

Tunable colors and conductivity by electroless growth of Cu/Cu₂O particles on sol-gel modified cellulose

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Supporting information to <https://doi.org/10.1007/s12274-020-2907-5>

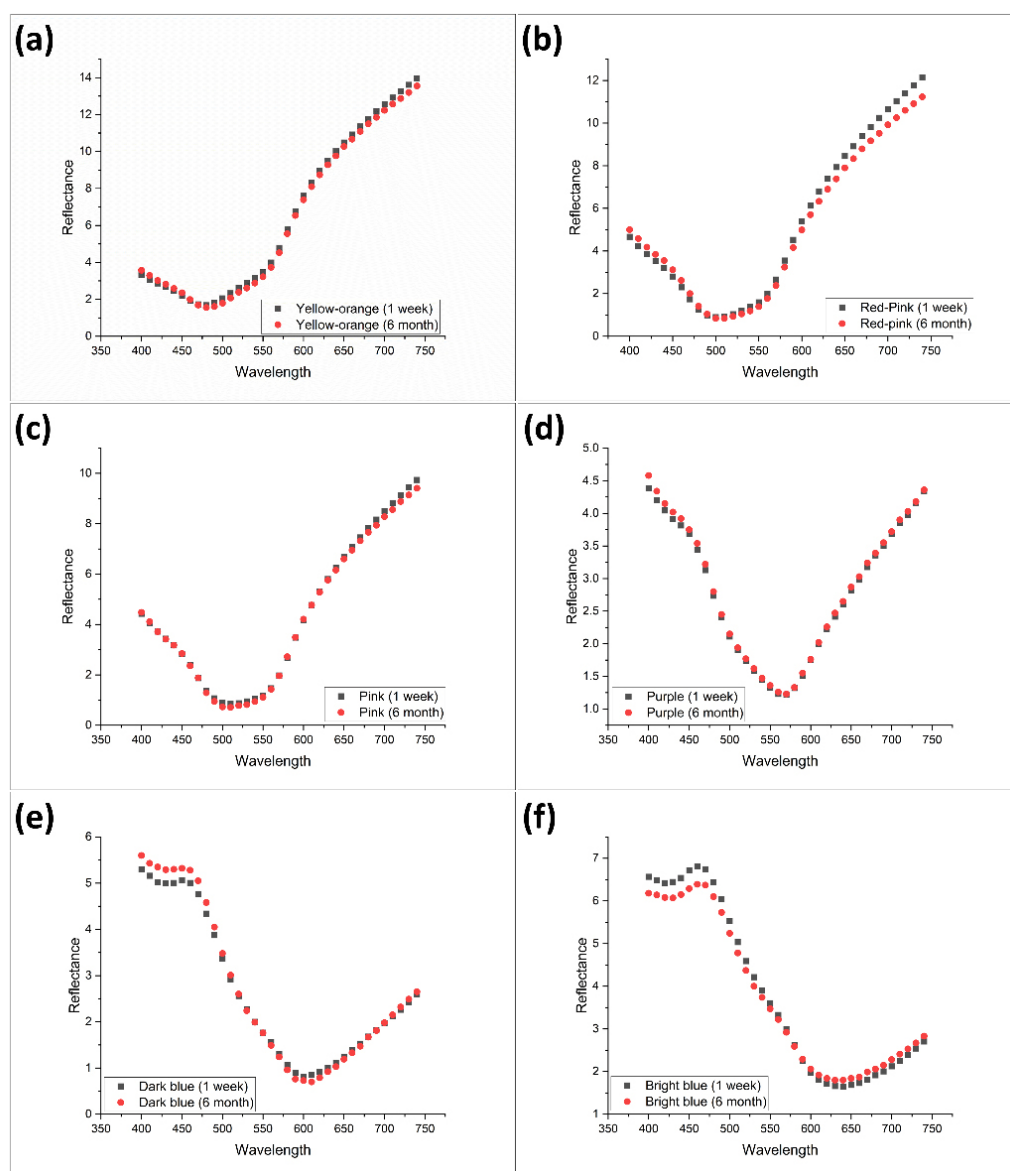


Figure S1 Reflectance data from colored samples measured 1 week (in black) and 6 months (in red) after sample preparation. The differences between the curves are minimal, which demonstrates the stability of the structural colors.

