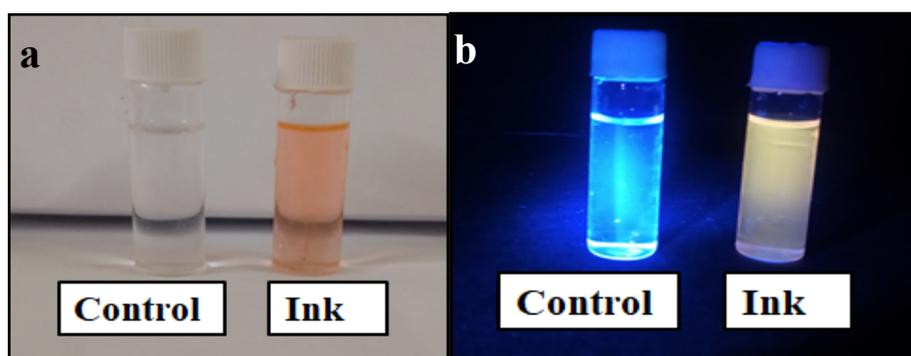
**SF11:** Time resolved fluorescence spectra of fourth fraction recorded at (a) 450 nm, (b) 490 nm and (c) 520 nm with mono-exponential decay.



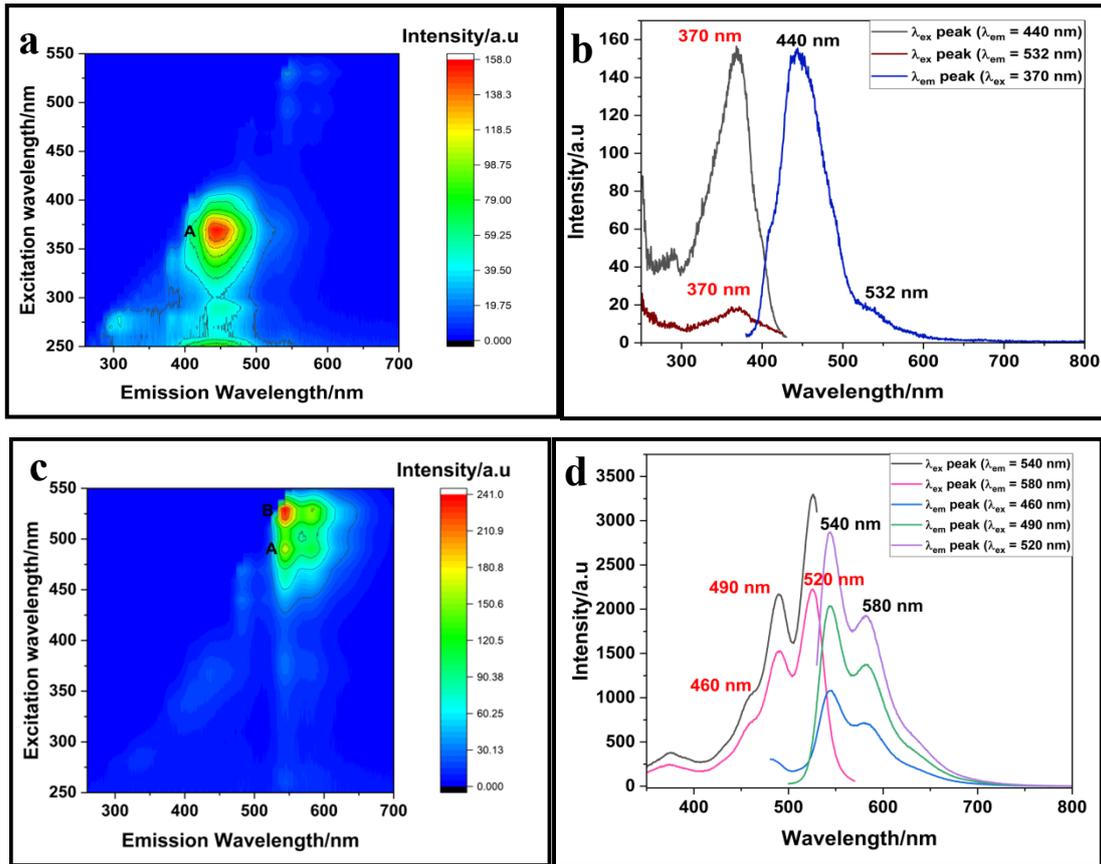
**SF12:** Time resolved fluorescence spectra of sixth fraction recorded at (a) 450 nm, (b) 490 nm and (c) 520 nm with mono-exponential decay.



