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(12) United States Patent
Baumann et al.

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(54) **ELECTRO-OPTIC SYSTEM CONFIGURED TO REDUCE A PERCEIVED COLOR CHANGE**

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(73) Assignee: **GENTEX CORPORATION**, Zeeland, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/816,660**

(22) Filed: **Aug. 3, 2015**

(65) **Prior Publication Data**

US 2016/0033843 A1 Feb. 4, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/628,592, filed on Feb. 23, 2015, now Pat. No. 9,096,181, which is a continuation of application No. 13/865,592, filed on Apr. 18, 2013, now Pat. No. 8,964,278, which is a

(Continued)

(51) **Int. Cl.**
G02F 1/153 (2006.01)
G02F 1/163 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***G02F 1/163*** (2013.01); ***B60R 1/08*** (2013.01); ***B60R 1/088*** (2013.01); ***B60R 1/1207*** (2013.01); ***G02F 1/155*** (2013.01); ***G02F 1/157*** (2013.01); ***G02F 1/161*** (2013.01)

(58) **Field of Classification Search**
CPC G02F 1/163
USPC 359/265
See application file for complete search history.

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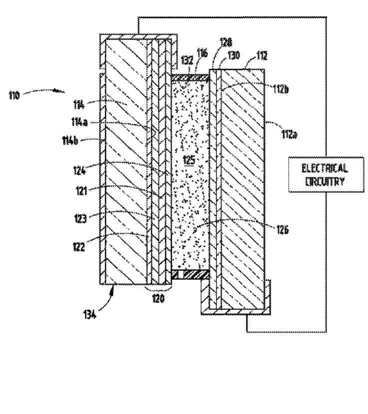
Primary Examiner — James Jones

(74) *Attorney, Agent, or Firm* — Price Heneveld LLP; Scott P. Ryan

(57) **ABSTRACT**

An electro-optic system is provided that includes a front element having first and second surfaces, a rear element including third and fourth surfaces, wherein the front and rear elements are sealably bonded together in a spaced-apart relationship to define a chamber, and an electro-optic medium contained in the chamber, and the electro-optic medium is adapted to be in at least a high transmittance state and a low transmittance state. The electro-optic system further includes a display device in optical communication with the electro-optic element, the display device including at least one light source and is configured to emit at least a first primary and a second primary, the first and second primaries each having a first hue (h_{ab}) when viewed through the electro-optic element in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electro-optic element in approximately the low transmittance state, wherein a change in the first and second hues (Δh_{ab}) for both first and second primaries is less than approximately 31 degrees.

20 Claims, 42 Drawing Sheets



Related U.S. Application Data

continuation-in-part of application No. 13/454,459, filed on Apr. 24, 2012, now Pat. No. 8,508,832, which is a continuation of application No. 12/852,790, filed on Aug. 9, 2010, now Pat. No. 8,228,590.

(51) **Int. Cl.**

B60R 1/08	(2006.01)
B60R 1/12	(2006.01)
G02F 1/155	(2006.01)
G02F 1/157	(2006.01)
G02F 1/161	(2006.01)

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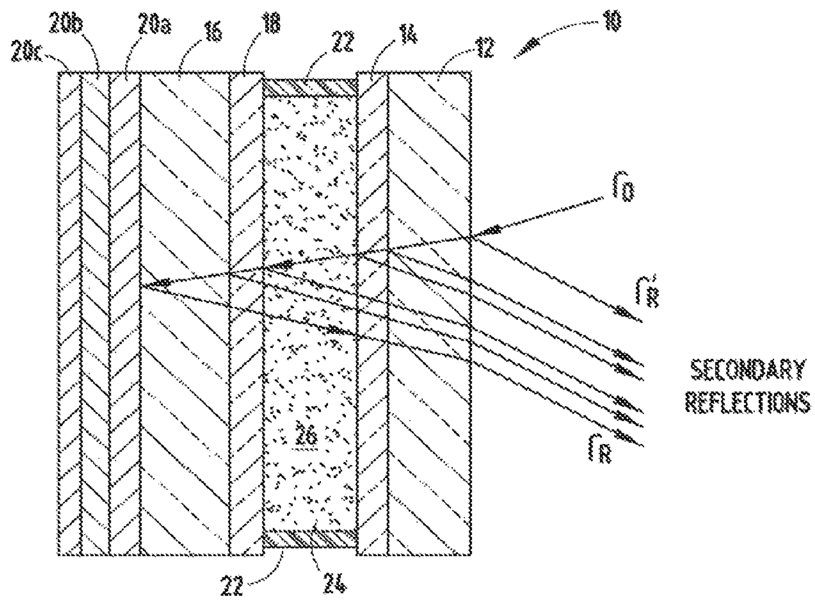


FIG. 1
(PRIOR ART)

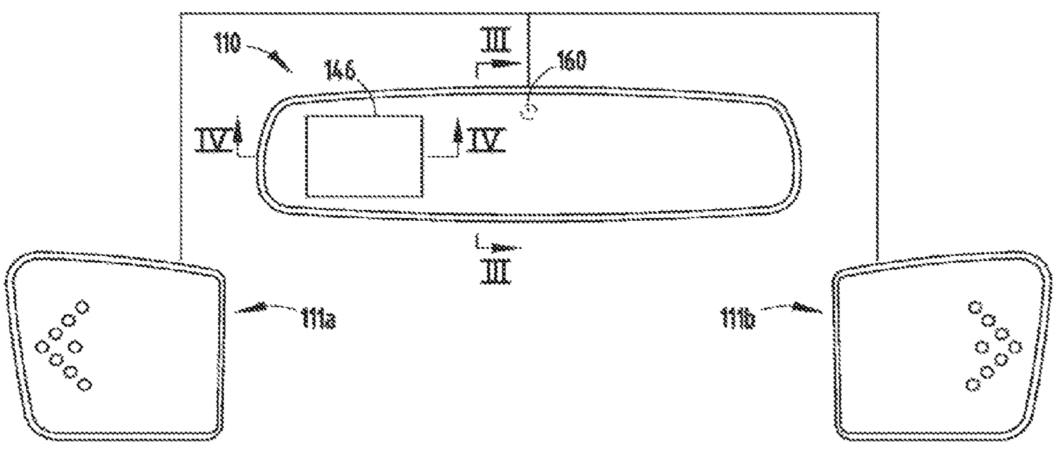
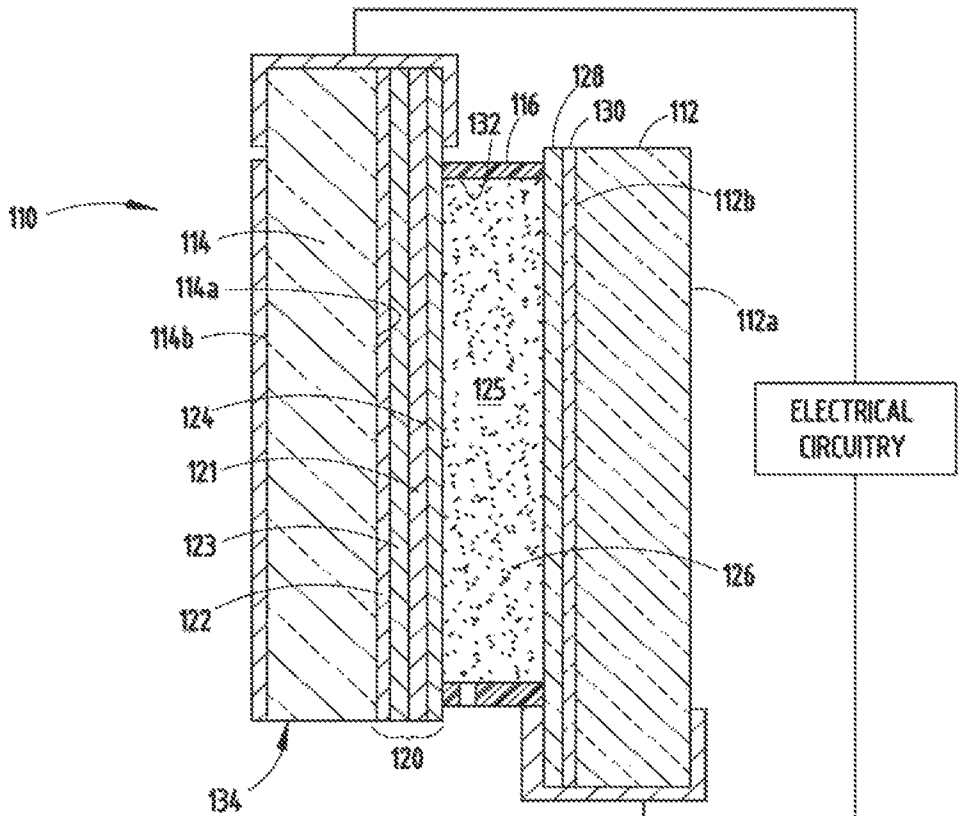


FIG. 2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ELECTRICAL CIRCUITRY

FIG. 3

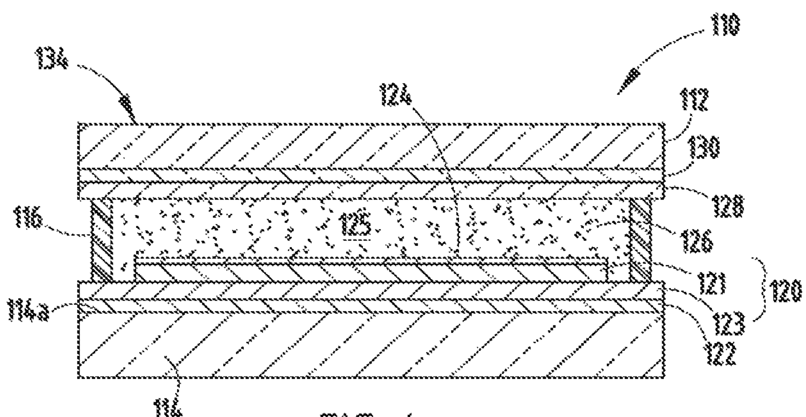
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FIG. 4

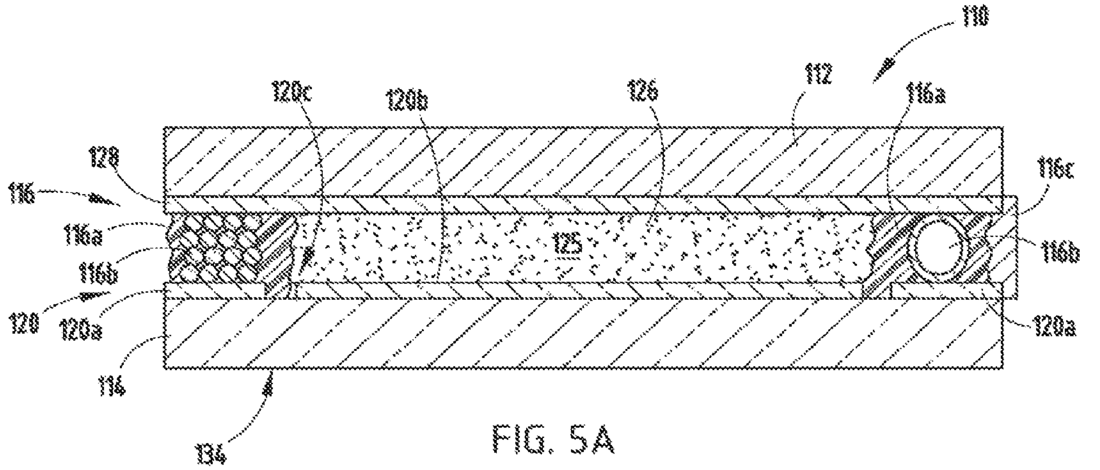

FIG. 5A

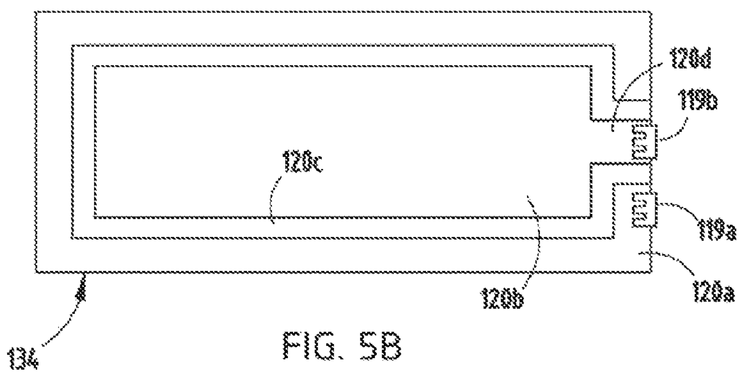

FIG. 5B

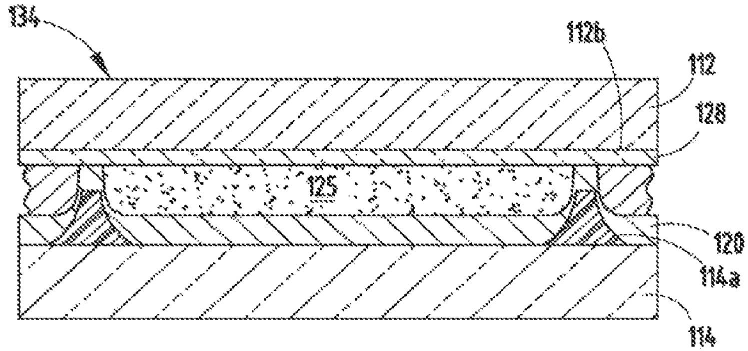

FIG. 6

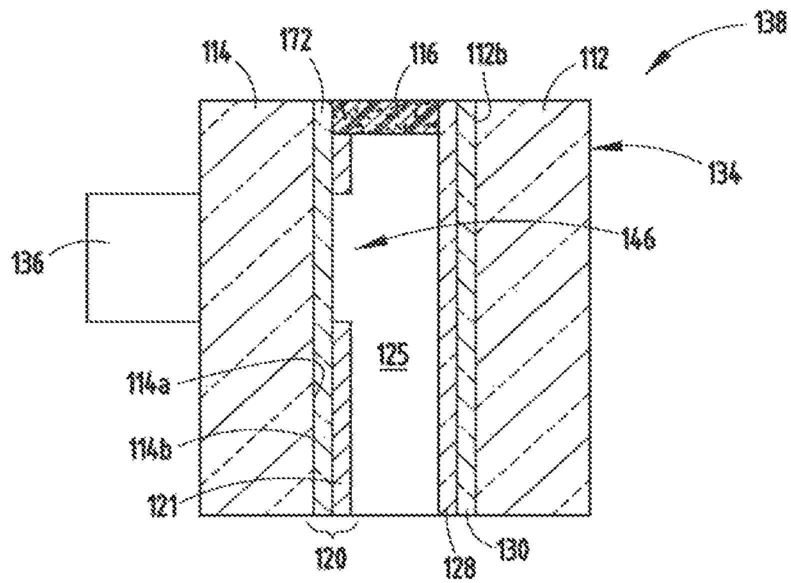
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FIG. 7A

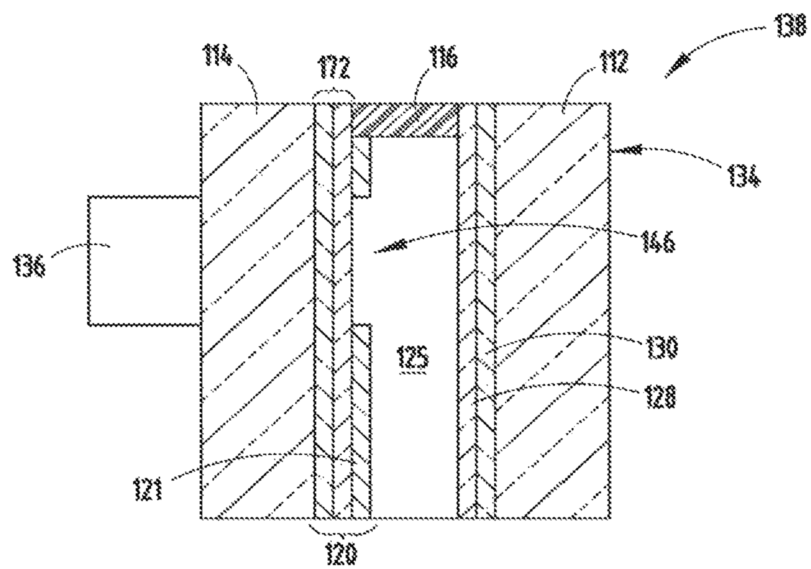
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FIG. 7B

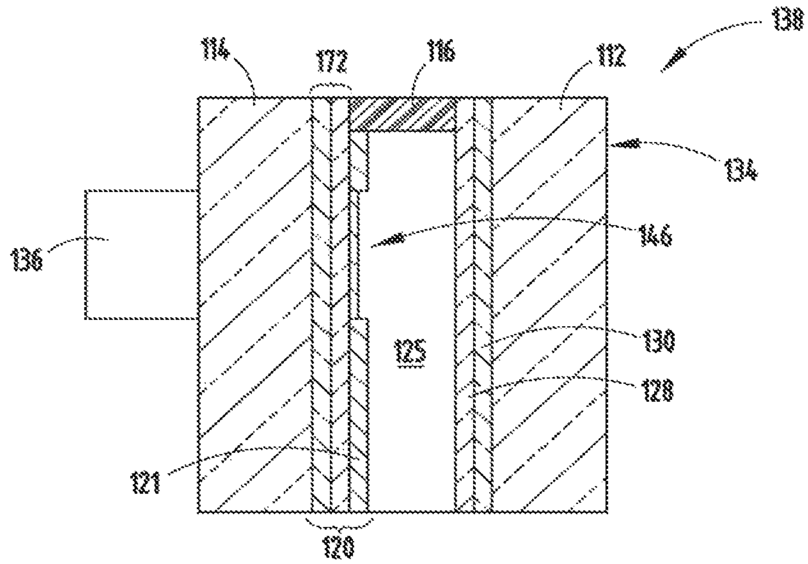
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FIG. 7C

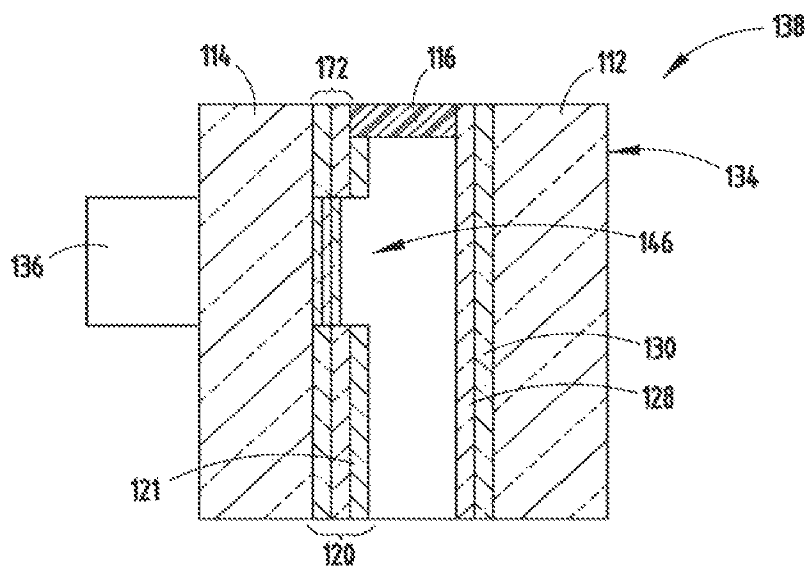
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FIG. 7D