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Table S2 Raw reflectance data of color measurements

(a) Reflectance data of reference samples showing no coloration effects.

λ	R1-1	R1-2	R1-3	R1-4	R1-5	R2-1	R2-2	R2-3	R2-4	R3-1	R3-2	R3-3	R3-4
400nm	4.04	3.58	3.39	4.33	3.43	5.49	4.83	5.26	5.69	8.85	9.16	6.28	6.42
410nm	4.25	3.73	3.47	4.58	3.45	5.85	5.09	5.79	5.99	9.09	9.67	6.68	6.71
420nm	4.44	3.82	3.58	4.79	3.46	6.12	5.37	6.12	6.24	9.42	10.19	7.06	6.99
430nm	4.59	3.91	3.67	5	3.54	6.41	5.69	6.46	6.53	9.81	10.66	7.44	7.28
440nm	4.72	4.03	3.79	5.25	3.62	6.73	6.01	6.76	6.81	10.27	11.16	7.82	7.57
450nm	4.82	4.14	3.88	5.47	3.72	7.02	6.34	7.01	7.08	10.69	11.66	8.2	7.89
460nm	4.93	4.26	3.97	5.67	3.83	7.32	6.64	7.36	7.33	11.11	12.14	8.59	8.17
470nm	4.98	4.36	4.09	5.89	3.96	7.57	6.93	7.72	7.57	11.43	12.56	8.95	8.47
480nm	5.02	4.45	4.16	6.05	4.1	7.79	7.19	8.01	7.73	11.8	12.97	9.27	8.72
490nm	5.07	4.54	4.23	6.19	4.17	7.98	7.38	8.36	7.9	11.92	13.28	9.57	8.9
500nm	5.1	4.63	4.32	6.34	4.32	8.18	7.62	8.62	8.08	12.23	13.63	9.87	9.13
510nm	5.07	4.69	4.4	6.43	4.44	8.37	7.83	8.86	8.19	12.53	13.93	10.08	9.32
520nm	5.11	4.78	4.46	6.56	4.56	8.53	8.04	9.03	8.31	12.85	14.21	10.34	9.51
530nm	5.12	4.88	4.51	6.66	4.68	8.66	8.17	9.25	8.41	13.08	14.51	10.59	9.69
540nm	5.16	4.96	4.57	6.75	4.8	8.86	8.38	9.52	8.55	13.37	14.86	10.9	9.92
550nm	5.18	5.04	4.61	6.88	4.94	9.19	8.72	9.85	8.79	13.93	15.47	11.4	10.28
560nm	5.22	5.16	4.65	7.08	5.07	9.77	9.33	10.45	9.18	14.98	16.53	12.2	10.91
570nm	5.29	5.28	4.8	7.48	5.22	10.74	10.31	11.4	9.85	16.46	18.06	13.36	11.82
580nm	5.38	5.41	4.97	8.03	5.37	11.84	11.45	12.51	10.66	18.11	19.76	14.63	12.85
590nm	5.48	5.55	5.19	8.58	5.53	12.84	12.46	13.51	11.41	19.6	21.33	15.78	13.8
600nm	5.57	5.67	5.35	9.07	5.68	13.62	13.24	14.29	12.04	20.8	22.49	16.68	14.54
610nm	5.65	5.82	5.53	9.52	5.82	14.24	13.84	14.95	12.58	21.72	23.47	17.42	15.19
620nm	5.74	5.95	5.71	9.86	5.98	14.78	14.41	15.47	13.04	22.57	24.29	18.09	15.75
630nm	5.83	6.07	5.85	10.21	6.11	15.28	14.89	15.99	13.48	23.28	25.05	18.69	16.27
640nm	5.86	6.16	5.94	10.45	6.21	15.74	15.34	16.38	13.83	23.94	25.73	19.2	16.71
650nm	5.99	6.33	6.09	10.74	6.36	16.22	15.88	16.88	14.27	24.61	26.45	19.77	17.21
660nm	6.02	6.4	6.18	10.94	6.45	16.67	16.3	17.28	14.64	25.22	27.07	20.28	17.62
670nm	6.12	6.55	6.3	11.19	6.6	17.16	16.83	17.74	15.04	25.87	27.74	20.82	18.09
680nm	6.16	6.64	6.38	11.38	6.69	17.62	17.27	18.14	15.38	26.45	28.34	21.34	18.51
690nm	6.24	6.77	6.48	11.66	6.81	18.09	17.72	18.61	15.79	26.95	28.95	21.84	18.91
700nm	6.33	6.91	6.59	11.88	6.94	18.58	18.25	19.05	16.17	27.57	29.59	22.38	19.36
710nm	6.38	7.02	6.67	12.05	7.04	19.04	18.73	19.46	16.54	28.1	30.18	22.86	19.76
720nm	6.46	7.14	6.75	12.26	7.14	19.49	19.21	19.89	16.93	28.61	30.76	23.36	20.18
730nm	6.52	7.27	6.82	12.42	7.26	20	19.72	20.34	17.29	29.15	31.31	23.83	20.57
740nm	6.6	7.39	6.9	12.66	7.36	20.53	20.23	20.81	17.7	29.64	31.89	24.34	20.96