**SF13:** QY values of precursor, ML-1 and corresponding fractions of ML-1.

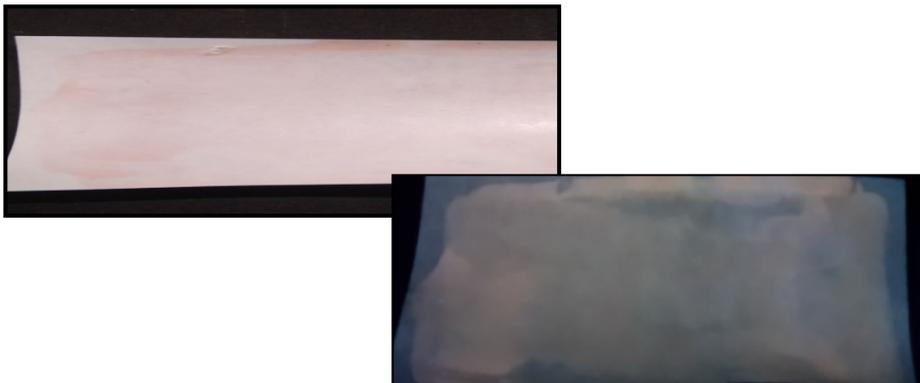


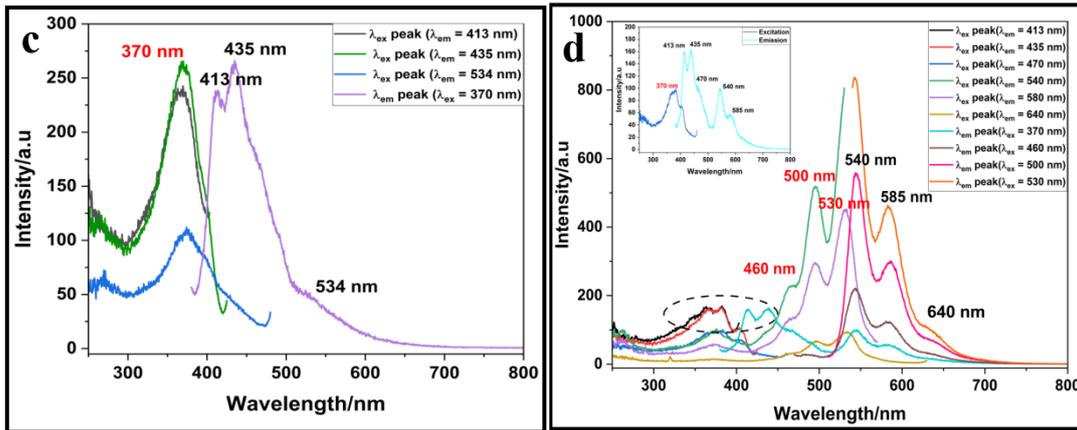
**SF14:** Photographs of control and ink formulation under (a) daylight and (b) UV illumination.



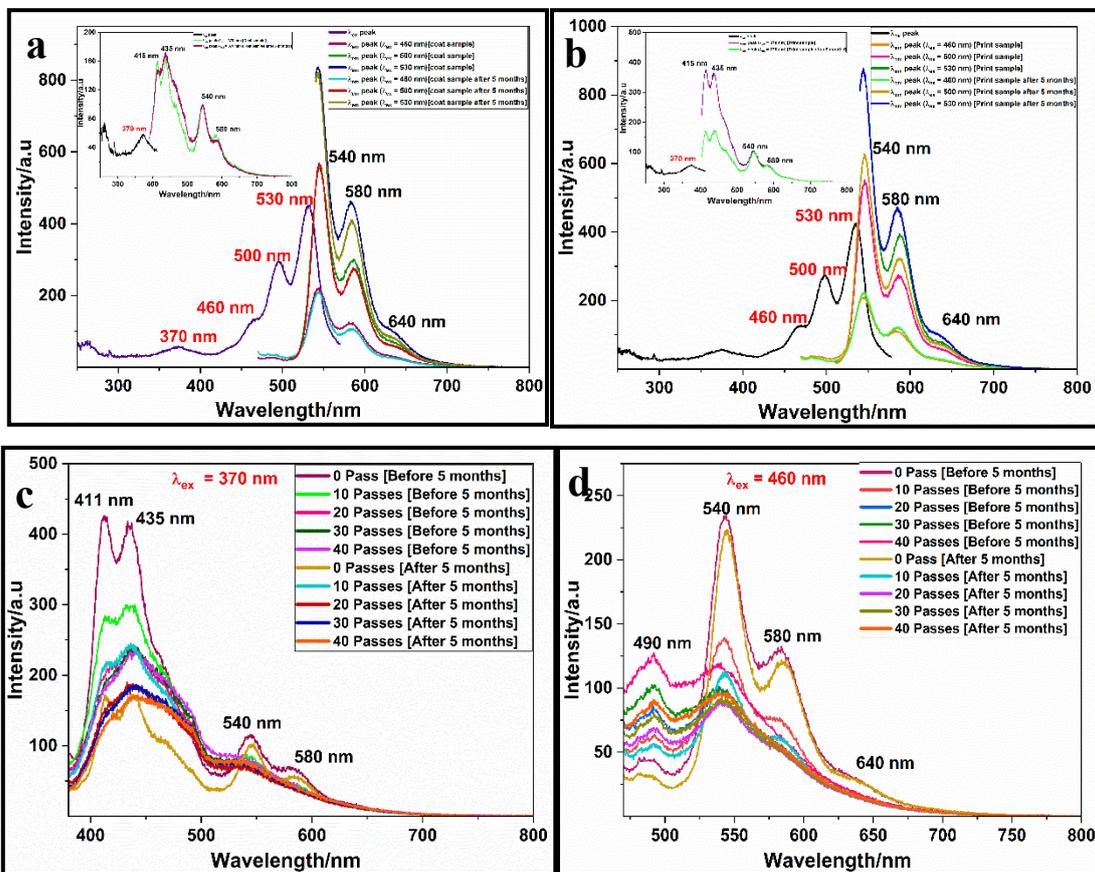
**SF15:** (a) 3D and b) 2D photoluminescence spectra of control formulation. (c) 3D and (d) 2D photoluminescence spectra of ink formulation.