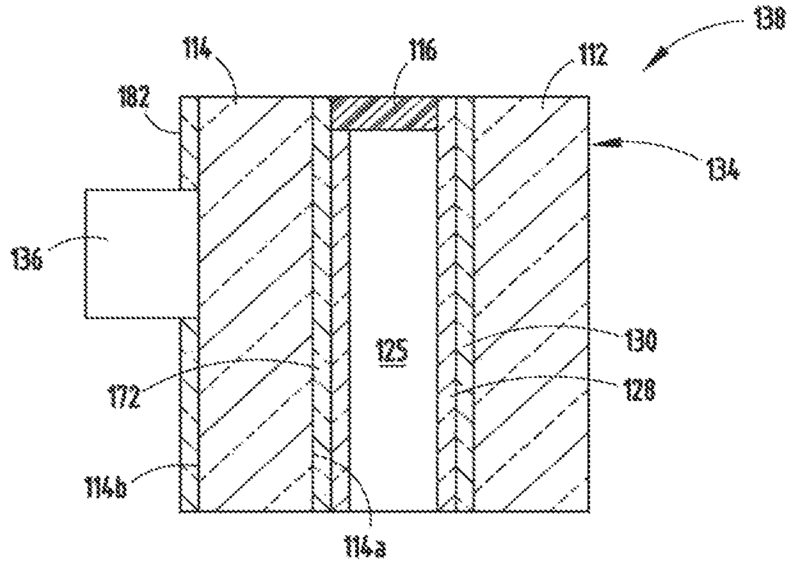
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FIG. 7E

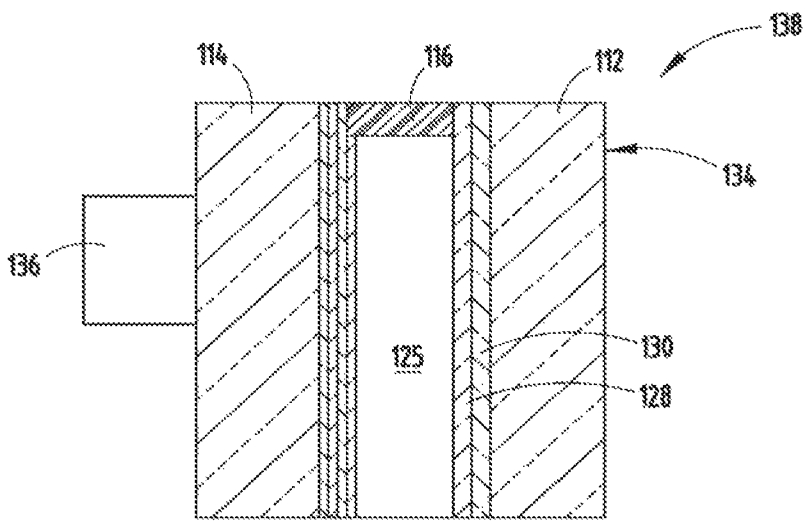
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FIG. 7F

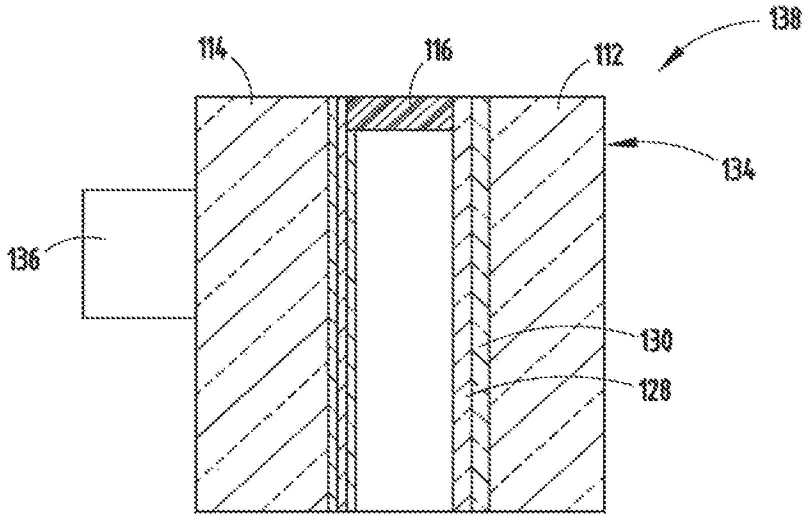
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FIG. 7G

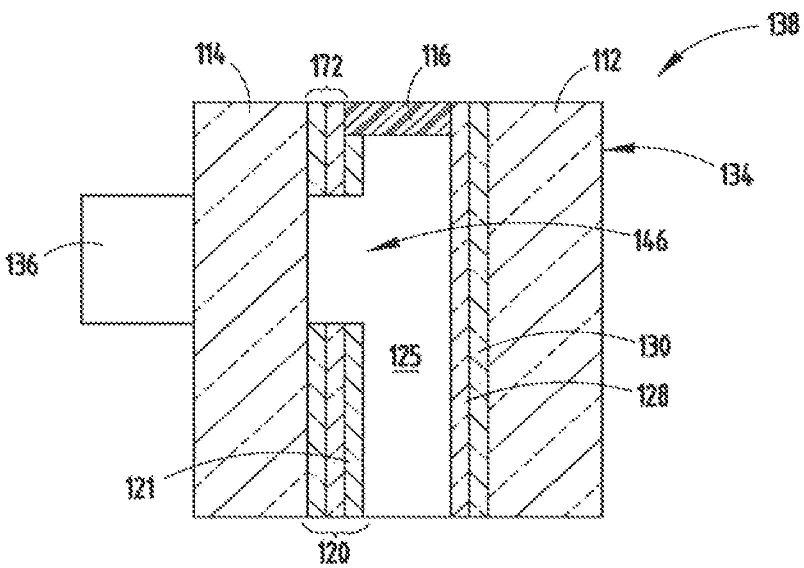
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FIG. 7H

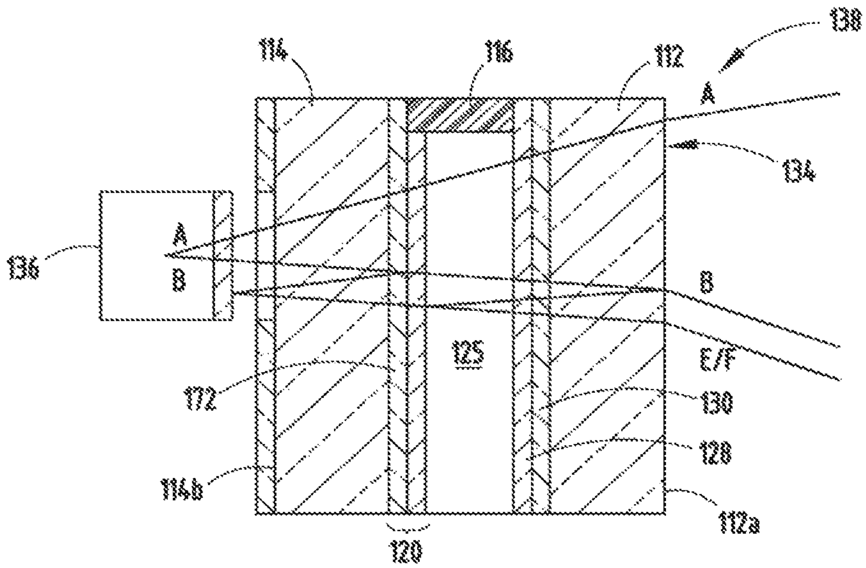
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FIG. 8

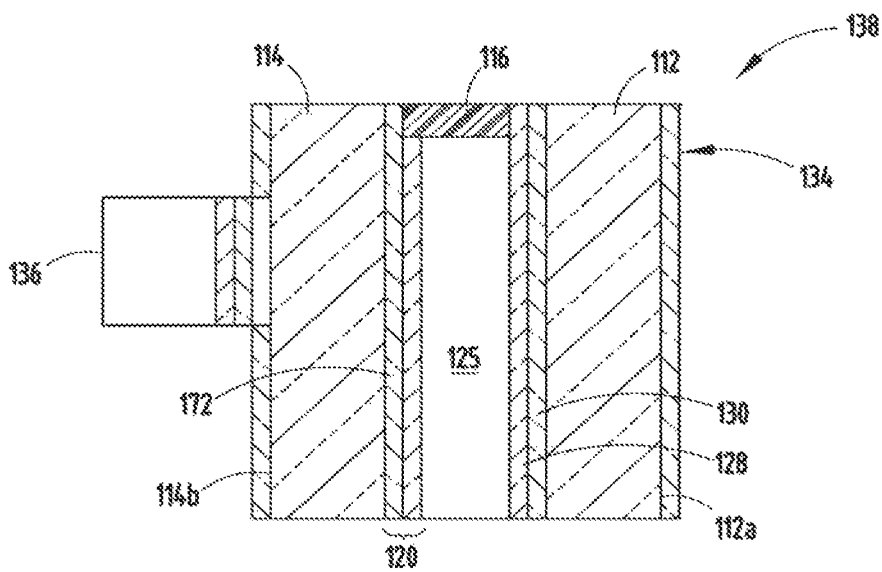
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FIG. 9A

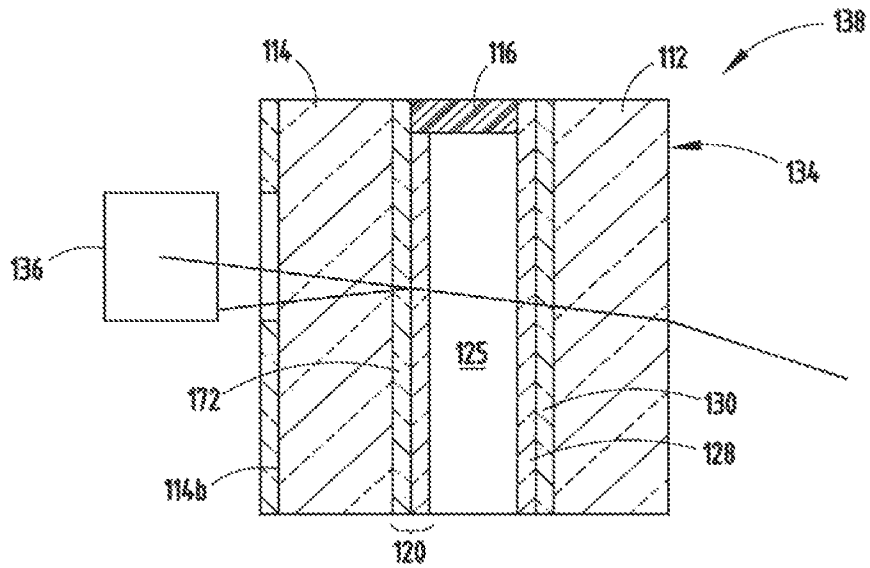
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FIG. 9B

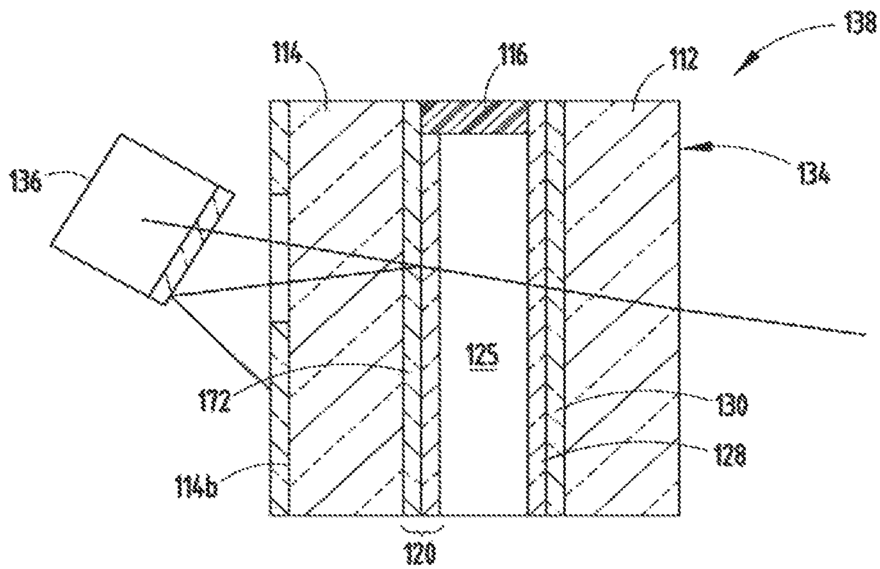
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FIG. 9C

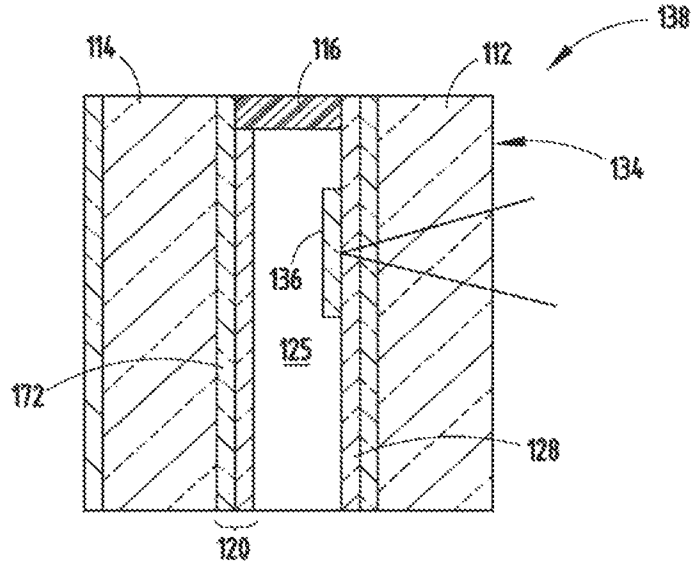
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FIG. 9D

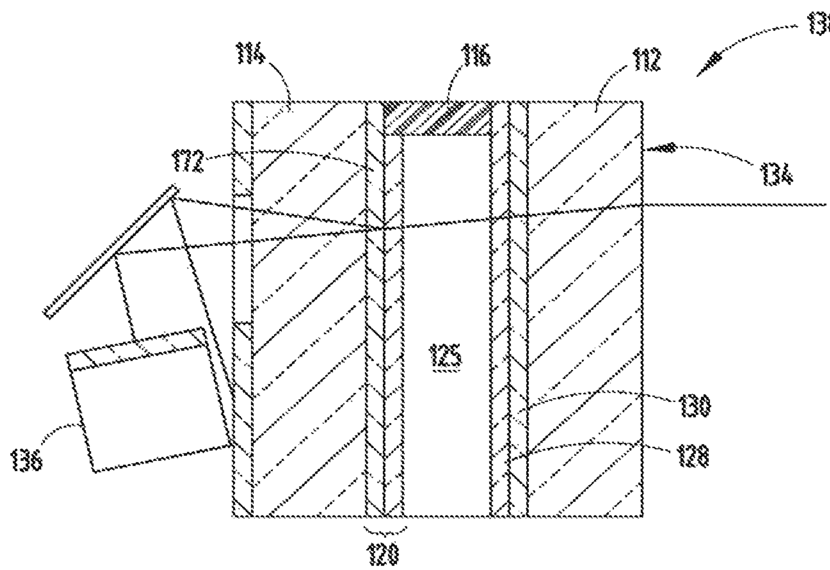
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FIG. 9E

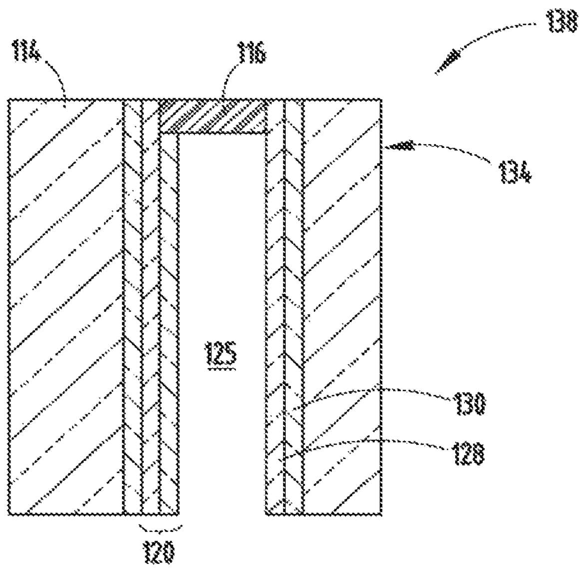
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FIG. 9F

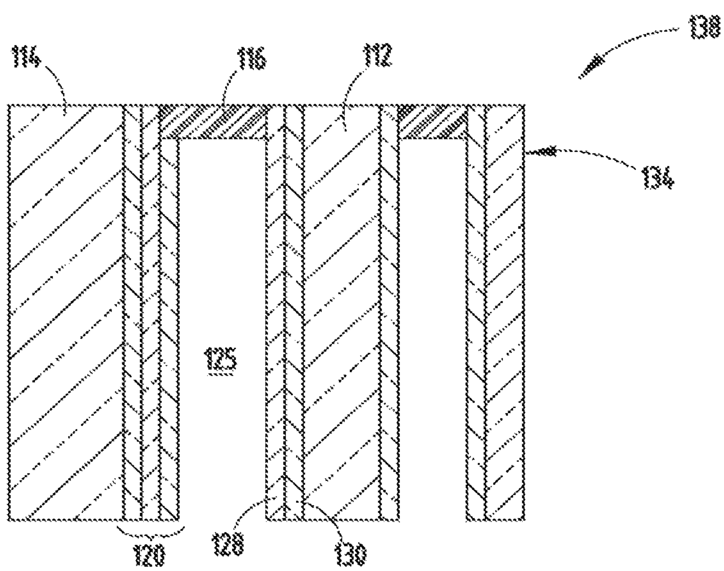
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FIG. 9G