(b) 2019/11/15: Time dependent coloration effects gained by electroless copper deposition at controlled conditions: 13-15 °C deposition temperature, relative motion of 33 meter per minute, and concentrations mentioned in section 2.3.

λ	40 min			45 min			50 min			55 min			60 min
	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1
400nm	3.29	3.32	3.36	3.77	3.89	3.89	4.46	4.88	4.12	4.7	4.6	4.79	5.81
410nm	3.06	3.09	3.08	3.48	3.58	3.55	4.12	4.48	3.73	4.22	4.18	4.34	5.37
420nm	2.87	2.86	2.84	3.22	3.33	3.3	3.81	4.16	3.41	3.86	3.82	3.95	5.03
430nm	2.66	2.69	2.68	3.01	3.08	3.07	3.55	3.86	3.17	3.52	3.5	3.59	4.75
440nm	2.45	2.49	2.45	2.77	2.85	2.82	3.3	3.6	2.89	3.19	3.17	3.28	4.5
450nm	2.18	2.23	2.19	2.48	2.51	2.51	2.97	3.24	2.59	2.76	2.77	2.85	4.19
460nm	1.89	1.97	1.92	2.15	2.18	2.18	2.54	2.79	2.18	2.26	2.26	2.33	3.76
470nm	1.69	1.79	1.7	1.86	1.9	1.94	2.04	2.23	1.68	1.7	1.7	1.75	3.15
480nm	1.61	1.77	1.68	1.77	1.73	1.84	1.52	1.67	1.24	1.23	1.24	1.24	2.42
490nm	1.72	1.91	1.79	1.82	1.78	1.94	1.21	1.3	0.98	0.98	0.98	0.96	1.85
500nm	1.94	2.17	2.04	1.99	1.97	2.18	1.01	1.06	0.87	0.89	0.9	0.89	1.38
510nm	2.21	2.48	2.31	2.24	2.21	2.44	0.92	0.9	0.84	0.92	0.94	0.9	1.06