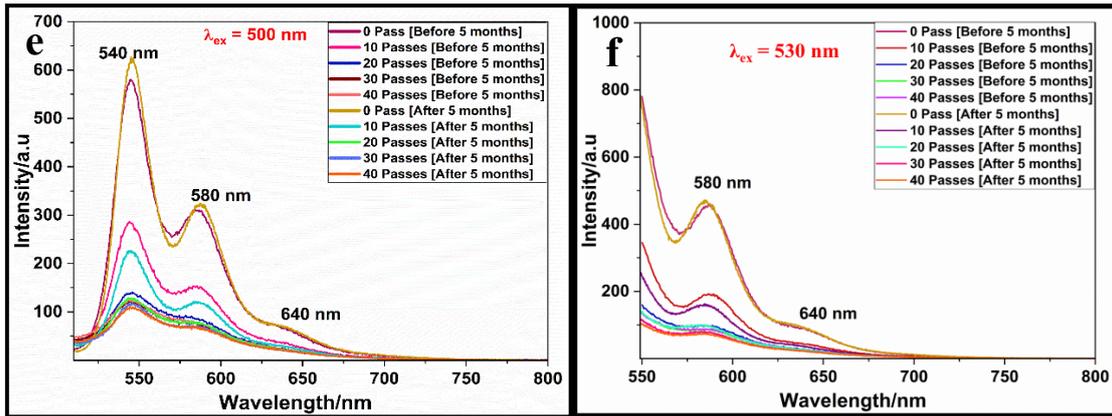
**a**



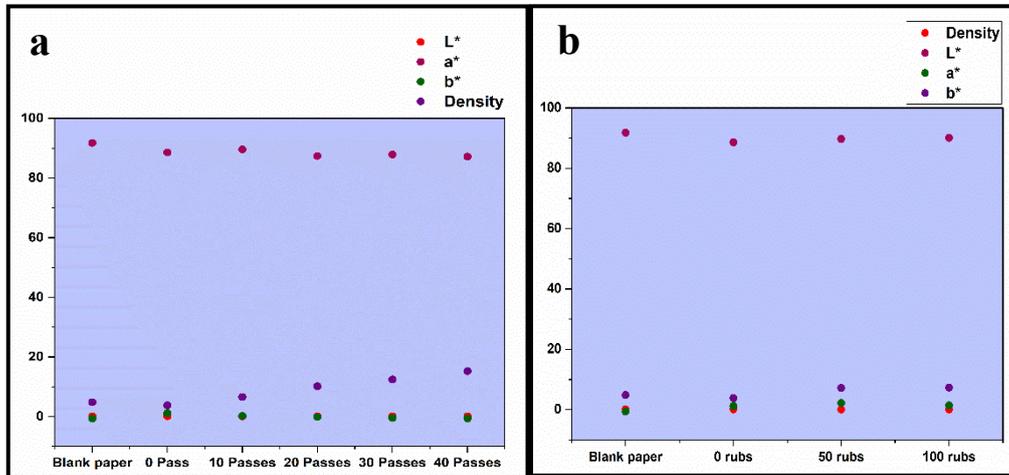


SF 16: Photographs of coated paper sample under (a) daylight and (b) UV illumination. Photoluminescence spectra of (c) control and (d) coated paper samples.