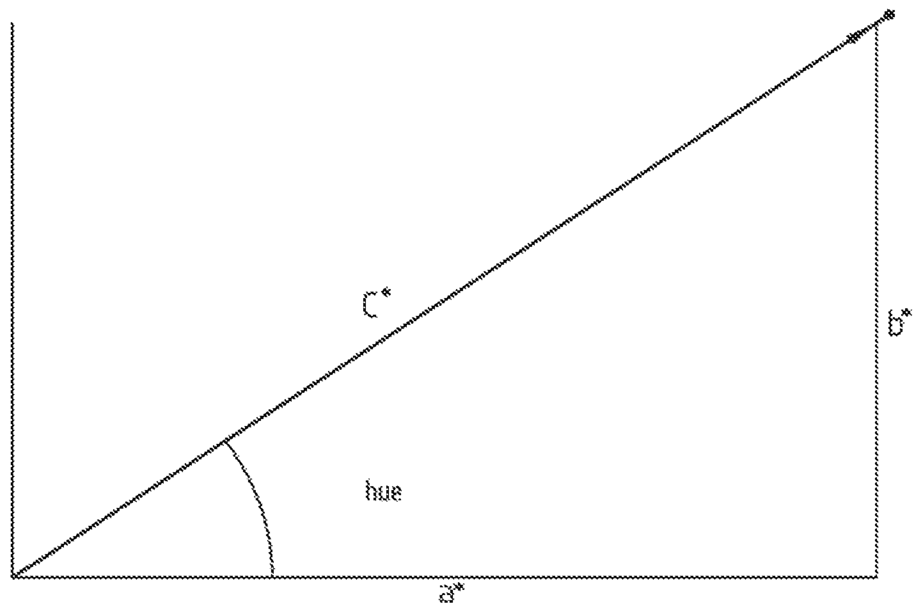
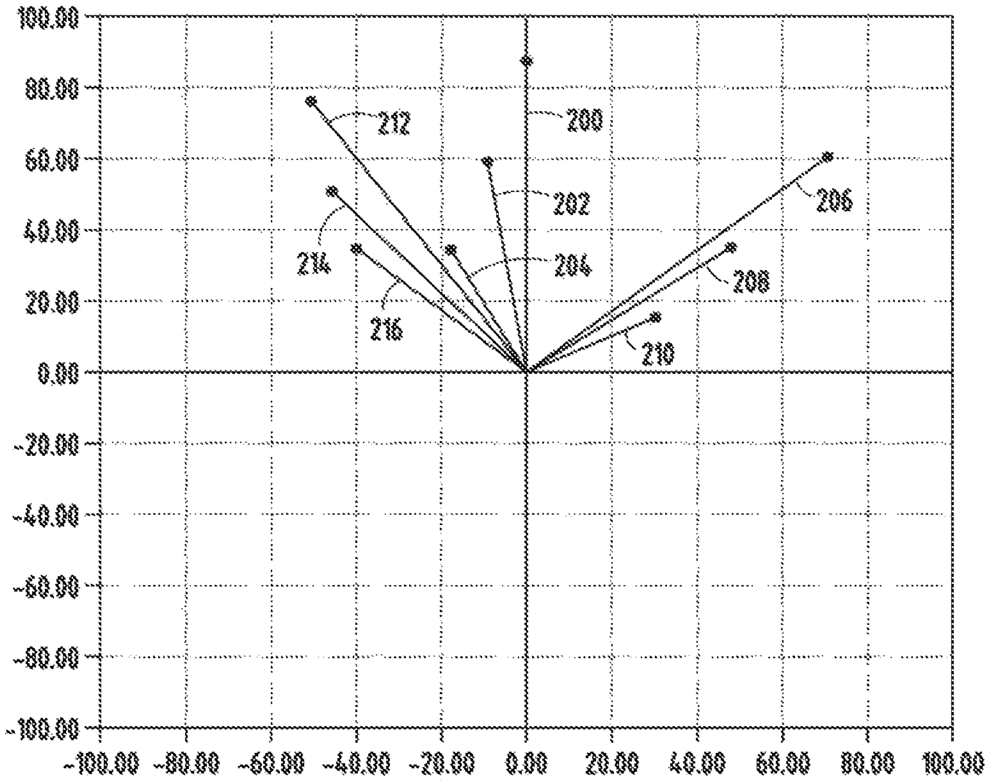

C*
b*
hue
a*

FIG.10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20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-100.00 -80.00 -60.00 -40.00 -20.00 0.00 20.00 40.00 60.00 80.00 100.00
212
200
202
206
214
204
208
216
210

FIG. 11


Abs.
0.200
0.000
400.0
480.0
520.0
600.0
800.0
WAVELENGTH (nm)
272
274
502nm

FIG. 12

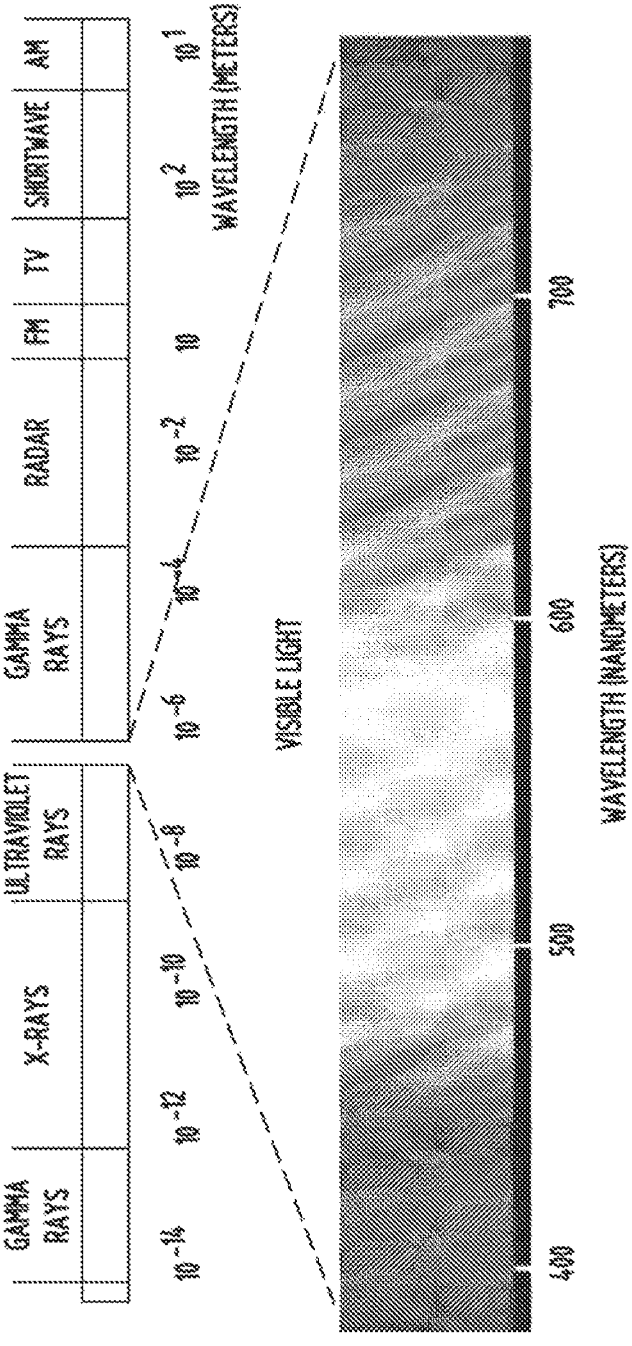

GAMMA RAYS
X-RAYS
ULTRAVIOLET RAYS
GAMMA RAYS
RADAR
FM
TV
SHORTWAVE
AM
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10
10^{2}
WAVELENGTH (METERS)
VISIBLE LIGHT
400
500
600
700
WAVELENGTH (NANOMETERS)

FIG. 13

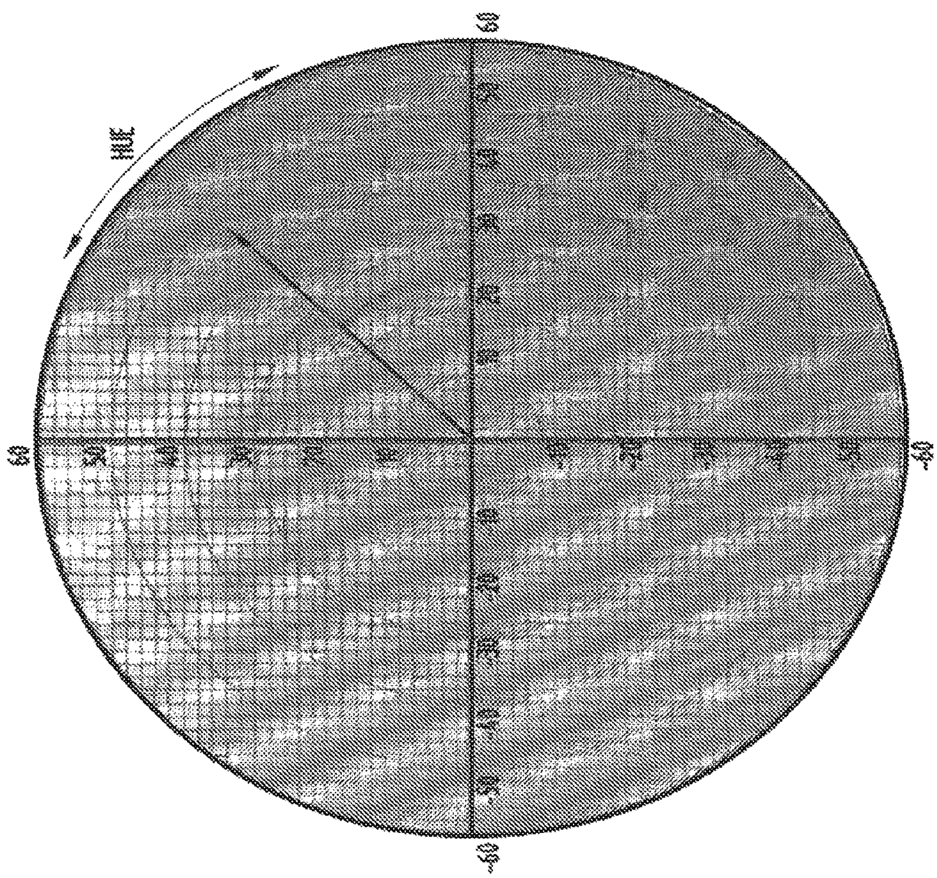


FIG. 14

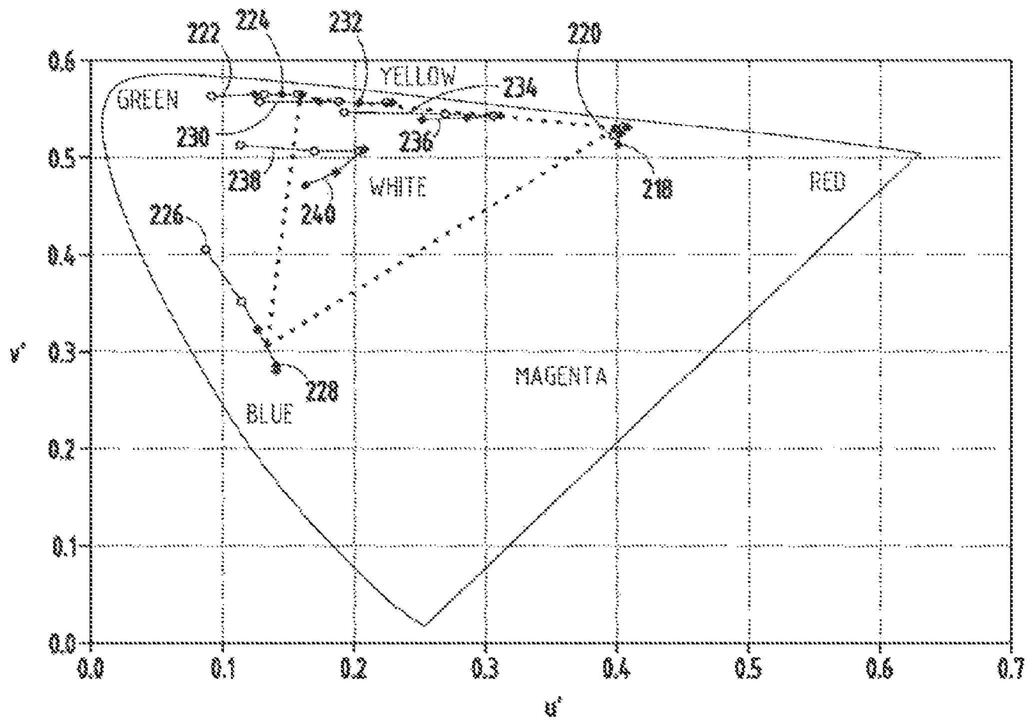


FIG. 15A

LED	ΔEu',v' (PRIOR ART)	ΔEu',v'
RED	0.010	0.019
GREEN	0.065	0.036
BLUE	0.094	0.046
WHITE	0.091	0.059
YELLOW	0.097	0.055
AMBER	0.114	0.060

FIG. 15B

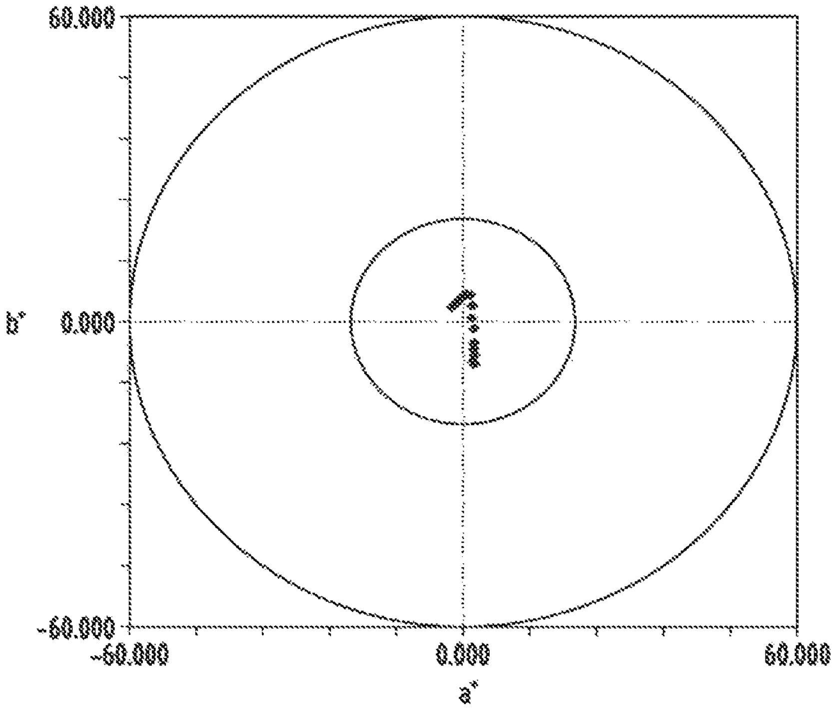


FIG. 16A

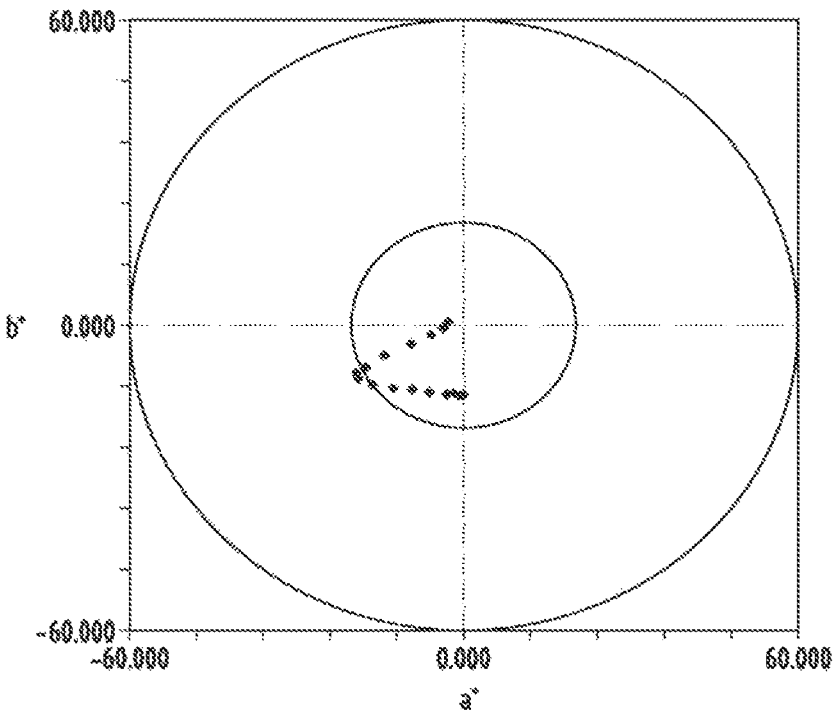


FIG. 16B
(PRIOR ART)

	EXAMPLE 1 (PRIOR ART)				EXAMPLE 2		
	RED				**RED**		
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.4046	0.5304	39.532821	**HIGH T**	0.4068	0.5305	40.312374
INT T	0.3998	0.5281	36.693982	**INT T**	0.404	0.5278	36.950414
LOW T	0.3993	0.5214	20.260877	**LOW T**	0.4003	0.5199	25.629261
	ΔEu'v'	0.010445			ΔEu'v'	0.012434	
	GREEN				**GREEN**		
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1572	0.5638	123.78843	**HIGH T**	0.1596	0.5638	123.77408
INT T	0.1315	0.5642	137.19527	**INT T**	0.1472	0.5638	130.50541
LOW T	0.0918	0.5621	155.32353	**LOW T**	0.1095	0.5634	148.78453
	ΔEu'v'	0.065422			ΔEu'v'	0.050102	
	BLUE				**BLUE**		
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1278	0.321	90.797968	**HIGH T**	0.1276	0.3217	91.867117
INT T	0.1134	0.3504	103.46725	**INT T**	0.1275	0.318	91.27702
LOW T	0.0859	0.4046	132.01785	**LOW T**	0.1092	0.354	106.91655
	ΔEu'v'	0.093512			ΔEu'v'	0.037173	
	YELLOW				**YELLOW**		
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.2248	0.5548	89.714233	**HIGH T**	0.2287	0.5546	89.560595
INT T	0.1879	0.5565	110.15056	**INT T**	0.2104	0.5555	98.882972
LOW T	0.1277	0.5571	145.10003	**LOW T**	0.1557	0.5565	132.09673
	ΔEu'v'	0.097127			ΔEu'v'	0.073025	
	AMBER				**AMBER**		
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.3061	0.5425	56.57025	**HIGH T**	0.3099	0.5421	56.687906
INT T	0.2688	0.5439	65.738873	**INT T**	0.292	0.542	59.40306
LOW T	0.192	0.5454	112.18612	**LOW T**	0.2313	0.5429	84.136208
	ΔEu'v'	0.114137			ΔEu'v'	0.078604	
	WHITE				**WHITE**		
	u'	v'			u'	v'	
HIGH T	0.2046	0.5062		**HIGH T**	0.2082	0.5072	
INT T	0.1697	0.5058		**INT T**	0.1915	0.5009	
LOW T	0.1133	0.5115		**LOW T**	0.1423	0.4978	
	ΔEu'v'	0.091454			ΔEu'v'	0.066567	