520nm	2.46	2.76	2.63	2.49	2.45	2.72	0.94	0.86	0.88	1.08	1.06	1.03	0.86
530nm	2.72	3.05	2.9	2.73	2.7	3.01	0.98	0.88	0.98	1.27	1.24	1.19	0.75
540nm	2.98	3.33	3.18	2.99	2.93	3.27	1.04	0.93	1.11	1.44	1.43	1.38	0.69
550nm	3.27	3.65	3.5	3.28	3.21	3.58	1.14	1.01	1.25	1.68	1.64	1.61	0.66
560nm	3.79	4.15	4.03	3.76	3.73	4.14	1.39	1.22	1.54	2.09	2.06	2.04	0.75
570nm	4.57	4.92	4.85	4.55	4.55	4.98	1.82	1.66	2.06	2.79	2.73	2.73	1.03
580nm	5.54	5.9	5.88	5.58	5.6	6.06	2.44	2.32	2.77	3.72	3.64	3.64	1.52
590nm	6.55	6.85	6.88	6.65	6.71	7.18	3.18	3.1	3.55	4.71	4.61	4.66	2.16
600nm	7.41	7.7	7.77	7.57	7.62	8.15	3.84	3.8	4.23	5.6	5.52	5.53	2.77
610nm	8.1	8.38	8.46	8.32	8.38	8.93	4.42	4.41	4.78	6.35	6.25	6.29	3.35
620nm	8.75	8.99	9.1	8.97	9.05	9.59	4.94	4.96	5.32	7.04	6.92	6.98	3.9
630nm	9.29	9.54	9.68	9.54	9.63	10.2	5.41	5.48	5.78	7.62	7.52	7.59	4.4
640nm	9.79	10.04	10.2	10.03	10.15	10.73	5.83	5.93	6.2	8.19	8.07	8.13	4.88
650nm	10.3	10.47	10.68	10.53	10.64	11.2	6.25	6.38	6.61	8.7	8.59	8.68	5.35
660nm	10.71	10.92	11.13	10.94	11.08	11.65	6.63	6.8	6.97	9.16	9.07	9.15	5.76
670nm	11.16	11.34	11.55	11.38	11.51	12.1	7.01	7.19	7.35	9.64	9.52	9.64	6.2
680nm	11.57	11.72	11.98	11.76	11.9	12.49	7.36	7.58	7.69	10.07	9.96	10.11	6.6
690nm	11.98	12.13	12.39	12.17	12.3	12.9	7.71	7.93	8	10.51	10.4	10.52	7.02
700nm	12.37	12.51	12.78	12.53	12.68	13.27	8.02	8.28	8.33	10.91	10.8	10.94	7.39
710nm	12.74	12.87	13.14	12.84	13.01	13.63	8.35	8.61	8.61	11.3	11.18	11.33	7.77
720nm	13.09	13.2	13.49	13.18	13.33	13.97	8.65	8.94	8.91	11.66	11.55	11.71	8.13
730nm	13.44	13.53	13.85	13.51	13.67	14.27	8.94	9.25	9.19	12.03	11.94	12.09	8.48
740nm	13.77	13.86	14.22	13.84	14.01	14.56	9.24	9.55	9.46	12.39	12.29	12.47	8.84

(b) λ	60 min		65 min		70 min		75 min	
	5-2	5-3	6-1	6-2	7-1	7-2	8-1	8-2
400nm	5.64	5.82	4.55	4.22	5.58	5.01	6.14	6.99
410nm	5.27	5.39	4.34	4.06	5.43	4.89	6.11	6.87
420nm	4.92	5.04	4.18	3.91	5.27	4.77	6.04	6.8
430nm	4.63	4.73	4.05	3.77	5.25	4.74	6.07	6.82
440nm	4.4	4.49	3.95	3.68	5.26	4.75	6.17	6.91
450nm	4.08	4.14	3.8	3.56	5.3	4.82	6.35	7.07
460nm	3.65	3.69	3.56	3.33	5.24	4.77	6.46	7.16
470nm	3.04	3.08	3.23	3.03	4.99	4.54	6.42	7.07
480nm	2.31	2.34	2.83	2.64	4.54	4.14	6.15	6.72
490nm	1.76	1.75	2.49	2.33	4.03	3.72	5.78	6.31
500nm	1.31	1.3	2.18	2.04	3.48	3.25	5.29	5.78
510nm	1	0.99	1.97	1.84	3.01	2.83	4.8	5.27
520nm	0.82	0.79	1.79	1.69	2.61	2.51	4.38	4.8
530nm	0.71	0.71	1.63	1.54	2.3	2.23	4.02	4.41
540nm	0.65	0.66	1.48	1.41	2.01	1.99	3.71	4.08
550nm	0.64	0.62	1.36	1.3	1.75	1.78	3.44	3.77
560nm	0.71	0.74	1.27	1.19	1.55	1.56	3.19	3.47
570nm	1	1.04	1.24	1.19	1.27	1.35	2.89	3.1
580nm	1.5	1.57	1.35	1.29	1.01	1.12	2.56	2.67
590nm	2.14	2.28	1.54	1.48	0.85	0.95	2.21	2.3
600nm	2.76	2.94	1.79	1.71	0.74	0.89	1.96	1.99
610nm	3.35	3.56	2.04	1.95	0.79	0.91	1.81	1.82
620nm	3.87	4.13	2.27	2.17	0.86	0.96	1.71	1.72
630nm	4.37	4.67	2.47	2.36	0.95	1.05	1.68	1.64
640nm	4.86	5.17	2.66	2.55	1.08	1.15	1.67	1.63
650nm	5.34	5.64	2.88	2.75	1.22	1.27	1.7	1.67
660nm	5.74	6.09	3.05	2.91	1.38	1.4	1.75	1.71
670nm	6.18	6.55	3.24	3.11	1.53	1.52	1.83	1.78
680nm	6.57	6.98	3.43	3.28	1.7	1.66	1.93	1.9