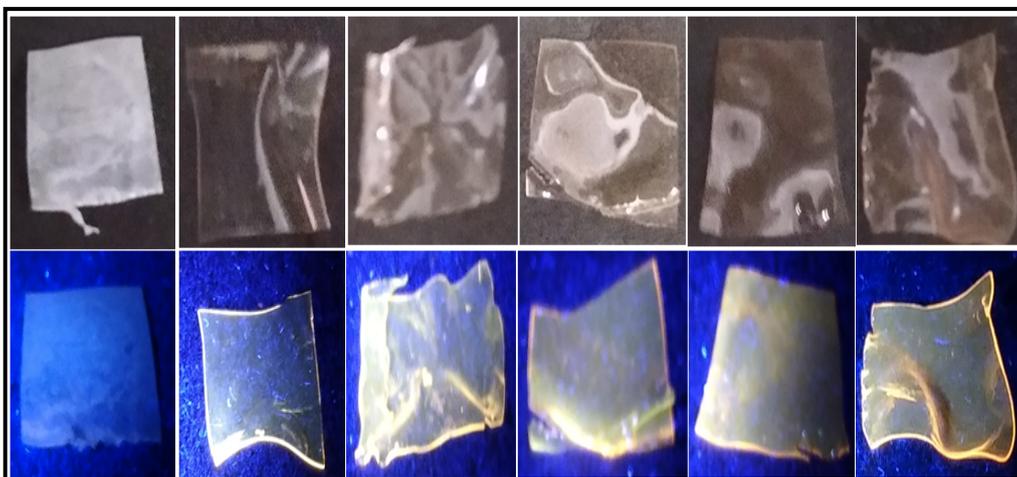




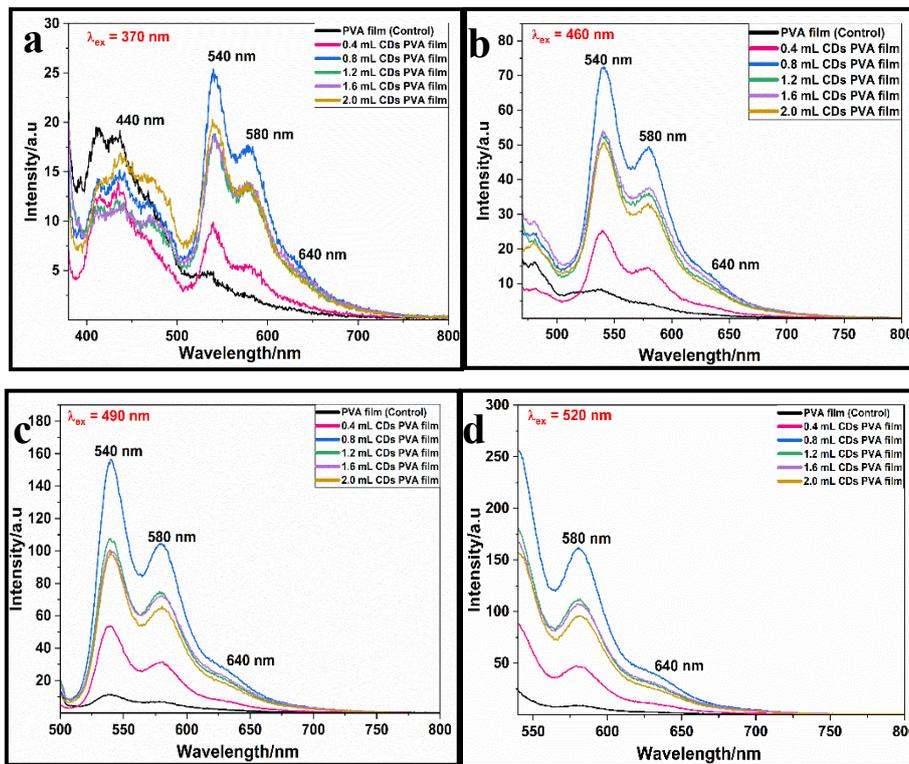
**SF17:** Photoluminescence spectra of (a) coated, (b) printed paper samples and UV exposed printed samples recorded at (c) 370 nm, (d) 460 nm, (e) 500 nm and (f) 530 nm after 5 months storage.



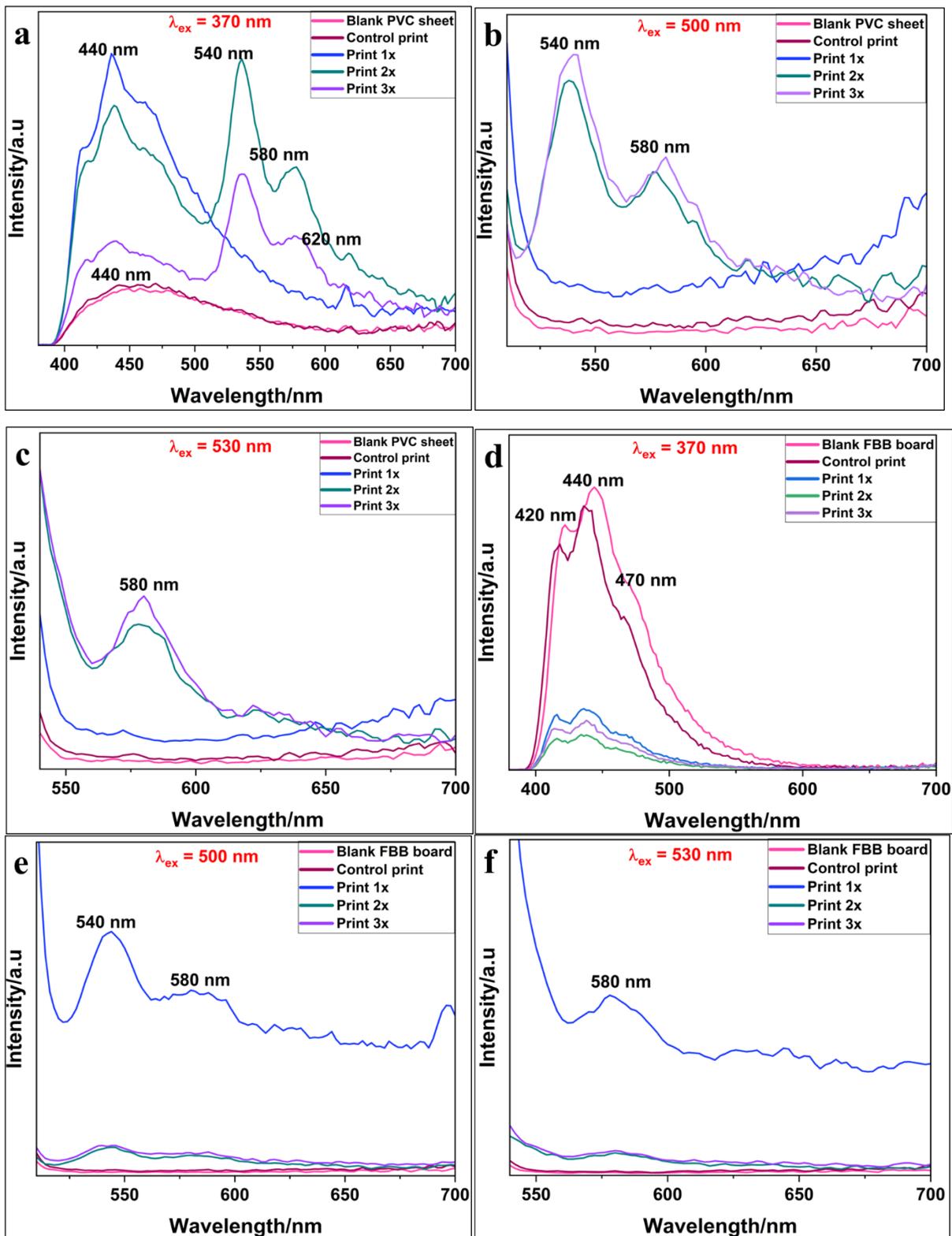
**SF18:** Graphical representation of  $L^*$ ,  $a^*$ ,  $b^*$  and density of (a) UV exposed and (b) abrasion tested print samples.