FIG. 17A

EXAMPLE 3				EXAMPLE 4			
RED				**RED**			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.4072	0.5308	40.791361	HIGH T	0.4074	0.5304	40.275933
INT T	0.4022	0.5256	34.536274	INT T	0.4034	0.5262	35.210429
LOW T	0.4033	0.5178	18.566187	LOW T	0.4004	0.5166	17.268353
	ΔEu'v'	0.013572			ΔEu'v'	0.015474	
GREEN				**GREEN**			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1595	0.5637	123.7974	HIGH T	0.1596	0.5636	123.78792
INT T	0.1369	0.564	135.65179	INT T	0.1404	0.564	133.88486
LOW T	0.1023	0.563	151.78383	LOW T	0.1019	0.5631	151.82628
	ΔEu'v'	0.057204			ΔEu'v'	0.057702	
BLUE				**BLUE**			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1275	0.3217	91.889726	HIGH T	0.1279	0.3216	91.745764
INT T	0.1265	0.3177	91.601143	INT T	0.1289	0.3129	89.815909
LOW T	0.1055	0.36	110.14911	LOW T	0.108	0.3555	107.8967
	ΔEu'v'	0.044169			ΔEu'v'	0.039309	
YELLOW				**YELLOW**			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.2285	0.5546	89.544764	HIGH T	0.2287	0.5546	89.568226
INT T	0.195	0.5555	107.93792	INT T	0.1998	0.5555	105.02635
LOW T	0.1436	0.5565	138.81735	LOW T	0.1439	0.5565	138.59927
	ΔEu'v'	0.084921			ΔEu'v'	0.084821	
AMBER				**AMBER**			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.3092	0.5424	57.036911	HIGH T	0.3114	0.5422	56.533878
INT T	0.2754	0.5418	63.129907	INT T	0.2827	0.5417	61.172772
LOW T	0.2135	0.5426	97.267507	LOW T	0.2173	0.5417	94.07589
	ΔEu'v'	0.0957			ΔEu'v'	0.094101	
WHITE				**WHITE**			
	u'	v'			u'	v'	
HIGH T	0.208	0.507		HIGH T	0.2081	0.5068	
INT T	0.1778	0.4948		INT T	0.1821	0.4951	
LOW T	0.1313	0.4971		LOW T	0.1326	0.4948	
	ΔEu'v'	0.077336			ΔEu'v'	0.076448	

FIG. 17B

EXAMPLE 5

RED

	u'	v'	h_{ab}
HIGH T	0.4059	0.5304	39.921925
INT T	0.4013	0.5261	34.783092
LOW T	0.3984	0.5187	18.857422
ΔEu'v'	0.013897		

GREEN

	u'	v'	h_{ab}
HIGH T	0.16	0.5637	123.52008
INT T	0.1366	0.5643	135.68256
LOW T	0.099	0.5631	152.99054
ΔEu'v'	0.061003		

BLUE

	u'	v'	h_{ab}
HIGH T	0.1272	0.323	92.145455
INT T	0.1221	0.3291	95.481389
LOW T	0.0998	0.374	116.30951
ΔEu'v'	0.057894		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2286	0.5546	89.395137
INT T	0.1946	0.5561	107.85015
LOW T	0.139	0.5568	141.13548
ΔEu'v'	0.089627		

AMBER

	u'	v'	h_{ab}
HIGH T	0.3129	0.542	55.869781
INT T	0.2795	0.542	61.970133
LOW T	0.213	0.5427	97.545105
ΔEu'v'	0.099902		

WHITE

	u'	v'
HIGH T	0.208	0.5076
INT T	0.1767	0.5
LOW T	0.1266	0.5012
ΔEu'v'	0.081651	

EXAMPLE 6

RED

	u'	v'	h_{ab}
HIGH T	0.407367	0.530653	40.386586
INT T	0.402336	0.526631	35.466319
LOW T	0.402209	0.517855	18.146529
ΔEu'v'	0.013799		

GREEN

	u'	v'	h_{ab}
HIGH T	0.159544	0.563561	123.76744
INT T	0.134644	0.564068	136.68646
LOW T	0.096686	0.562613	154.02066
ΔEu'v'	0.062865		

BLUE

	u'	v'	h_{ab}
HIGH T	0.127029	0.322123	91.94672
INT T	0.119536	0.335432	97.756607
LOW T	0.095631	0.384536	121.44812
ΔEu'v'	0.069866		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.228135	0.554673	89.495554
INT T	0.192185	0.556055	109.19656
LOW T	0.135676	0.557027	142.35369
ΔEu'v'	0.092489		

AMBER

	u'	v'	h_{ab}
HIGH T	0.314925	0.541571	55.151677
INT T	0.279766	0.542137	61.991686
LOW T	0.211455	0.542687	98.579769
ΔEu'v'	0.103476		

WHITE

	u'	v'
HIGH T	0.207559	0.507101
INT T	0.17408	0.501113
LOW T	0.12291	0.504696
ΔEu'v'	0.084682	

FIG. 17C

EXAMPLE 7				EXAMPLE 8			
RED				RED			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.4068	0.5307	40.112942	HIGH T	0.4064	0.5306	40.157991
INT T	0.4029	0.5253	33.665512	INT T	0.4028	0.524	32.616321
LOW T	0.406	0.5152	17.924193	LOW T	0.4023	0.5156	19.96418
ΔEu'v'	0.015521			ΔEu'v'	0.01555		
GREEN				GREEN			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1597	0.5638	123.68637	HIGH T	0.1595	0.5637	123.58285
INT T	0.1436	0.564	132.33039	INT T	0.1412	0.5636	133.66404
LOW T	0.1117	0.5634	148.11838	LOW T	0.1131	0.5633	147.21315
ΔEu'v'	0.048002			ΔEu'v'	0.046402		
BLUE				BLUE			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1272	0.3237	92.164104	HIGH T	0.1274	0.3221	91.774848
INT T	0.1339	0.301	85.881767	INT T	0.135	0.2963	84.681479
LOW T	0.1192	0.3295	96.619866	LOW T	0.1222	0.3217	93.887341
ΔEu'v'	0.009881			ΔEu'v'	0.005215		
YELLOW				YELLOW			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.2281	0.5546	89.369232	HIGH T	0.2276	0.5548	89.558284
INT T	0.2037	0.5552	102.49074	INT T	0.1996	0.555	104.8583
LOW T	0.1571	0.5558	132.03302	LOW T	0.1582	0.5554	131.17961
ΔEu'v'	0.07101			ΔEu'v'	0.069403		
AMBER				AMBER			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.3148	0.5419	55.293126	HIGH T	0.3133	0.5419	55.636668
INT T	0.2908	0.5403	57.046867	INT T	0.2852	0.5401	58.293727
LOW T	0.2377	0.5397	76.962042	LOW T	0.238	0.539	76.347417
ΔEu'v'	0.077131			ΔEu'v'	0.075356		
WHITE				WHITE			
	u'	v'			u'	v'	
HIGH T	0.2079	0.5084		HIGH T	0.2073	0.5073	
INT T	0.1867	0.493		INT T	0.183	0.4887	
LOW T	0.1443	0.4882		LOW T	0.1465	0.4845	
ΔEu'v'	0.066731			ΔEu'v'	0.064934		

FIG. 17D

EXAMPLE 9

RED

	u'	v'	h_{ab}
HIGH T	0.4062	0.5304	40.053651
INT T	0.4017	0.5246	33.227684
LOW T	0.3987	0.5156	22.741947
ΔEu'v'	0.016592		

GREEN

	u'	v'	h_{ab}
HIGH T	0.1599	0.5637	123.74355
INT T	0.1392	0.5644	134.29372
LOW T	0.1143	0.5656	145.00874
ΔEu'v'	0.04564		

BLUE

	u'	v'	h_{ab}
HIGH T	0.1276	0.3217	91.800198
INT T	0.1318	0.3062	87.613869
LOW T	0.1253	0.3184	92.212268
ΔEu'v'	0.004022		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2285	0.5546	89.580338
INT T	0.1977	0.5557	106.2982
LOW T	0.1609	0.5571	128.50314
ΔEu'v'	0.067646		

AMBER

	u'	v'	h_{ab}
HIGH T	0.315	0.5418	55.547139
INT T	0.2842	0.5406	59.435254
LOW T	0.2426	0.5401	75.102778
ΔEu'v'	0.07242		

WHITE

	u'	v'
HIGH T	0.2083	0.5075
INT T	0.1811	0.4926
LOW T	0.1501	0.4853
ΔEu'v'	0.06229	

EXAMPLE 10

RED

	u'	v'	h_{ab}
HIGH T	0.4076	0.5305	40.153284
INT T	0.4031	0.5231	31.700072
LOW T	0.4012	0.5129	21.048188
ΔEu'v'	0.018728		

GREEN

	u'	v'	h_{ab}
HIGH T	0.1599	0.5637	123.52778
INT T	0.144	0.5638	132.14892
LOW T	0.1236	0.5643	141.86609
ΔEu'v'	0.036305		

BLUE

	u'	v'	h_{ab}
HIGH T	0.1271	0.3234	92.200977
INT T	0.1405	0.2833	81.05478
LOW T	0.1401	0.2795	80.710774
ΔEu'v'	0.045784		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2285	0.5547	89.333296
INT T	0.2032	0.5547	102.90827
LOW T	0.1733	0.5553	121.87672
ΔEu'v'	0.055203		

AMBER

	u'	v'	h_{ab}
HIGH T	0.3113	0.5422	56.22316
INT T	0.2856	0.5397	57.904937
LOW T	0.2519	0.538	67.823609
ΔEu'v'	0.059548		

WHITE

	u'	v'
HIGH T	0.2078	0.5074
INT T	0.1868	0.4838
LOW T	0.1627	0.4699
ΔEu'v'	0.058654	

FIG. 17E

EXAMPLE 11				EXAMPLE 12			
RED				RED			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.4067	0.5307	40.777892	HIGH T	0.4074	0.5303	40.587225
INT T	0.4025	0.5232	32.277314	INT T	0.4035	0.5246	34.061302
LOW T	0.4022	0.5146	22.989407	LOW T	0.4036	0.5171	25.752015
ΔEu'v'	0.016717			ΔEu'v'	0.013736		
GREEN				GREEN			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1596	0.5637	123.72329	HIGH T	0.16	0.5635	123.91347
INT T	0.1436	0.5638	132.3175	INT T	0.1466	0.5647	130.12928
LOW T	0.1258	0.5643	140.76042	LOW T	0.1287	0.5655	138.45038
ΔEu'v'	0.033805			ΔEu'v'	0.031364		
BLUE				BLUE			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1276	0.3236	92.372472	HIGH T	0.129	0.3173	90.859983
INT T	0.1408	0.2823	80.978499	INT T	0.1407	0.2868	81.757448
LOW T	0.1411	0.2768	80.153448	LOW T	0.1403	0.2832	81.380412
ΔEu'v'	0.048708			ΔEu'v'	0.035924		
YELLOW				YELLOW			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.2296	0.5544	89.306631	HIGH T	0.2296	0.5544	89.780911
INT T	0.2041	0.5545	102.9038	INT T	0.2074	0.5553	101.18388
LOW T	0.1768	0.555	120.07154	LOW T	0.1803	0.5563	117.22969
ΔEu'v'	0.052803			ΔEu'v'	0.049337		
AMBER				AMBER			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.3146	0.5418	56.041217	HIGH T	0.315	0.5415	56.068526
INT T	0.2891	0.5391	57.197572	INT T	0.2926	0.5404	58.431653
LOW T	0.2572	0.5372	65.573648	LOW T	0.2611	0.5391	66.494292
ΔEu'v'	0.057584			ΔEu'v'	0.053953		
WHITE				WHITE			
	u'	v'			u'	v'	
HIGH T	0.2083	0.5062		HIGH T	0.209	0.5059	
INT T	0.1871	0.4818		INT T	0.191	0.489	
LOW T	0.1646	0.4676		LOW T	0.1679	0.4771	
ΔEu'v'	0.058307			ΔEu'v'	0.050186		

FIG. 17F

EXAMPLE 13				EXAMPLE 14			
RED				RED			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.4079	0.5301	40.375173	HIGH T	0.4077	0.5302	40.450738
INT T	0.4042	0.5255	34.964396	INT T	0.405	0.5255	35.063039
LOW T	0.4024	0.5167	24.558805	LOW T	0.4036	0.5172	25.967142
ΔEu'v'	0.014485			ΔEu'v'	0.013631		
GREEN				GREEN			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.16	0.5638	123.56362	HIGH T	0.1602	0.5637	123.47875
INT T	0.1441	0.565	131.14326	INT T	0.1492	0.5644	128.7885
LOW T	0.1206	0.566	141.61146	LOW T	0.1287	0.5654	138.38456
ΔEu'v'	0.039461			ΔEu'v'	0.031546		
BLUE				BLUE			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.1293	0.3181	90.792333	HIGH T	0.1295	0.3168	90.47831
INT T	0.1345	0.3026	86.146315	INT T	0.1409	0.2865	81.526199
LOW T	0.13	0.309	88.971686	LOW T	0.1408	0.2813	80.839874
ΔEu'v'	0.009127			ΔEu'v'	0.037255		
YELLOW				YELLOW			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.2292	0.5546	89.798224	HIGH T	0.2288	0.5545	89.920418
INT T	0.2041	0.5561	102.682	INT T	0.2108	0.5553	99.040664
LOW T	0.1691	0.5578	122.93412	LOW T	0.1797	0.5562	117.39192
ΔEu'v'	0.060185			ΔEu'v'	0.049129		
AMBER				AMBER			
	u'	v'	h_{ab}		u'	v'	h_{ab}
HIGH T	0.3138	0.5419	56.562314	HIGH T	0.3133	0.5418	56.573697
INT T	0.2885	0.5414	60.182475	INT T	0.2949	0.5407	58.166335
LOW T	0.2492	0.5413	73.628034	LOW T	0.2607	0.5391	66.454393
ΔEu'v'	0.064603			ΔEu'v'	0.052669		
WHITE				WHITE			
	u'	v'			u'	v'	
HIGH T	0.2086	0.5058		HIGH T	0.2084	0.5055	
INT T	0.1873	0.4943		INT T	0.1938	0.4898	
LOW T	0.1574	0.4851		LOW T	0.1675	0.4749	
ΔEu'v'	0.055226			ΔEu'v'	0.05108		

FIG. 17G

EXAMPLE 15

RED

	u'	v'	h_{ab}
HIGH T	0.4076	0.5302	40.262993
INT T	0.4037	0.5253	34.50413
LOW T	0.4047	0.519	26.890329
ΔEu'v'	0.011569		

GREEN

	u'	v'	h_{ab}
HIGH T	0.16	0.5638	123.55342
INT T	0.1426	0.5652	131.68546
LOW T	0.124	0.5663	139.9102
ΔEu'v'	0.036087		

BLUE

	u'	v'	h_{ab}
HIGH T	0.1288	0.3188	91.011406
INT T	0.1346	0.3016	85.928969
LOW T	0.1312	0.3072	88.078527
ΔEu'v'	0.011846		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2289	0.5547	89.724563
INT T	0.202	0.5563	103.78636
LOW T	0.1741	0.5577	119.96113
ΔEu'v'	0.054882		

AMBER

	u'	v'	h_{ab}
HIGH T	0.3114	0.5423	57.080733
INT T	0.2838	0.5419	61.597676
LOW T	0.2499	0.5417	73.359996
ΔEu'v'	0.061503		

WHITE

	u'	v'
HIGH T	0.2085	0.5064
INT T	0.1855	0.4938
LOW T	0.1603	0.486
ΔEu'v'	0.052339	

EXAMPLE 16

RED

	u'	v'	h_{ab}
HIGH T	0.4076	0.5304	40.718755
INT T	0.404	0.5248	34.256682
LOW T	0.4027	0.5178	26.140148
ΔEu'v'	0.013519		

GREEN

	u'	v'	h_{ab}
HIGH T	0.1603	0.5636	123.5249
INT T	0.1451	0.5647	130.78761
LOW T	0.1256	0.5656	139.70775
ΔEu'v'	0.034758		

BLUE

	u'	v'	h_{ab}
HIGH T	0.1294	0.3171	90.633474
INT T	0.1383	0.2917	83.19767
LOW T	0.1361	0.2938	84.304471
ΔEu'v'	0.024244		

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2292	0.5544	89.855757
INT T	0.2048	0.5556	102.46728
LOW T	0.1762	0.5566	119.47256
ΔEu'v'	0.053046		

AMBER

	u'	v'	h_{ab}
HIGH T	0.3124	0.542	56.84192
INT T	0.2879	0.541	59.995991
LOW T	0.2554	0.5403	69.937388
ΔEu'v'	0.057025		

WHITE

	u'	v'
HIGH T	0.2087	0.5057
INT T	0.1883	0.4901
LOW T	0.1639	0.4799
ΔEu'v'	0.051698	

FIG. 17H

EXAMPLE 17

RED

	u'	v'	h_{ab}
HIGH T	0.4058	0.5299	39.567384
INT T	0.4026	0.5256	34.787587
LOW T	0.3999	0.5148	23.694242
ΔEu'v'		0.016212	

GREEN

	u'	v'	h_{ab}
HIGH T	0.1582	0.5635	123.34419
INT T	0.1503	0.5643	127.12497
LOW T	0.1267	0.565	138.60238
ΔEu'v'		0.031536	

BLUE

	u'	v'	h_{ab}
HIGH T	0.1302	0.3134	88.773949
INT T	0.1406	0.2845	80.465643
LOW T	0.1425	0.2767	78.815902
ΔEu'v'		0.038706	

YELLOW

	u'	v'	h_{ab}
HIGH T	0.2245	0.5547	90.411227
INT T	0.211	0.5552	97.255119
LOW T	0.1765	0.5558	117.90623
ΔEu'v'		0.048013	

AMBER

	u'	v'	h_{ab}
HIGH T	0.303	0.5427	57.912858
INT T	0.2881	0.5416	59.40751
LOW T	0.2484	0.5395	70.816293
ΔEu'v'		0.054694	

WHITE

	u'	v'
HIGH T	0.2049	0.5043
INT T	0.1944	0.4916
LOW T	0.1653	0.4727
ΔEu'v'		0.050663