690nm	6.99	7.41	3.59	3.42	1.85	1.78	2.02	1.99
700nm	7.38	7.81	3.77	3.6	2.01	1.92	2.13	2.12
710nm	7.74	8.21	3.95	3.75	2.19	2.05	2.27	2.24
720nm	8.08	8.6	4.07	3.88	2.36	2.16	2.38	2.4
730nm	8.44	8.97	4.27	4.05	2.53	2.31	2.54	2.54
740nm	8.82	9.35	4.46	4.22	2.72	2.47	2.7	2.71

(c) 2020/05/06: Color measurements repeated after approximately 6 month of storage time in ambient conditions. The numeration corresponds to the data shown in (b), but the samples were not measured exactly at the same spots.

λ	40 min				55 min				60 min		65 min	70 min	
	1-1	1-2	1-3	1-4	4-1	4-2	4-3	4-4	5-1	5-2	6-1	7-1	7-2
400nm	3.57	3.56	3.89	3.88	5.04	5.05	4.52	4.85	5.99	6.31	4.58	5.63	5.25
410nm	3.3	3.29	3.6	3.61	4.6	4.61	4.12	4.48	5.67	5.91	4.34	5.49	5.09
420nm	3.04	3.05	3.33	3.35	4.22	4.19	3.75	4.09	5.31	5.53	4.17	5.38	5
430nm	2.83	2.83	3.07	3.09	3.86	3.85	3.44	3.83	5.05	5.23	4.03	5.3	4.93
440nm	2.59	2.61	2.84	2.87	3.57	3.54	3.19	3.55	4.84	4.98	3.93	5.34	4.95
450nm	2.35	2.35	2.55	2.57	3.19	3.15	2.87	3.25	4.64	4.73	3.8	5.38	5.01
460nm	1.98	2	2.18	2.2	2.67	2.63	2.39	2.79	4.27	4.29	3.56	5.31	4.95
470nm	1.69	1.7	1.85	1.88	2.06	2.03	1.88	2.23	3.7	3.69	3.25	5.08	4.77
480nm	1.58	1.55	1.66	1.7	1.45	1.44	1.31	1.62	2.95	2.89	2.82	4.6	4.32
490nm	1.62	1.58	1.66	1.69	1.07	1.08	0.97	1.23	2.3	2.19	2.48	4.1	3.85
500nm	1.8	1.71	1.78	1.79	0.86	0.87	0.76	0.94	1.71	1.58	2.16	3.52	3.35
510nm	2.09	1.95	1.99	2.03	0.81	0.87	0.73	0.82	1.28	1.19	1.95	3.03	2.94
520nm	2.38	2.19	2.23	2.26	0.88	0.95	0.78	0.82	1	0.91	1.79	2.64	2.6
530nm	2.62	2.42	2.42	2.44	0.96	1.05	0.85	0.84	0.79	0.71	1.62	2.28	2.29
540nm	2.89	2.65	2.63	2.67	1.1	1.2	0.96	0.91	0.67	0.59	1.48	2.02	2.06
550nm	3.23	2.94	2.91	2.95	1.28	1.41	1.12	1.03	0.55	0.53	1.36	1.78	1.84
560nm	3.73	3.41	3.36	3.39	1.63	1.76	1.43	1.29	0.53	0.55	1.25	1.5	1.6
570nm	4.54	4.16	4.1	4.15	2.26	2.4	1.97	1.79	0.67	0.78	1.23	1.24	1.37