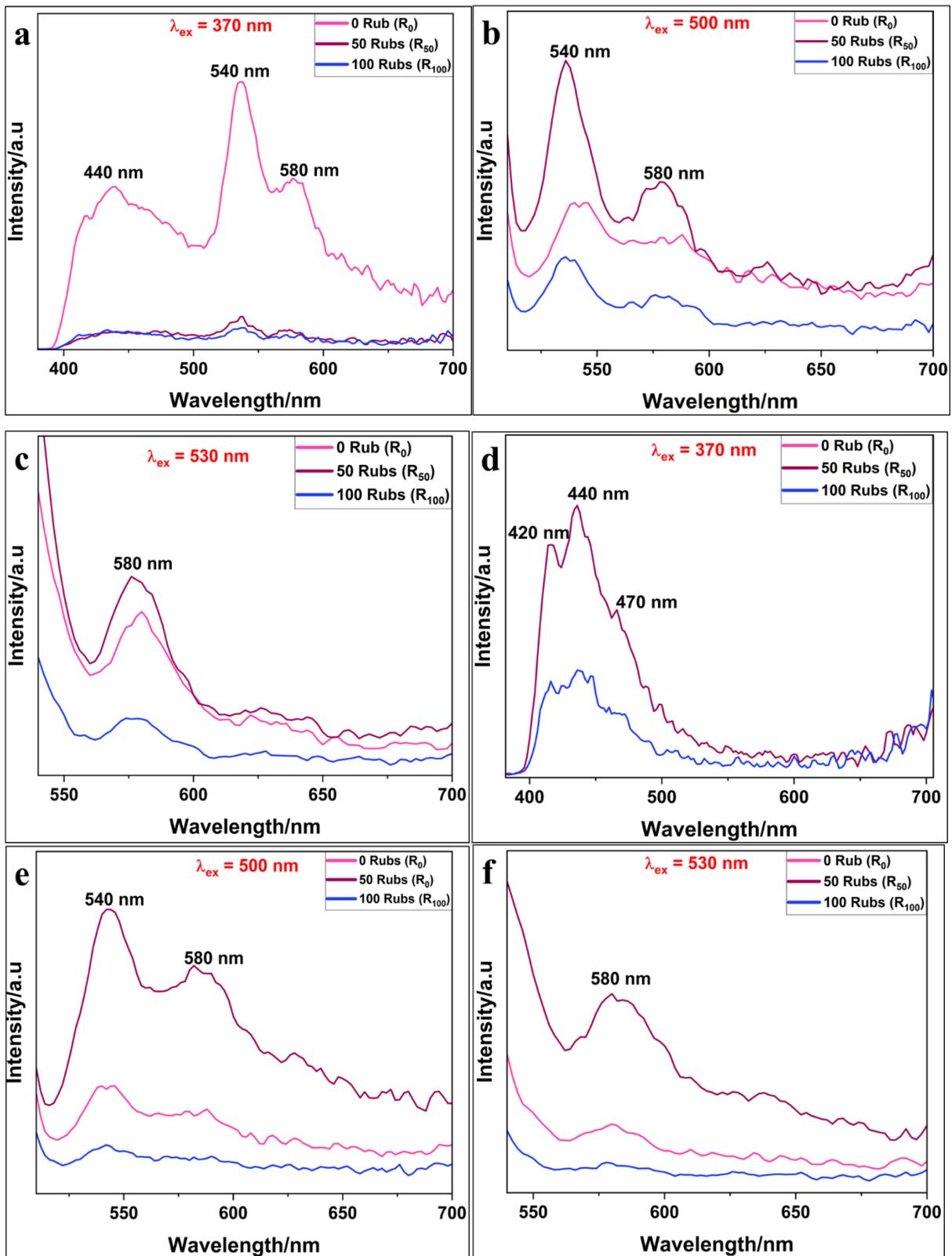
**SF19:** Photographs of PVA & PVA-CDs composite films under daylight and UV illumination.