FIG. 17I

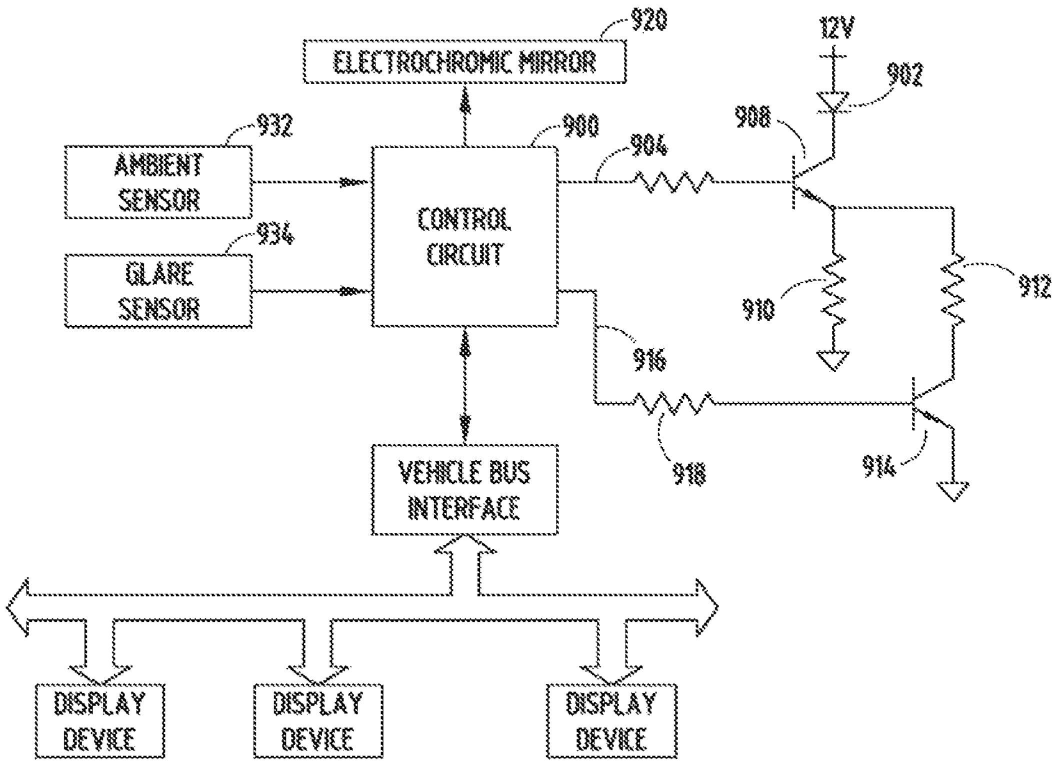

920
ELECTROCHROMIC MIRROR
12V
902
908
900
904
932
AMBIENT SENSOR
CONTROL CIRCUIT
934
GLARE SENSOR
912
910
916
918
914
VEHICLE BUS INTERFACE
DISPLAY DEVICE
DISPLAY DEVICE
DISPLAY DEVICE

FIG. 18

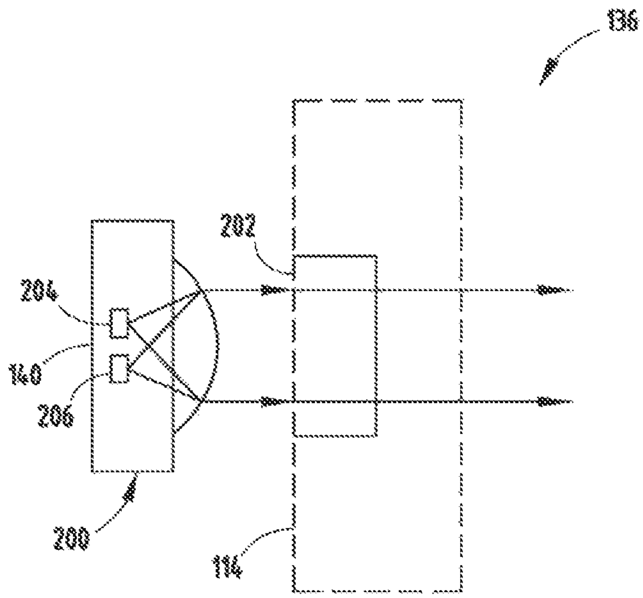

136
202
204
140
206
200
114

FIG. 19

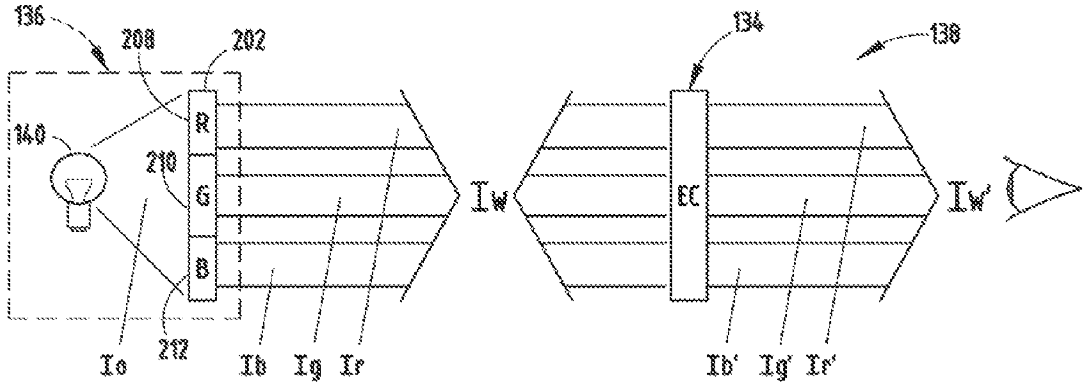


FIG. 20

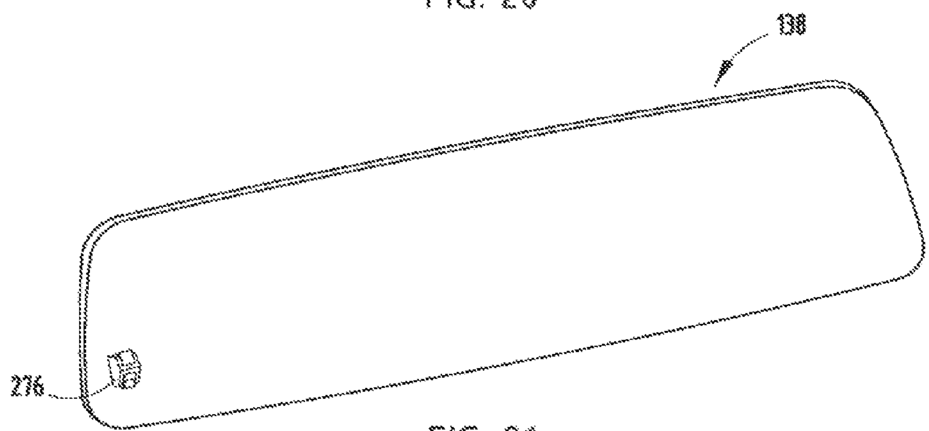


FIG. 21

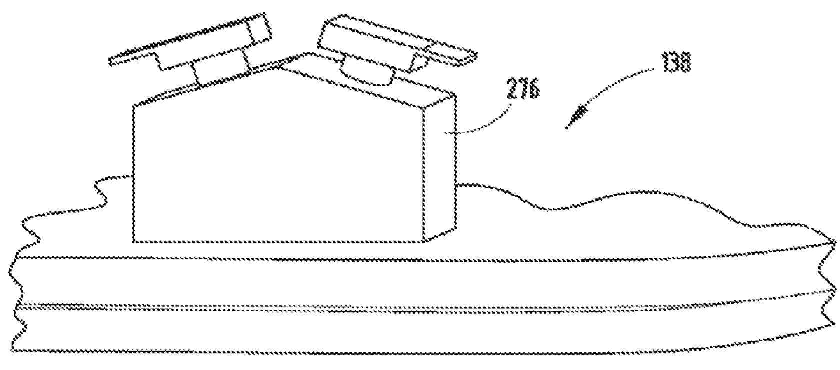


FIG. 22

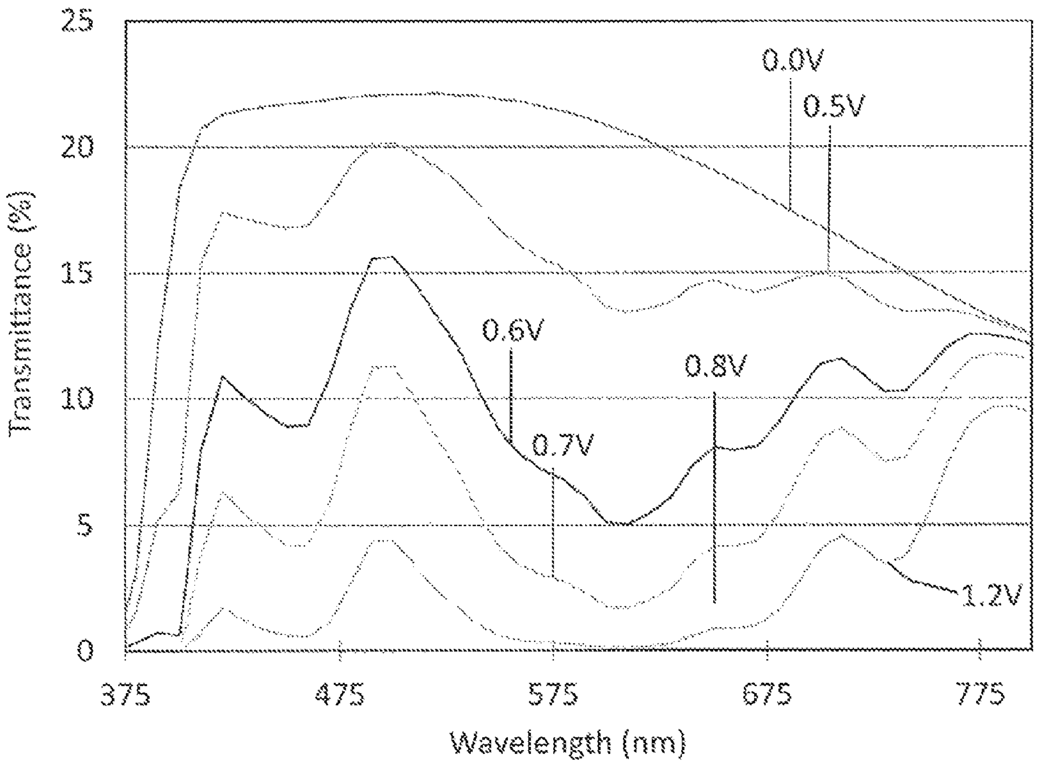


FIG. 23

Primaries (Wavelength (nm))	ΔEu',v'
420/600	0.278
420/650	0.061
500/650	0.074
450/600	0.162
420/490/650	0.098
420/490/690	0.081

FIG. 24

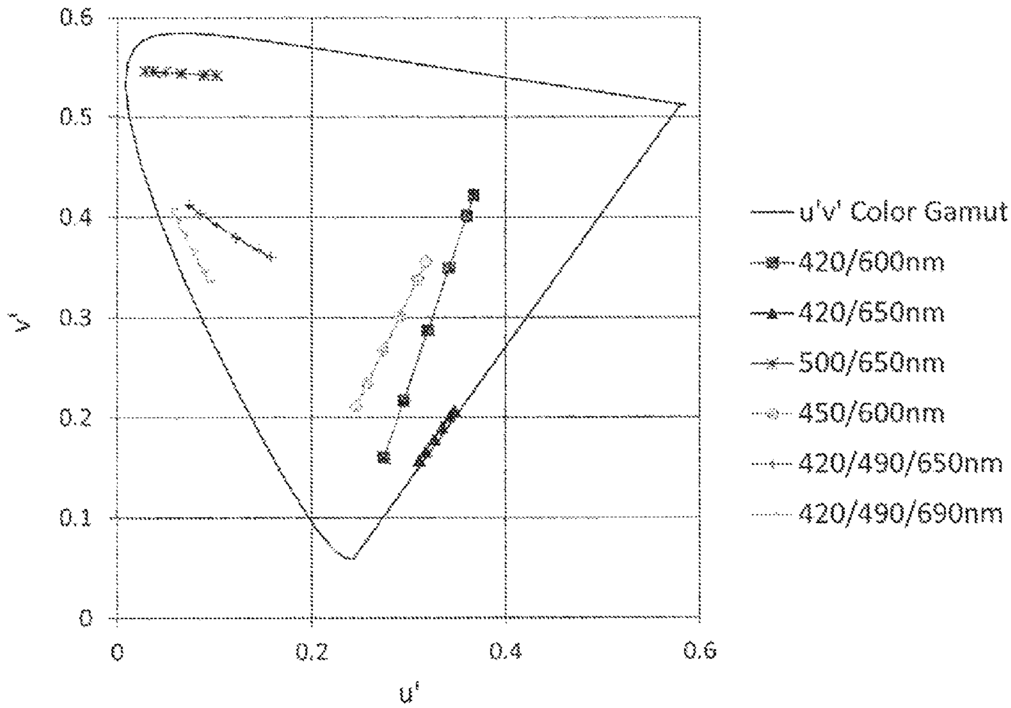

0.6
0.5
0.4
0.3
0.2
0.1
0
v'
0
0.2
0.4
0.6
u'
u'v' Color Gamut
420/600nm
420/650nm
500/650nm
450/600nm
420/490/650nm
420/490/690nm

FIG. 25

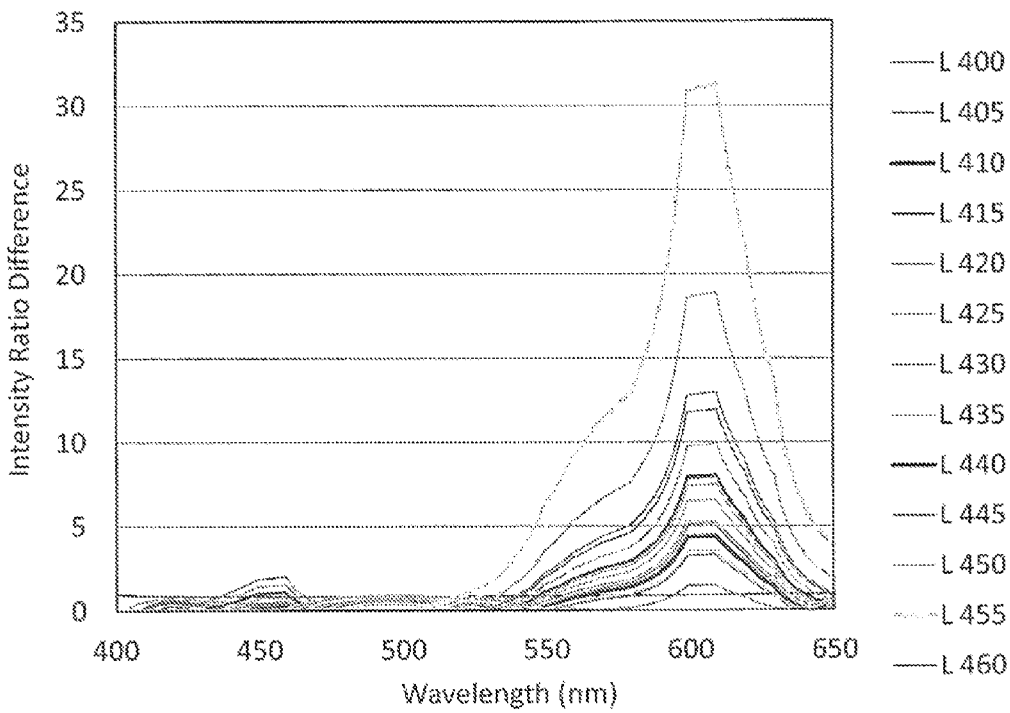
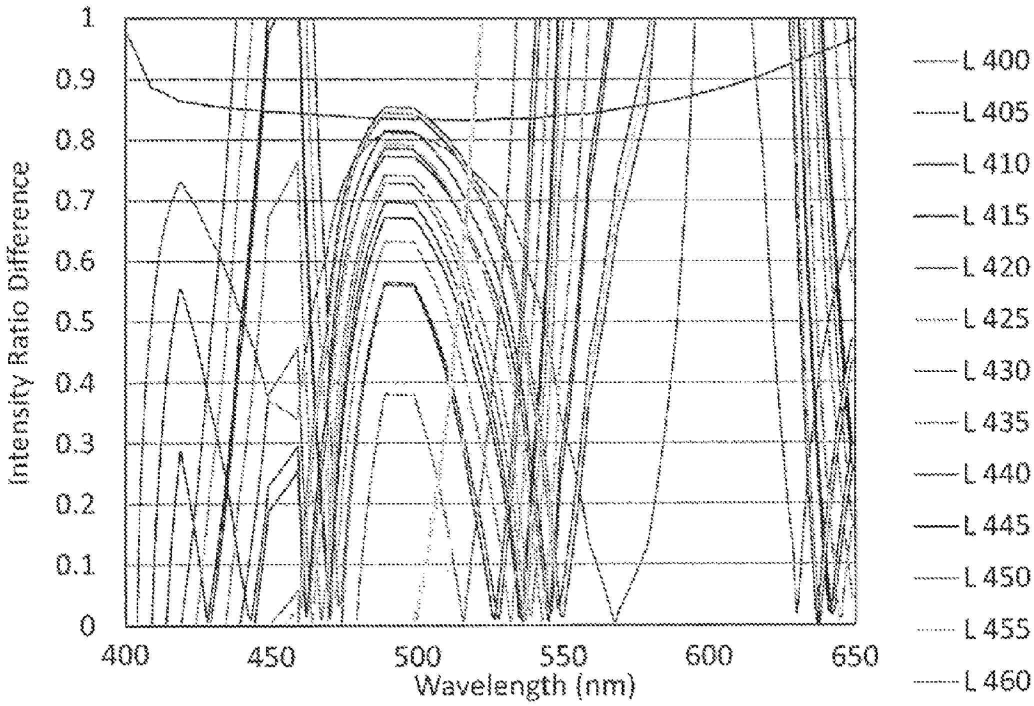
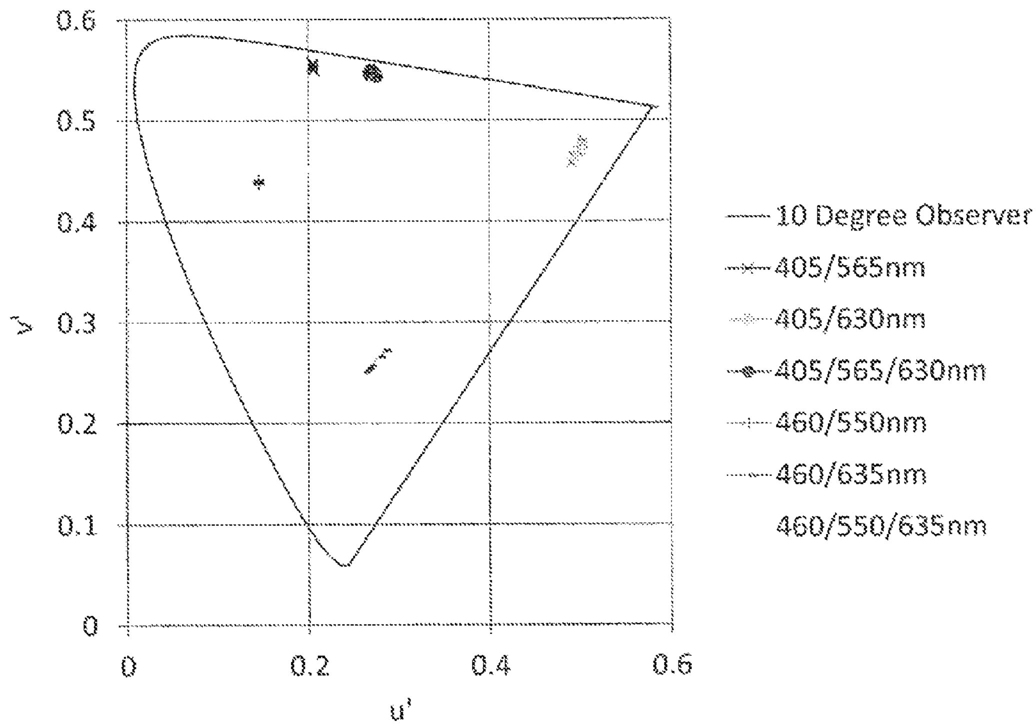