580nm	5.55	5.08	5.1	5.15	3.1	3.24	2.72	2.5	1.01	1.22	1.33	0.97	1.12
590nm	6.55	6.05	6.13	6.16	4.04	4.17	3.51	3.3	1.5	1.84	1.54	0.79	0.98
600nm	7.41	6.85	7	7.05	4.85	5	4.21	3.99	1.99	2.45	1.77	0.71	0.92
610nm	8.14	7.54	7.74	7.79	5.58	5.71	4.8	4.63	2.49	3.02	2.02	0.72	0.92
620nm	8.74	8.13	8.36	8.4	6.23	6.35	5.33	5.18	2.95	3.55	2.25	0.8	0.99
630nm	9.3	8.64	8.91	8.96	6.81	6.9	5.77	5.66	3.38	4.07	2.47	0.92	1.07
640nm	9.78	9.1	9.38	9.42	7.32	7.41	6.19	6.09	3.79	4.54	2.65	1.03	1.17
650nm	10.27	9.56	9.84	9.91	7.83	7.91	6.62	6.54	4.2	5.02	2.86	1.19	1.3
660nm	10.68	9.95	10.24	10.29	8.28	8.34	6.96	6.94	4.59	5.46	3.01	1.33	1.41
670nm	11.1	10.37	10.64	10.7	8.74	8.79	7.34	7.33	4.98	5.93	3.22	1.48	1.57
680nm	11.49	10.73	11.02	11.08	9.15	9.19	7.68	7.7	5.36	6.34	3.39	1.67	1.7
690nm	11.87	11.07	11.36	11.41	9.54	9.55	7.98	8.04	5.69	6.74	3.54	1.81	1.82
700nm	12.24	11.44	11.7	11.77	9.94	9.95	8.3	8.4	6.06	7.16	3.72	1.99	1.97
710nm	12.58	11.75	12.02	12.08	10.3	10.28	8.6	8.72	6.4	7.54	3.89	2.16	2.09
720nm	12.9	12.06	12.31	12.39	10.65	10.61	8.9	9.02	6.73	7.94	4.05	2.33	2.23
730nm	13.23	12.37	12.59	12.65	10.98	10.96	9.18	9.35	7.05	8.33	4.2	2.51	2.39
740nm	13.58	12.69	12.88	12.96	11.34	11.28	9.46	9.68	7.42	8.72	4.37	2.69	2.53

(c)	75 min	
λ	8-1	8-2
400nm	6.18	5.61
410nm	6.14	5.54
420nm	6.08	5.52
430nm	6.07	5.51
440nm	6.15	5.58
450nm	6.29	5.68
460nm	6.39	5.76

470nm	6.37	5.74
480nm	6.1	5.54
490nm	5.73	5.26
500nm	5.24	4.87
510nm	4.78	4.52
520nm	4.37	4.19
530nm	4	3.91
540nm	3.74	3.62
550nm	3.47	3.32
560nm	3.22	3.00
570nm	2.92	2.66
580nm	2.59	2.37
590nm	2.29	2.19
600nm	2.06	2.09
610nm	1.92	2.06
620nm	1.84	1.95
630nm	1.8	1.92
640nm	1.8	1.92
650nm	1.84	1.95
660nm	1.87	1.99
670nm	1.99	2.02
680nm	2.06	2.10
690nm	2.15	2.22
700nm	2.28	2.30
710nm	2.41	2.47
720nm	2.53	2.61
730nm	2.67	2.84
740nm	2.83	2.90