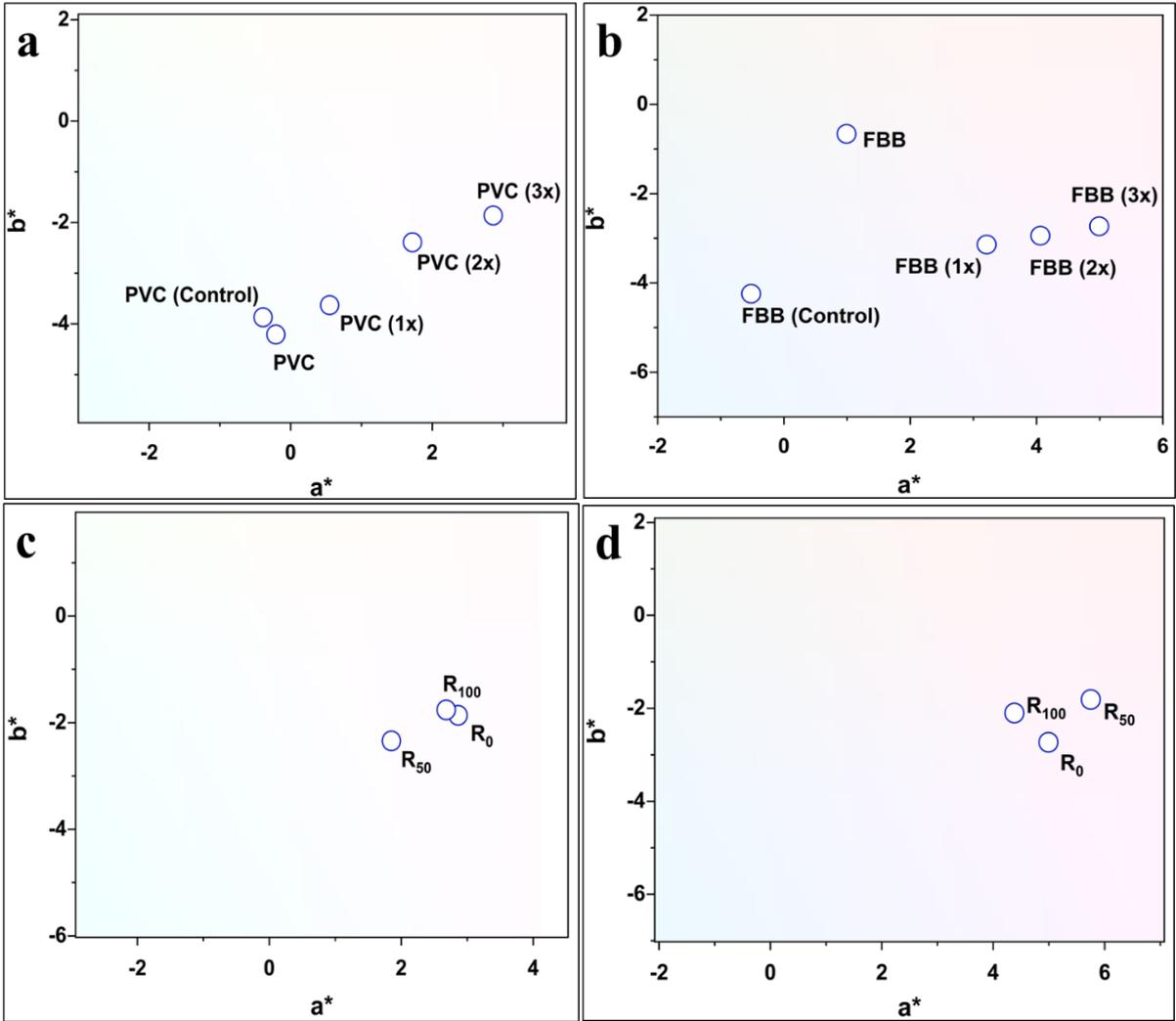
**SF20:** 2D Photoluminescence spectra of PVA and PVA-CDs film at (a) 370 nm, (b) 460 nm, (c) 490 nm and (d) 520 nm excitation.



**SF21:** Photoluminescence spectra of printed PVC proofs recorded at (a) 370 nm, (b) 500 nm and (c) 530 nm excitations. Photoluminescence spectra of printed FBB proofs recorded at (d) 370 nm, (e) 500 nm and (f) 530 nm excitations.



**SF22:** Photoluminescence spectra of abrasion tested printed PVC proofs recorded at (a) 370 nm, (b) 500 nm and (c) 530 nm. Photoluminescence spectra of abrasion tested printed FBB board recorded at (d) 370 nm, (e) 500 nm and (f) 530 nm.