35
30
25
20
15
10
5
0
Intensity Ratio Difference
400
450
500
550
600
650
Wavelength (nm)
L 400
L 405
L 410
L 415
L 420
L 425
L 430
L 435
L 440
L 445
L 450
L 455
L 460

FIG. 26



Intensity Ratio Difference
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
Wavelength (nm)
L 400
L 405
L 410
L 415
L 420
L 425
L 430
L 435
L 440
L 445
L 450
L 455
L 460

FIG. 27



0.6
0.5
0.4
v'
0.3
0.2
0.1
0
0
0.2
0.4
0.6
u'
10 Degree Observer
405/565nm
405/630nm
405/565/630nm
460/550nm
460/635nm
460/550/635nm

FIG. 28

Primary Combinations (Wavelength (nm))	Δ Eu',v'
405/565	0.001
405/630	0.005
405/565/630	0.008
460/550	0.002
460/635	0.027
460/550/635	0.010

FIG. 29

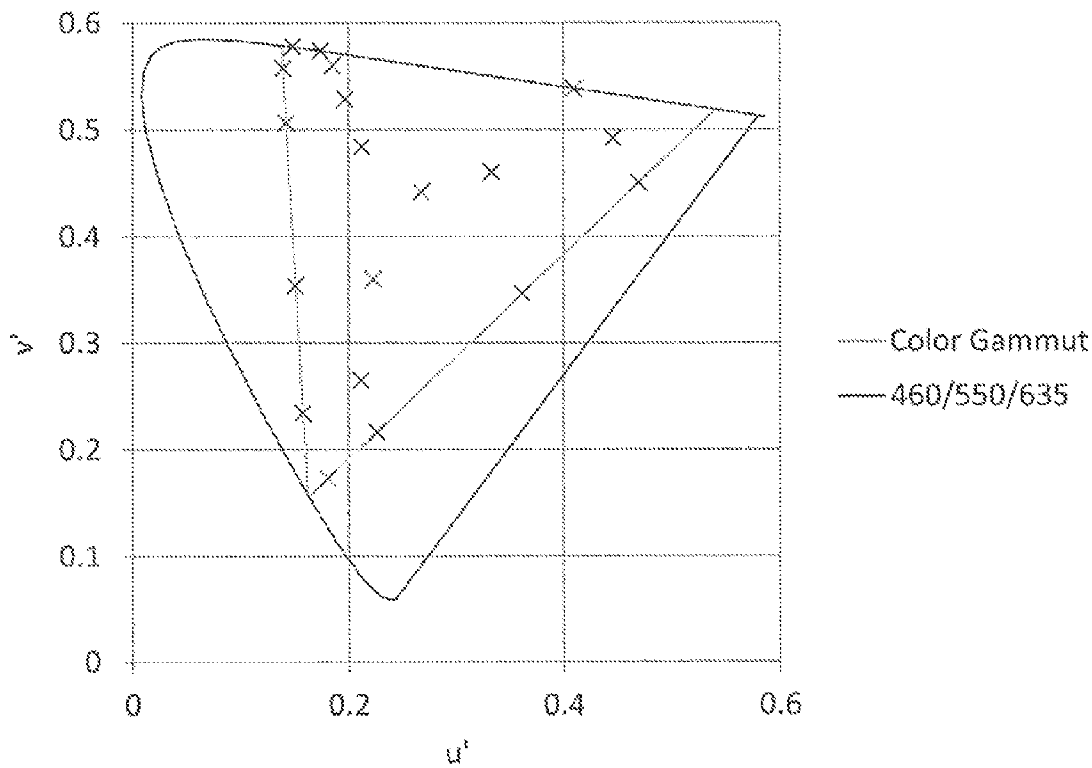


FIG. 30

Primary Wavelengths

460	**550**	**635**	Avg. ΔEu',v'	Max ΔEu',v'
90	5	5	0.010	0.015
5	90	5	0.003	0.005
5	5	90	0.010	0.013
70	15	15	0.022	0.035
15	70	15	0.010	0.017
15	15	70	0.018	0.025
50	25	25	0.025	0.041
25	50	25	0.016	0.028
25	25	50	0.020	0.032
90	0	10	0.005	0.007
10	0	90	0.019	0.026
70	0	30	0.015	0.020
30	0	70	0.029	0.039
90	10	0	0.002	0.003
10	90	0	0.001	0.001
70	30	0	0.004	0.005
30	70	0	0.002	0.003
0	90	10	0.002	0.002
0	10	90	0.017	0.024
0	70	30	0.006	0.008
0	30	70	0.016	0.022

FIG. 31

ITO Thickness (Å)	Dark State Reflectance (%)
70	9.4
80	9.2
90	8.6
100	7.7
110	6.7
120	5.8
130	5.1
140	4.9
150	5
160	5.5
170	6.2
180	7.0
190	7.7
200	8.2
210	8.5

FIG. 32

Stack	Reflectance in Dark State (%)
1/2 wave with 1.68 RI base layer	5.9
1/2 wave with 2.0 RI base layer	10.8
1/2 wave with 2.2 RI base layer	15.5
1/2 wave with 2.3 RI base layer	18.0

FIG. 33

Thickness	Reflectance	a*	b*	C*
70	9.4	-9.5	-3.8	10.2
80	9.2	-10.0	-0.4	10.0
90	8.8	-10.1	3.4	10.6
100	8.2	-9.6	6.4	11.5
110	7.4	-8.2	7.0	10.8
120	6.7	-6.1	4.1	7.4
130	6.2	-3.9	-1.6	4.2
140	5.9	-2.6	-7.7	8.1
150	5.9	-2.8	-12.3	12.6
160	6.2	-4.8	-14.4	15.2
170	6.7	-8.1	-13.8	16.0
180	7.2	-11.7	-11.0	16.0
190	7.8	-14.9	-6.4	16.2
200	8.2	-16.9	-0.9	16.9
210	8.5	-17.3	4.4	17.9

FIG. 34A

		Reflected Color		
Coating Stack	Layer Thicknesses	Y	a*	b*
Glass/Mid*/ITO	81nm/149nm	5.48	0.44	-2.45
Glass/IZO#/SiO2##/ITO	15nm/37nm/149nm	5.17	-0.09	-0.02
Glass/Simulated Gradient**/ITO	100nm/149nm	5.74	-3.59	-0.2

FIG. 34B

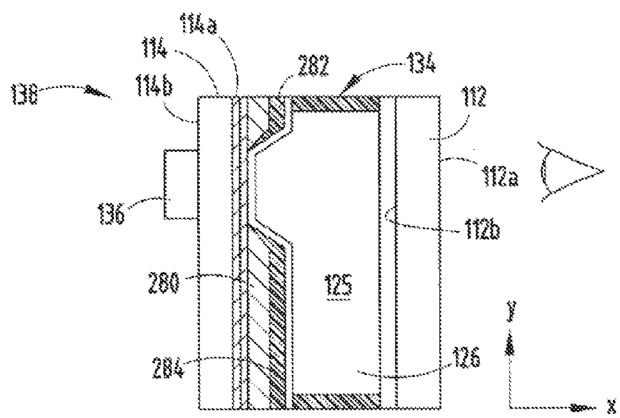


FIG. 35

Position across substrate (in)	Glass Thickness (mm)	TiO_2 (Å)	ITO (Å)	Cr (Å)	Ru (Å)	Silver Alloy (Å)	% T	% R
-5	1.6	480	180	174	19.7	55.8	7.1	57.7
-4.75	1.6	480	180	73.4	10.4	118	16	56.9
-4.5	1.6	480	180	1.18	0.72	184	31.9	56
-4.375	1.6	480	180	0	0	183	33	55.6
-2.25	1.6	480	180	0.07	0.01	183	33	55.6
-2	1.6	480	180	0.33	0.08	186	32.1	56.3
-1.75	1.6	480	180	7.9	1.1	181	29.1	57.1
-1.5	1.6	480	180	21.1	2.6	177	24.2	58.1
-1.25	1.6	480	180	52.8	6.6	150	17.8	58.8
-1	1.6	480	180	121	14.5	98	10.2	59.7
-0.75	1.6	480	180	235	26.8	60	3.6	60.5
-0.5	1.6	480	180	359	38.4	63	0.95	61.3
-0.25	1.6	480	180	442	45.4	71	0.31	62.3
0	1.6	480	180	476	48.1	78	0.25	63
0.25	1.6	480	180	497	49.8	85	0.2	63.9
0.5	1.6	480	180	500	49.9	92	0.18	64.9
5	1.6	480	180	500	50	92	0.18	64.9

FIG. 36

Position across substrate (in)	Glass Thickness (mm)	TiO_2 (Å)	ITO (Å)	Cr (Å)	Ru (Å)	Silver Alloy (Å)	% T	% R
-5.50	1.6	480	180	454	46.5	92.2	0.3	65.0
-5.25	1.6	480	180	387	40.9	90.9	0.6	65.0
-5.00	1.6	480	180	273	30.6	90	2.0	65.0
-4.75	1.6	480	180	149	17.88	119	6.6	65.0
-4.50	1.6	480	180	66.5	8.3	177	12.5	65.0
-4.25	1.6	480	180	26.2	3.3	213	17.5	65.0
-4.00	1.6	480	180	10	1.4	227	20.5	65.0
-3.75	1.6	480	180	1.1	0.4	234	22.6	65.0
-3.50	1.6	480	180	0	0	234	22.6	65
-3.25	1.6	480	180	0	0	234	22.6	65
-3.00	1.6	480	180	0	0	234	22.6	65
-2.75	1.6	480	180	0	0	234	22.6	65
-2.50	1.6	480	180	0	0	234	22.6	65
-2.25	1.6	480	180	0	0	234	22.6	65
-2.00	1.6	480	180	0	0	234	22.6	65
-1.75	1.6	480	180	0	0	234	22.6	65
-1.50	1.6	480	180	1.1	0.4	234	22.6	65.0
-1.25	1.6	480	180	10	1.4	227	20.5	65.0
-1.00	1.6	480	180	26.2	3.3	213	17.5	65.0
-0.75	1.6	480	180	66.5	8.3	177	12.5	65.0
-0.50	1.6	480	180	149	17.8	119	6.6	65.0
-0.25	1.6	480	180	273	30.6	90	2.0	65.0
0.00	1.6	480	180	387	40.9	90.9	0.6	65.0
0.25	1.6	480	180	454	46.5	92.2	0.3	65.0
0.50	1.6	480	180	480	48.5	92.6	0.2	65.0
0.75	1.6	480	180	496	49.8	92.7	0.2	65.0
1.00	1.6	480	180	497	49.7	92.8	0.2	65.0
1.50	1.6	480	180	494	49.4	92.7	0.2	65.0
2.00	1.6	480	180	488	48.8	92.7	0.2	65.0
6.00	1.6	480	180	488	48.8	92.7	0.2	65.0

FIG. 37

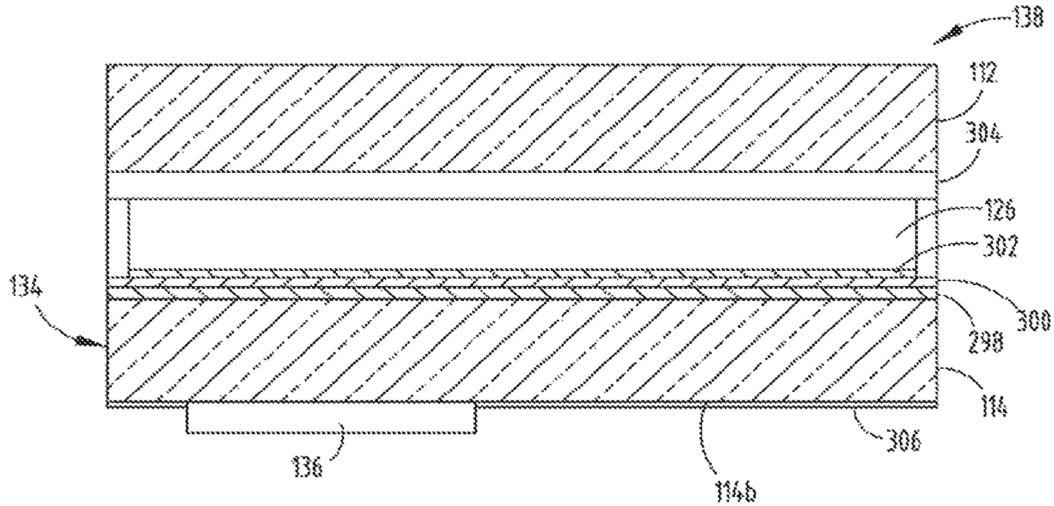


FIG. 38

	REFLECTANCE	TRANSMITTANCE
Y	65.1%	21.51%
L*	84.53	53.5
a*	-3.67	-0.18
b*	1.66	0.9

FIG. 39

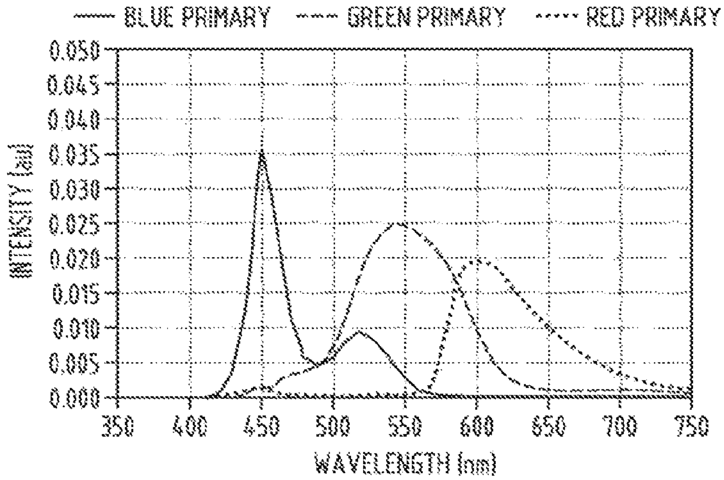


FIG. 40

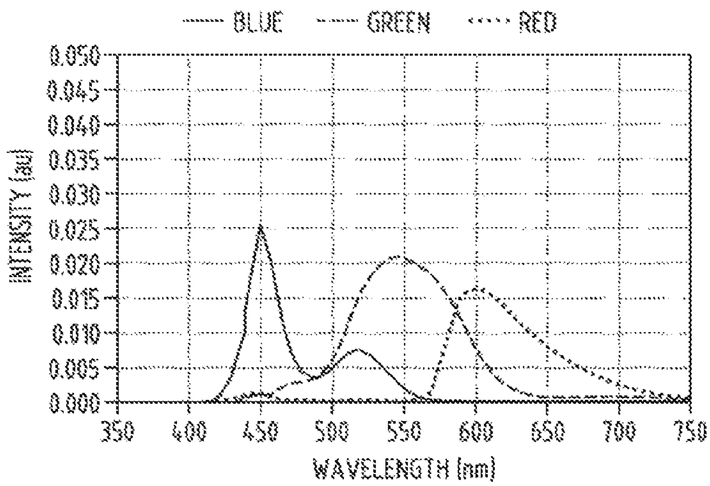


FIG. 41A

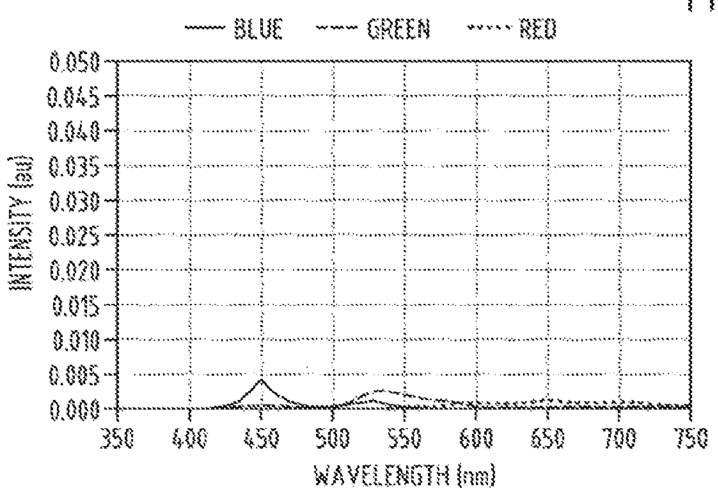


FIG. 41B

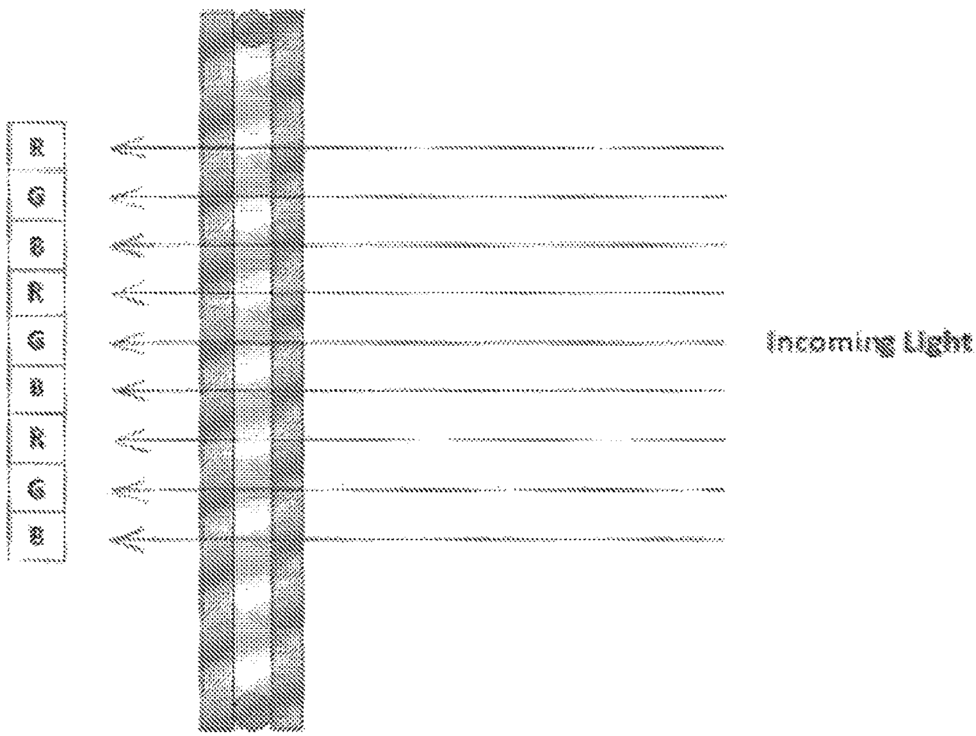


FIG. 42

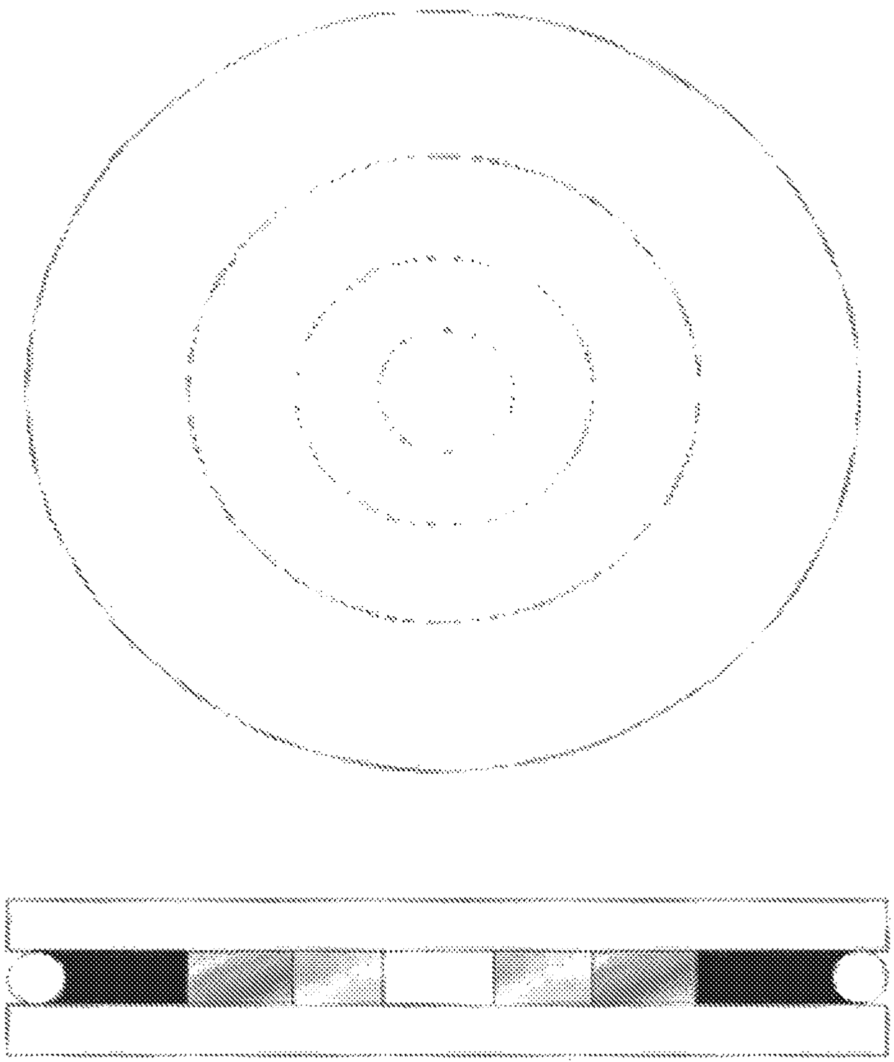


FIG. 43A

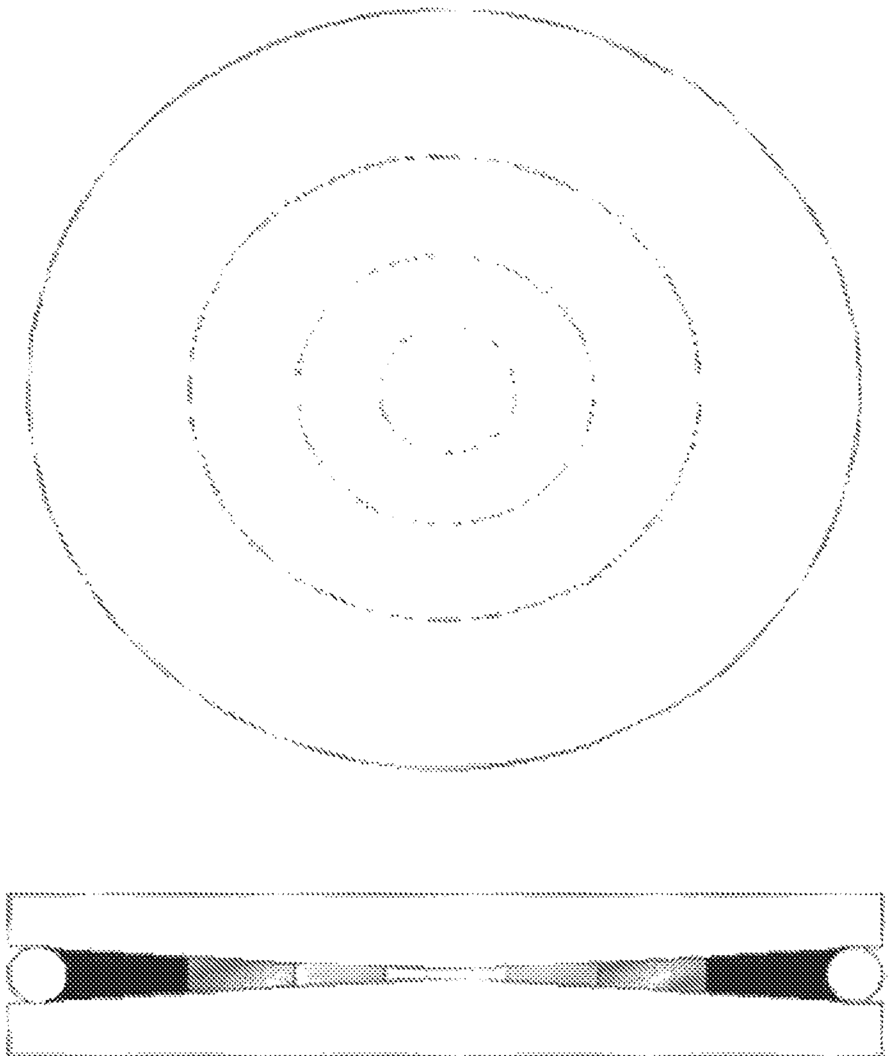


FIG. 43B

ELECTRO-OPTIC SYSTEM CONFIGURED TO REDUCE A PERCEIVED COLOR CHANGE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/628,592 filed on Feb. 23, 2015, now U.S. Pat. No. 9,096,181, which is a continuation of U.S. patent application Ser. No. 13/865,592 filed on Apr. 18, 2013, now U.S. Pat. No. 8,964,278, which is a continuation-in-part of U.S. patent application Ser. No. 13/454,459 filed on Apr. 24, 2012, and now U.S. Pat. No. 8,508,832, which is a continuation of U.S. patent application Ser. No. 12/852,790 filed Aug. 9, 2010, and now U.S. Pat. No. 8,228,590. The disclosures of the above mentioned applications are hereby incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates to an electro-optic system, and more particularly, an electro-optic system configured to reduce a perceived change of color of light propagating through a variable electro-optic element.

BACKGROUND OF THE INVENTION

Generally, various rearview mirrors for motor vehicles have been proposed which change from the full reflectance mode (day) to the partial reflectance mode(s) (night) for glare-protection purposes from light emanating from the headlights of vehicles approaching from the rear. The reflectance is varied by positioning a transmittance altering device between the viewer and the reflector. Among such devices are those wherein the transmittance is varied by thermochromic, photochromic, or electro-optic means (e.g., liquid crystal, dipolar suspension, electrophoretic, or electrochromic), and where the variable transmittance characteristic affects electromagnetic radiation that at least partly includes the visible spectrum. Devices of reversibly variable transmittance to electromagnetic radiation have been proposed as the variable transmittance element in variable transmittance light-filters, variable reflectance mirrors, and display devices, which employ such light-filters or mirrors in conveying information. These variable transmittance light filters have included windows.

In the past, information, images or symbols from displays, such as vacuum fluorescent displays, have been displayed in electrochromic rearview mirrors for motor vehicles with reflective layers on the third surface or fourth surface of the mirror. In one such device the display is visible to the vehicle occupant by removing all of the reflective layer on a portion of the selected layer and placing the display in that area. FIG. **1** shows a one type of electrochromic mirror device **10**, having front and rear planar elements **12** and **16**, respectively. A transparent conductive coating **14** is placed on the rear face of the front element **12**, and another transparent conductive coating **18** is placed on the front face of rear element **16**. A reflector (**20***a*, **20***b* and **20***c*), typically having a silver metal layer **20***a* covered by a protective copper metal layer **20***b*, and one or more layers of protective paint **20***c*, is disposed on the rear face of the rear element **16**. For clarity of description of such a structure, the front surface of the front glass element is sometimes referred to as the first surface, and the inside surface of the front glass element is sometimes referred to as the second surface. The inside surface of the rear glass element is sometimes referred to as the third surface, and the back surface of the rear glass element is sometimes referred to as the fourth surface. The front and rear elements are held in a parallel and spaced-apart relationship by seal **22**, thereby creating a chamber **26**. The electrochromic medium **24** is contained in space **26**. The electrochromic medium **24** is in direct contact with transparent electrode layers **14** and **18**, through which passes electromagnetic radiation whose intensity is reversibly modulated in the device by a variable voltage or potential applied to electrode layers **14** and **18** through clip contacts and an electronic circuit.

The electrochromic medium **24** placed in space **26** may include surface-confined, electrodeposition-type or solution-phase-type electrochromic materials. In an all solution-phase medium, the electrochemical properties of the solvent, optional inert electrolyte, anodic materials, cathodic materials, and any other components that might be present in the solution can be selected, such that no significant electrochemical or other changes occur at a potential difference which oxidizes anodic material and reduces the cathodic material other than the electrochemical oxidation of the anodic material, electrochemical reduction of the cathodic material, and the self-erasing reaction between the oxidized form of the anodic material and the reduced form of the cathodic material.

In most cases, when there is no electrical potential difference between transparent conductors **14** and **18**, the electrochromic medium **24** in space **26** is essentially colorless or nearly colorless, and incoming light (I_o) enters through front element **12**, passes through transparent coating **14**, electrochromic containing chamber **26**, transparent coating **18**, rear element **16**, and reflects off layer **20***a* and travels back through the device and out front element **12**. Typically, the magnitude of the reflected image (I_R) with no electrical potential difference is about forty-five percent (45%) to about eighty-five percent (85%) of the incident light intensity (I_o). The exact value depends on many variables outlined below, such as, for example, the residual reflection (I_R) from the front face of the front element, as well as secondary reflections from the interfaces between: the front element **12** and the front transparent electrode **14**, the front transparent electrode **14** and the electrochromic medium **24**, the electrochromic medium **24** and the second transparent electrode **18**, and the second transparent electrode **18** and the rear element **16**. These reflections are well known in the art and are due to the difference in refractive indices between one material and another as the light crosses the interface between the two. If the front element and the back element are not substantially parallel, then the residual reflectance (I_R) or other secondary reflections will not superimpose with the reflected image (I_R) from mirror surface **20***a*, and a double image will appear (where an observer would see what appears to be double (or triple) the number of objects actually present in the reflected image).

There are minimum requirements for the magnitude of the reflected image depending on whether the electrochromic mirrors are placed on the inside or the outside of the vehicle. For example, according to some requirements from most automobile manufacturers, inside mirrors have a high end reflectivity greater than fifty-five percent (55%) and in some cases approximately of at least seventy percent (70%), and outside mirrors have a high end reflectivity of at least thirty-five percent (35%).

Electrode layers **14** and **18** are connected to electronic circuitry which is effective to electrically energize the electrochromic medium, such that when a potential is applied across the transparent conductors **14** and **18**, electrochromic medium in space **26** darkens, such that incident light (I_o) is attenuated as the light passes toward the reflector **20***a* and as it passes back through after being reflected. By adjusting the potential difference between the transparent electrodes, such a device can function as a "gray-scale" device, with continuously variable transmittance over a wide range. For solution-phase electrochromic systems, when the potential between the electrodes is removed or returned to zero, the device spontaneously returns to the same, zero-potential, equilibrium color and transmittance as the device had before the potential was applied. Other electrochromic materials are available for making electrochromic devices. For example, the electrochromic medium may include electrochromic materials that are solid metal oxides, redox active polymers, and hybrid combinations of solution-phase and solid metal oxides or redox active polymers; however, the above-described solution-phase design is typical of most of the electrochromic devices presently in use.

Others have the reflector on the third surface of the structure which simultaneously acts as an electrode for the electrochromic system. Over time, the reflective surface has changed from being on the fourth surface to being on the third surface. Silver or silver alloys such as silver gold are commonly used as the third surface reflector electrode. The thickness of the silver gold layer is commonly adjusted such that the system has a so-call transflective property, wherein the system has both appreciable transmittance and reflectance. Silver based materials are particularly well suited for this application due to their low absorption of visible light. Displays are often placed behind transflective systems. The transflective nature of the system shields the display from the viewer providing a stealthy characteristic.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, an electrochromic system is provided that includes an electrochromic element that has a front element having first and second surfaces, a rear element including third and fourth surfaces, wherein the front and rear elements are sealably bonded together in a spaced-apart relationship to define a chamber, such that the second surface and the third surface face one another, a transparent first electrode including a layer of conductive material carried on the second surface, an electrochromic medium contained in the chamber, wherein the electrochromic medium is adapted to be in at least a high transmittance state and a low transmittance state, and an at least partially transmissive, partially reflective second electrode. The electrochromic system further includes a display device in optical communication with the electrochromic element, the display device including at least one light source, and being configured to emit at least a first primary and a second primary, and the first and second primaries each having a first hue (h_{ab}) when viewed through the electrochromic element in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electrochromic device in approximately the low transmittance state, wherein a change in the first and second hues (Δh_{ab}) for both first and second primaries is less than approximately 31 degrees.

According to another aspect of the present invention, a rearview mirror is provided that includes an electro-optic element that has a front element having first and second surfaces, a rear element including third and fourth surfaces, at least one reflective surface, and an electro-optic medium in optical communication between the front element and the rear element, wherein the electro-optic medium is configured to adjust between at least a high transmittance state and a low transmittance state. The rearview mirror also includes a display device in optical communication with the electro-optic element, the display device including at least one light source, and being configured to emit at least a first primary and a second primary, and the first and second primaries each having a first hue (h_{ab}) when viewed through the electro-optic element in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electro-optic element in approximately the low transmittance state, wherein a change in the first and second hues (Δh_{ab}) for both first and second primaries is less than approximately 31 degrees.

According to another aspect of the present invention, an electrochromic system is provided that includes an electrochromic element that has a front element having first and second surfaces, a rear element including third and fourth surfaces, wherein the front and rear elements are sealably bonded together in a spaced-apart relationship to define a chamber, such that the second surface and the third surface face one another, a transparent first electrode including a layer of conductive material carried on the second surface, an electrochromic medium contained in the chamber, wherein the electrochromic medium is adapted to be in at least a high transmittance state and a low transmittance state, and a partially transmissive, partially reflective layer. The electrochromic system further includes a display device in optical communication with the electrochromic element, the display device including at least one light source, and being configured to emit at least one primary that is light having at least one of a yellow hue and an amber hue, and the at least one primary having a first hue (h_{ab}) when viewed through the electrochromic element in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electrochromic device in approximately the low transmittance state, wherein a change in the first and second hues (Δh_{ab}) is less than approximately 55 degrees.

According to yet another aspect of the present invention, an electrochromic system is provided that includes an electrochromic element that has a front element having first and second surfaces, a rear element including third and fourth surfaces, wherein the front and rear elements are sealably bonded together in a spaced-apart relationship to define a chamber, such that the second surface and the third surface face one another, a transparent first electrode including a layer of conductive material carried on the second surface, an electrochromic medium contained in the chamber, wherein the electrochromic medium is adapted to be in at least a high transmittance state and a low transmittance state, and a partially transmissive, partially reflective layer. The electrochromic system further includes a display device in optical communication with the electrochromic element, the display device including at least one light source, and being configured to emit a primary that is light having a blue hue, and the primary having a first hue (h_{ab}) when viewed through the electrochromic element in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electrochromic device in approximately the low transmittance state, wherein a change in the first and second hues (Δh_{ab}) is less than approximately 49 degrees.

These and other features, advantages, and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a cross-sectional view of a prior art electrochromic mirror assembly;

FIG. **2** is a front elevational view schematically illustrating an inside/outside electrochromic rearview mirror system for motor vehicles, wherein the inside and outside mirrors incorporate an electro-optic system, in accordance with one embodiment of the present invention;

FIG. **3** is a cross-sectional view of the inside electrochromic rearview mirror incorporating a third surface reflector/electrode illustrated in FIG. **2**, taken on the line III-III thereof, in accordance with one embodiment of the present invention;

FIG. **4** is a cross-sectional view of an electrochromic mirror incorporating an alternate embodiment of a third surface reflector/electrode, taken on the line IV-IV of FIG. **2**, in accordance with one embodiment of the present invention;

FIG. **5**A is a cross-sectional view of an electrochromic system having an improved arrangement for applying a drive potential to the transparent conductor on the second surface of the mirror, in accordance with one embodiment of the present invention;

FIG. **5**B is a top view of the third surface reflector of FIG. **5**A, in accordance with one embodiment of the present invention;

FIG. **6** is a cross-sectional view of an electrochromic system using a cured and machine-milled epoxy seal to hold the transparent elements in a spaced-apart relationship, in accordance with one embodiment of the present invention;

FIGS. **7**A-**7**H are partial cross-sectional views of alternative constructions of an electrochromic system, in accordance with various embodiments of the present invention;

FIG. **8** is a partial cross-sectional view of an electrochromic system, in accordance with one embodiment of the present invention;

FIGS. **9**A-**9**G are partial cross-sectional views of additional constructions of an electrochromic system, in accordance with various embodiments of the present invention;

FIG. **10** is a diagram illustrating characteristics of an emitted light with respect to a*, b*, C*, and hue values;

FIG. **11** is a chart illustrating changes in h_{ab} for various primaries emitted from a display device that are viewed through an electrochromic medium that is altered between approximately a high transmittance state and approximately a low transmittance state, in accordance with one embodiment of the present invention;

FIG. **12** is a chart illustrating a comparison of light absorption by an electrochromic medium with respect to wavelength for a prior art electrochromic element and an electrochromic medium in accordance with one embodiment of the present invention;

FIG. **13** is a chart illustrating a spectrum of visible light;

FIG. **14** is a chart illustrating in the L*a*b* color space, a* and b* being converted into C* and a hue;

FIG. **15**A is a chart illustrating a comparison of a perceived change in color in the u',v' color space as a transmittance state varies for a prior art electrochromic element and an electrochromic system in accordance with one embodiment of the present invention;

FIG. **15**B is a table illustrating a comparison of a perceived color change in the u',v' color space illustrated in FIG. **15**A;

FIG. **16**A is a chart illustrating a reflected color of an electrochromic system as an electrochromic medium alters transmittance states, in accordance with one embodiment of the present invention;

FIG. **16**B is a chart illustrating a reflected color of a prior art electrochromic element as an electrochromic medium alters transmittance states;

FIGS. **17**A-**17**I are tables illustrating various examples of perceived color change, in accordance with various embodiments of the present invention and the prior art;

FIG. **18** is an electrical circuit diagram in block and schematic form for controlling a contrast ratio of a display associated with an electrochromic mirror, in accordance with one embodiment of the present invention;