**SF23:** Colorimetric plots for (a) printed PVC sheets and (b) printed FBB boards. Colorimetric plots for abrasion test performed (c) printed PVC sheets and (d) printed FBB boards.

**ST1:** Retention time values corresponding to different fractions of ML-1 to ML-5 during column chromatography.

<b>ML-1</b>	<b>Retention time</b>
First	10 min
Second	15 min
Third	1 h
Fourth	1 h 5 min
Fifth	1 h 25 min
Sixth	1 h 30 min

<b>ML-3</b>	<b>Retention time</b>
First	15 min
Second	20 min
Third	40 min
Fourth	1 h 25 min

<b>ML-5</b>	<b>Retention time</b>
First	15 min
Second	50 min
Third	1h 50 min

**ST2: Individual lifetime values for fourth fraction.**

Sample	Excitation ( $\lambda_{ex}$ ), nm	Emission ( $\lambda_{em}$ ), nm	$\tau_1$ (ns)	$A_1$ (%)	$\tau_{avg}$ (ns)	$\chi^2$
Fraction 4 (Liquid)	455	540	4.07	100.0	4.07	1.06
		575	4.05	100.0	4.05	1.08
		626	4.05	100.0	4.05	1.05
	490	540	4.04	100.0	4.04	1.03
		575	4.04	100.0	4.04	1.10
		626	4.06	100.0	4.06	1.06
	520	540	4.07	100.0	4.07	1.02
		575	4.07	100.0	4.07	1.05
		626	4.08	100.0	4.08	0.99

**ST3: Individual lifetime values for fifth fraction.**

Sample	Excitation ( $\lambda_{ex}$ ), nm	Emission ( $\lambda_{em}$ ), nm	$\tau_1$ (ns)	$A_1$ (%)	$\tau_{avg}$ (ns)	$\chi^2$
Fraction 5 (Liquid)	455	540	4.03	100.0	4.03	1.05
		575	4.01	100.0	4.01	1.06
		626	4.04	100.0	4.04	1.01
	490	540	4.00	100.0	4.00	1.00
		575	4.00	100.0	4.00	1.02
		626	4.03	100.0	4.03	1.02
	520	540	4.00	100.0	4.00	1.11
		575	4.01	100.0	4.01	1.00
		626	4.01	100.0	4.01	1.04

**ST4:** Individual lifetime values for sixth fraction.

Sample	Excitation ( $\lambda_{ex}$ ), nm	Emission ( $\lambda_{em}$ ), nm	$\tau_1$ (ns)	$A_1$ (%)	$\tau_2$ (ns)	$A_2$ (%)	$\tau_{avg}$ (ns)	$\chi^2$
Fraction 6 (Liquid)	370	435	1.39	100.0	-	-	1.39	1.19
		487	1.25	61.88	3.61	38.12	1.67	1.08
	450	488	3.95	100.0	-	-	3.95	1.02
		540	4.35	100.0	-	-	4.35	1.04
		578	4.34	100.0	-	-	4.34	1.03
	465	488	3.95	100.0	-	-	3.95	0.98
		540	4.34	100.0	-	-	4.34	1.05
		580	4.36	100.0	-	-	4.36	1.05
	520	540	4.22	100.0	-	-	4.22	1.06
		580	4.23	100.0	-	-	4.23	0.96

**ST5:** Radiative ( $k_r$ ) and non-radiative rate ( $k_{nr}$ ) constant associated during fluorescence phenomenon.

Samples	Excitation (nm)		Radiative rate constant ( $k_r$ ) ( $\times 10^7$ s)	Non-radiative rate constant ( $k_{nr}$ ) ( $\times 10^7$ s)
Fourth fraction	455	540	1.21	98.78
		575	1.21	98.78
		630	1.21	98.78
	490	540	1.22	98.77
		575	1.22	98.77
		630	1.21	98.78
	520	540	1.21	98.78
		575	1.21	98.78
		630	1.21	98.78
Fifth fraction	455	540	13.20	86.79
		575	13.27	86.72
		630	13.17	86.82
	490	540	13.30	86.69
		575	13.30	86.69
		630	13.20	86.79
	520	540	13.30	86.69
		575	13.27	86.72
		630	13.27	86.72
Sixth fraction	450	488	11.07	88.92
		540	10.05	89.94
		578	10.08	89.91
	465	488	11.07	88.92
		540	10.08	89.91
		580	10.03	89.96
	520	540	10.36	86.63
580		10.34	89.65	

**ST6:** Values for  $2\theta$  and corresponding planes of diffraction of Graphite (2H) carbon.

No	2 $\theta$ (°)	Plane of diffraction
a	26.3	(002)
b	42.2	(100)
c	44.3	(101)
d	50.4	(102)
e	54.5	(004)
f	59.6	(103)
g	77.2	(110)

**ST7:** Raman shift values for PTCDA, NMP and fifth fraction acquired at 785 nm excitation.

Sample	Raman shift (cm <sup>-1</sup> )
Precursor PTCDA	a. 1054 b. 1310 c. 1381 d. 1456 e. 1576 f. 1595 g. 1776 h. 1877
Solvent NMP	a. 622 b. 749 c. 930 d. 1026 e. 1228 f. 1430 g. 1670
Fifth fraction	a. 1380 b. 1607 c. 1894

**ST8:** FT-IR peak values of PTCDA, NMP, ML-1 and fifth fraction.

<b>Sample</b>	<b>Wavenumber (cm<sup>-1</sup>)</b>	<b>Sample</b>	<b>Wavenumber (cm<sup>-1</sup>)</b>
Precursor PTCDA	a. 734 b. 804 c. 860 d. 1017 e. 1120 f. 1300 g. 1409 h. 1594 i. 1764 j. 3118	<b>ML-1</b>	a. 952 b. 1028 c. 1099 d. 1256 e. 1387 f. 1660 g. 2924
Solvent NMP	a. 984 b. 1109 c. 1295 d. 1398 e. 1505 f. 1665 g. 2875 h. 2957	<b>Fifth fraction</b>	a. 923 b. 1023 c. 1077 d. 1306 e. 1409 f. 1480 g. 1650 h. 1730 i. 1760 j. 2886 k. 2940

**ST9:** Individual lifetime value along with the average lifetime values of CDs coated on UV dull paper corresponding to different excitations and emissions

Sample	Excitation ( $\lambda_{ex}$ ) nm	Emission ( $\lambda_{em}$ ) nm	$\tau_1$ (ns)	$A_1$ (%)	$\tau_2$ (ns)	$A_2$ (%)	$\tau_{avg}$ (ns)	$\chi^2$
CDs coated on UV dull paper	460	540	3.90	100.0	-	-	3.90	1.17
		590	3.96	100.0	-	-	3.96	1.31
		640	0.43	5.64	4.13	94.36	2.79	1.22
	500	540	3.78	100.0	-	-	3.78	1.29
		590	3.88	100.0	-	-	3.88	1.35
		640	0.72	4.25	4.13	95.75	3.44	1.07
	520	540	3.85	100.0	-	-	3.85	1.25
		590	3.90	100.0	-	-	3.90	1.20
		640	0.68	3.36	4.06	96.64	3.49	1.05

**ST 10:**  $L^*$ ,  $a^*$ ,  $b^*$  and density values of UV exposed print samples.

Sample name	Density	$L^*$	$a^*$	$b^*$
Blank	0.13	91.79	-0.64	4.85
0 Pass	0.13	88.6	1.2	3.8
10 Passes	0.12	89.6	0.3	6.6
20 Passes	0.15	87.4	-0.1	10.2
30 Passes	0.14	87.9	-0.4	12.5
40 Passes	0.15	87.2	-0.6	15.3

**ST11:**  $L^*$ ,  $a^*$ ,  $b^*$  and density values of abrasion tested print samples.

Sample name	Density	$L^*$	$a^*$	$b^*$
Blank	0.13	91.79	-0.64	4.85
0 Rubs ( $R_0$ )	0.13	88.6	1.2	3.8
50 Rubs ( $R_{50}$ )	0.08	89.7	2.2	7.2
100 Rubs ( $R_{100}$ )	0.08	90.1	1.4	7.3

**ST12:**  $L^*$ ,  $a^*$ ,  $b^*$  and density values for printed PVC sheets.

<b>Samples</b>	<b>L*</b>	<b>a*</b>	<b>b*</b>	<b>Density</b>
PVC sheet	100.6	-0.21	-4.21	0.01
control	99.44	-0.39	-3.87	0.02
1x	99.32	0.55	-3.63	0.02
2x	91.97	1.72	-2.39	0.02
3x	90.96	2.86	-1.86	0.04

**ST13:** L\*, a\*, b\* and density values for printed FBB boards.

<b>Samples</b>	<b>L*</b>	<b>a*</b>	<b>b*</b>	<b>Density</b>
FBB Board	97.26	0.99	-0.66	0.01
Control	96.56	-0.52	-4.24	0.02
1x	93.44	3.21	-3.14	0.01
2x	92.08	4.06	-2.94	0.01
3x	91.91	4.99	-2.73	0.09

**ST14:** L\*, a\*, b\* and density values for abrasion tested printed PVC sheet.

<b>Samples</b>	<b>L*</b>	<b>a*</b>	<b>b*</b>	<b>Density</b>
0 Rub (R <sub>0</sub> )	91.91	4.99	-2.73	0.09
50 Rubs (R <sub>50</sub> )	92.49	5.75	-1.81	0.09
100 Rubs (R <sub>100</sub> )	98.84	4.38	-2.1	0.09

**ST15:** L\*, a\*, b\* and density values for abrasion tested printed FBB boards.

<b>Samples</b>	<b>L*</b>	<b>a*</b>	<b>b*</b>	<b>Density</b>
0 Rub (R <sub>0</sub> )	90.96	2.86	-1.86	0.04
50 Rubs (R <sub>50</sub> )	91.87	1.85	-2.34	0.02
100 Rubs (R <sub>100</sub> )	96.39	2.68	-1.76	0.01