FIG. **19** is a block diagram of a display device, in accordance with one embodiment of the present invention;

FIG. **20** is a schematic diagram of an electrochromic system, in accordance with one embodiment of the present invention;

FIG. **21** is a perspective view of a rearview mirror assembly having a display device that includes a sensor, in accordance with one embodiment of the present invention;

FIG. **22** is a perspective view of the display device of FIG. **21**;

FIG. **23** is a chart illustrating examples of transmittance at various wavelengths in an electrochromic system at various applied potentials, in accordance with one embodiment of the present invention;

FIG. **24** is a table illustrating $\Delta E_{u',v'}$ for exemplary primaries, in accordance with one embodiment of the present invention;

FIG. **25** is a chart illustrating examples of u',v' values at various wavelength combinations, in accordance with one embodiment of the present invention;

FIG. **26** is a chart illustrating exemplary intensity ratio differences at various wavelengths, in accordance with one embodiment of the present invention;

FIG. **27** is a chart illustrating exemplary intensity ratio differences at various wavelengths, in accordance with one embodiment of the present invention;

FIG. **28** is a chart illustrating examples of u',v' values at various wavelength combinations, in accordance with one embodiment of the present invention;

FIG. **29** is a table illustrating $\Delta E_{u',v'}$ for exemplary primaries, in accordance with one embodiment of the present invention;

FIG. **30** is a chart illustrating examples of u',v' values at various wavelengths, in accordance with one embodiment of the present invention;

FIG. **31** is a table illustrating $\Delta E_{u',v'}$ values for exemplary primaries, in accordance with one embodiment of the present invention;

FIG. **32** is a table illustrating ITO thickness with respect to low reflectance state percentage, in accordance with one or more embodiments of the present invention;

FIG. **33** is a table illustrating a reflectance in low reflectance state with respect to exemplary stacks, in accordance with one or more embodiments of the present invention;

FIG. **34**A is a table illustrating calculated reflective color for various idealized thin film stacks in the low reflectance state, in accordance with one or more embodiments of the present invention;

FIG. **34**B is a table illustrating three examples of coating stacks that can provide neutral reflected color, in accordance with one or more embodiments of the present invention;

FIG. **35** is a cross-sectional view of an electrochromic system that includes a graded transition between an opaque area and a display area, in accordance with one embodiment of the present invention;

FIG. **36** is a table illustrating various characteristics of a stack in an electrochromic system, in accordance with one or more embodiments of the present invention;

FIG. **37** is a table illustrating various characteristics of a stack in an electrochromic system, in accordance with one or more embodiments of the present invention;

FIG. **38** is a cross-sectional view of an electrochromic system, in accordance with one embodiment of the present invention;

FIG. **39** is a table of characteristics of a stack in an electrochromic system, in accordance with one embodiment of the present invention;

FIG. **40** is a chart illustrating an output from a display device, in accordance with one embodiment of the present invention;

FIG. **41**A is a chart illustrating an output of light viewed through an electrochromic medium in approximately its high transmittance state, in accordance with one embodiment of the present invention;

FIG. **41**B is a chart illustrating an output of light viewed through an electrochromic medium in approximately its low transmittance state, in accordance with one embodiment of the present invention;

FIG. **42** is a diagram illustrating light passing through an electro-optic device, in accordance with one embodiment of the present invention;

FIG. **43**A is a diagram illustrating rings or gradient of potential, in accordance with one embodiment of the present invention; and

FIG. **43**B is a diagram illustrating non-uniform cell spacing, in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

With respect to FIG. **2**, an inside mirror assembly **110** and two outside rearview mirror assemblies **111***a* and **111***b* are schematically illustrated for the driver-side and passenger-side, respectively, all of which can be adapted to be installed on a motor vehicle in a conventional manner and where the mirrors face the rear of the vehicle and can be viewed by the driver of the vehicle to provide a rearward view, according to one embodiment. The inside mirror assembly **110** and the outside rearview mirror assemblies **111***a* and **111***b* may incorporate light-sensing electronic circuitry of the type illustrated and described in Canadian Patent No. 1,300,945, entitled "AUTOMATIC REARVIEW MIRROR SYSTEM FOR AUTOMOTIVE VEHICLES," U.S. Pat. No. 5,204,778, entitled "CONTROL SYSTEM FOR AUTOMATIC REARVIEW MIRRORS," U.S. Pat. No. 5,451,822, entitled "ELECTRONIC CONTROL SYSTEM," U.S. Pat. No. 6,359,274, entitled "PHOTODIODE LIGHT SENSOR," U.S. Pat. No. 6,402,328, entitled "AUTOMATIC DIMMING MIRROR USING SEMICONDUCTOR LIGHT SENSOR WITH INTEGRAL CHARGE COLLECTION," U.S. Pat. No. 6,379,013, entitled "VEHICLE EQUIPMENT CONTROL WITH SEMICONDUCTOR LIGHT SENSORS," or U.S. Pat. No. 7,543,946, entitled "DIMMABLE REARVIEW ASSEMBLY HAVING A GLARE SENSOR," the entire references hereby being incorporated herein by reference, and other circuits capable of sensing glare and ambient light and applying a drive potential to the electrochromic element. The mirror elements contained in the mirror assemblies **110**, **111***a*, and **111***b* are essentially identical in that like numbers identify like components of the inside and outside mirrors **110**, **111***a*, **111***b*. These components may be slightly different in configuration, but function in substantially the same manner and obtain substantially the same results as similarly numbered components. For example, the shape of the front glass element of the inside mirror **110** is generally longer and narrower than the outside mirrors **111***a* and **111***b*. There are also some different performance standards placed on the inside mirror **110** as compared to the outside mirrors **111***a* and **111***b*. For example, the inside mirror **110** generally, when fully cleared, should have a reflectance value of greater than fifty percent (50%), and in some cases of about fifty-five percent (55%) to about eighty-five percent (85%) or higher, whereas the outside mirrors often have a reflectance of about forty percent (40%) to about sixty-five percent (65%). Also, in the United States (as supplied by the automobile manufacturers), the passenger-side mirror **111***b* typically has a convex shape, whereas the driver-side mirror **111***a* and inside mirror **110** presently must be flat. In Europe, the driver-side mirror **111***a* is commonly flat or aspheric, whereas the passenger-side mirror **111***b* has a convex or aspheric shape. In Japan, both outside mirrors have a convex shape. The following description is generally applicable to all mirror assemblies of the present invention.

Regarding to FIG. **3**, an exemplary cross-sectional view of mirror assembly **110** is illustrated having a front transparent element **112** having a front or first surface **112***a* and a rear or second surface **112***b*, and a rear element **114** having a front or third surface **114***a* and a rear or fourth surface **114***b*. For clarity of description of such a structure, the following designations will be used hereinafter. The front surface **112***a* of the front transparent element **112** will be referred to as the first surface, and the back surface **112***b* of the front transparent element **112** will be referred to as the second surface. The front surface **114***a* of the rear transparent element **114** will be referred to as the third surface, and the back surface **114***b* of the rear transparent element **114** will be referred to as the fourth surface. A chamber **125** can be defined by one or more layers that make up an at least partially transparent conductor **128** (carried on second surface **112***b*), a reflector/electrode **120** (disposed on third surface **114***a*), and an inner circumferential wall **132** of sealing member **116**. An electrochromic medium **126** can be contained within a chamber **125**. According to one embodiment, the reference to an electrode or layer as being "carried" on at least a portion of the surface of an element, refers to both electrodes or layers that are disposed directly on at least a portion of the surface of an element or disposed at least partially on another coating, layer, or layers that are disposed directly on at least a portion of the surface of the element.

The front element **112**, the rear element **114**, and the electrochromic medium **126** contained in the chamber **125** can be included in an electrochromic element, generally indicated at reference identifier **134** (FIGS. **3**-**9**G, **35**, and **38**), according to one embodiment. A display device or light engine **136** (FIGS. **7**A-**9**E, **19**, **20**, **35**, and **38**) can be in optical communication with the electrochromic element **134**, such that the display device **136** is configured to emit light that is viewed through the electrochromic element **134**. Typically, the display device **136** can be configured to emit light in a plurality of colors. Alternatively, the electrochromic medium **126** contained in the chamber **125** can be any suitable electro-optic medium, such that an electro-optic element can include a front element **112**, the rear element

114, and an electro-optic medium, and the display device 136 is in optical communication with the electro-optic element. According to one embodiment, an electrochromic system, generally indicated at reference identifier 138 (FIGS. 7A-9G, 20-22, 35, and 38), includes the electrochromic element 134 and the display device 136. The electrochromic system 138 and the electro-optic element are described herein with respect to a rearview mirror for purposes of explanation and not limitation, and can be other types of systems or devices, such as, but not limited to, an electrochromic or electro-optic window.

The electrochromic system 138 can include an electrochromic element 134 having the front element 112 including the first surface 112*a* and the second surface 112*b*, and the rear element 114 including the third surface 114*a* and the fourth surface 114*b*, wherein the front and rear elements 112, 114 are sealably bonded together in a spaced-apart relationship to define the chamber 125, according to one embodiment. The electrochromic element 134 can also include the transparent first electrode 128 having one or more layers with at least one of which is a conductive material carried on the second surface 112*b*, the electrochromic medium 126 contained in the chamber 125, wherein the electrochromic medium 126 is adapted to be in at least a high transmittance state and a low transmittance state, and a partially transmissive, partially reflective second electrode 120. The partially transmissive partially reflective second electrode 120 can be disposed over at least a portion of the third surface 114*a* and/or the fourth surface 114*b*. The electrochromic system 138 can further include the display device 136 in optical communication with the electrochromic element 134, wherein the display device 136 includes at least one light source 140.

Generally, the electrochromic element 134 and display device 136 can have a plurality of elements that affect the light (e.g., intensity versus wavelength and/or h_{ab}) emitted by a light source 140 of the display device 136. Thus, light passing through all of the optical elements after the light has been emitted by the light source 140, and viewed through one or more elements of the display device 136 and the electrochromic element 134, typically has different intensity levels across the visible spectrum than the original light that could be viewed directly from the light source 140. In some embodiments, it may be important for the light passing through all of the components to have certain characteristics such as meeting a certain color gamut. In embodiments where there is not a perfect match of the color before and after a given component, the components may be designed or selected to compensate for weaknesses or characteristics in the other components of the electrochromic system 138. The electrochromic element 134, the display device 136, or a combination thereof, can have one or more components configured to enhance the actual perceived light due to any adverse affects one or more components of the electrochromic element 134 and the display device 136 may have on the emitted light, as described in greater detail herein.

As illustrated in FIG. 20, by way of example, the electrochromic system 138 can include the electrochromic element 134 and the display device 136, wherein the display device 136 can include the light source 140 and the display element 202. In such an embodiment, the display device 136 can be an LCD. Typically, the light emitted by the light source 140 includes light at various wavelengths (I_O). The light when viewed through the display element 202, which is exemplary illustrated as having a red filter 208, a green filter 210, and a blue filter 212. Generally, the light emitted from the light source 140 when viewed through the red filter 208 appears as red I_r, the light emitted from the light source 140 when viewed through the green filter 210 appears as green I_g, and the light emitted from the light source 140 when viewed through the blue filter 212 appears as blue I_b to generate the red, green, and blue primaries; although other primaries may be used. The red, green, and blue primaries, I_r, I_g, I_b can blend together I_w to have a hue that can be based upon the intensity of the red, green, and blue primaries I_r, I_g, I_b. The light output of the display device is illustrated in the chart of FIG. 40.

These the red, green, and blue primaries I_r, I_g, I_b and combinations thereof can be viewed through the display device 136 by the user. The red, green, and blue primaries I_r, I_g, I_b may be altered by the electrochromic element 134 in the high transmittance state, wherein the altered primaries are represented in FIG. 20 by I_r', I_g', and I_b', respectively. The output of light viewed through the electrochromic medium 126 in approximately the high transmittance state is illustrated in the chart of FIG. 41A. Furthermore, the red, green, and blue primaries I_r, I_g, I_b may be altered by the electrochromic element 134 in a reduced transmittance state, and such altered primaries can also be represented in FIG. 20 by I_r', I_g', and I_b', respectively. The output of light viewed through the electrochromic medium 126 in approximately the low transmittance state is illustrated in the chart of FIG. 41B. Typically, the electrochromic system 138 is configured such that the final colors have the proper characteristics. This is, by way of example, illustrated in the charts of FIGS. 41A and 41B, which show a ratio of the red, green, and blue light that will appear approximately color neutral to a viewer when the electrochromic medium 126 is in approximately its high and low transmittance state, respectively.

As described in greater detail herein, the electrochromic element 134, the display device 136, or a combination thereof can be configured to reduce the perceived hue difference between I_r', I_g', and I_b' and when the electrochromic element 134 is in approximately the high transmittance state and in a reduced transmittance state. This is exemplary illustrated in the chart of FIG. 40, which shows the red, green, and blue primaries projected to a level that will appear approximately color neutral to a viewer. As described in greater detail herein, the electrochromic element 134, the display device 136, or a combination thereof can be configured to eliminate or reduce the perceived color difference between I_r', I_g', and I_b' when the electrochromic element 134 is driven from a high transmittance state to a reduced transmittance state. Various embodiments are proposed to achieve adequate color preservation for different applications. One embodiment of the present invention is illustrated in FIGS. 41A and 41B, which show the same primaries when modulated by the electrochromic element 134 in approximately the high transmittance state and approximately the low transmittance state.

The display device 136 can be an emissive display that uses the principles of additive color mixing to achieve a range of colors used in the display device 136, according to one embodiment. Typically, in additive color mixing three "primaries" (e.g., red, green, and blue) can be mixed with various intensities to produce a desired color, although other primaries may be used.

The display device 136 can include the light source 140, and the light source 140 can include one or more lighting elements (e.g., light emitting diodes (LEDs)). According to one embodiment, the light source 140 can be a white lighting element. Alternatively, the light source 140 can include a plurality of red, green, and blue (RGB) lighting elements. Exemplary devices are described in U.S. Patent Application

Publication 2008/0068520, entitled "VEHICLE REARVIEW MIRROR ASSEMBLY INCLUDING A HIGH INTENSITY DISPLAY," and U.S. Pat. No. 6,521,916, entitled "RADIATION EMITTER DEVICE HAVING AN ENCAPSULANT WITH DIFFERENT ZONES OF THERMAL CONDUCTIVITY," the entire references hereby being incorporated herein by reference.

FIG. **19** exemplary illustrates an embodiment, wherein an illumination device generally indicated at reference identifier **200** is positioned behind a display element **202** for projecting light through the display element **202**. The display element **202** may be a dynamically variable light shutter, such as an LCD or an electrochromic display provided on or near the rear element **114**. Examples of display elements in the form of an appliqué positioned behind an electrochromic mirror are disclosed in U.S. Pat. No. 6,870,655, entitled "REARVIEW MIRROR DISPLAY," the entire reference hereby being incorporated herein by reference.

The illumination device **200** may include one or more light emitting packages, such as, but not limited to, NICHIA™ Corp. part number NSSW064A, or packages disclosed in commonly assigned U.S. Pat. No. 6,335,548, entitled "SEMICONDUCTOR RADIATION EMITTER PACKAGE," the entire reference hereby being incorporated herein by reference. The light source **140** can include a plurality of lighting elements **204** and **206**, such as, but not limited to, LED chips or other semiconductor radiation emitters that can be provided in a single package and may be individually activated by selective application of power to different leads that are attached to the LED chips. At least two LED chips can be included in the package, with one LED **204** emitting red light and another LED **206** emitting green light so as to mix and form amber light that is emitted from the display device **136**. It should be appreciated by those skilled in the art that illumination device **200** may be positioned behind, about the edges, or slightly in front of display element **202**. The illumination device **200** can be used to provide backlighting for the display element **202**, which can be an LCD element or the like. The LCD element used can be a twisted nematic, super twist, active matrix, dichroic, dichroic phase change, cholesteric, smectic, ferroelectric, IPS, or MVA type.

The display device **136** may be any type of photoemissive source having more than one color, for example, include a vacuum fluorescent display that utilizes a combination of red and green phosphors (or another combination thereof). An example of the display device can be a subassembly, such as, but not limited to, TOSHIBA™ display part number LTA035B3J1F with fifty percent (50%) color gamut compared to NTSC. Similarly, an LED display may be constructed utilizing two or more colors, such as, red, green, and blue, or different colored LEDs. Thus, as broadly defined herein, the display device **136** may include one or more "lighting elements" for emitting light of first and second colors, according to one embodiment. Such light sources may include photoluminescent light sources such as phosphorescent or fluorescent materials, and/or may include electroluminescent light sources, including, but not limited to, semiconductor radiation emitters such as LEDs, OLEDs, LEPs, etc.

LEDs of the display device **136** may be of the type trade named "Pixar" by HEWLETT PACKARD. Due to the loss of light in the transflective coating, bright LEDs are needed. AlInGaP based LEDs are suitable for this application and are available in green, red, amber, and various similar colors. Blue and green colors can be achieved by using InGaN LEDs. When using InGaN LEDs, there are many fewer LEDs needed than would be used in a segmented display. As an alternative to using packaged LEDs such as the "Pixar" LED, they can be bonded to the circuit board directly using a technique commonly known in the industry as Chip-On-Board.

Exemplary light engines or display devices are described in U.S. Pat. No. 6,639,360, entitled "HIGH POWER RADIATION EMITTER DEVICE AND HEAT DISSIPATING PACKAGE FOR ELECTRONIC COMPONENTS," U.S. Pat. No. 7,075,112, entitled "HIGH POWER RADIATION EMITTER DEVICE AND HEAT DISSIPATING PACKAGE FOR ELECTRONIC COMPONENTS," U.S. Pat. No. 7,489,031, entitled "HIGH POWER RADIATION EMITTER DEVICE AND HEAT DISSIPATING PACKAGE FOR ELECTRONIC COMPONENTS," U.S. Pat. No. 5,803,579, entitled "ILLUMINATOR ASSEMBLY INCORPORATING LIGHT EMITTING DIODES," U.S. Pat. No. 6,132,072, entitled "LED ASSEMBLY," U.S. Pat. No. 6,523,976, entitled "WHITE LIGHT-EMITTING DISCRETE LED COMPONENT, LED ASSEMBLY, AND LICENSE PLATE ILLUMINATOR," U.S. Pat. No. 7,524,097, entitled "LIGHT EMITTING ASSEMBLY," U.S. Pat. No. 6,828,170, entitled "METHOD OF MAKING A SEMICONDUCTOR RADIATION EMITTER," U.S. Pat. No. 7,253,448, entitled "SEMICONDUCTOR RADIATION EMITTER PACKAGE," U.S. Pat. No. 7,342,707, entitled "INDICATORS AND ILLUMINATORS USING A SEMICONDUCTOR," and U.S. Patent Application Publication No. 2009/0096937, entitled "VEHICLE REARVIEW ASSEMBLY INCLUDING A DISPLAY FOR DISPLAYING VIDEO CAPTURED BY A CAMERA AND USER INSTRUCTIONS," the entire references hereby being incorporated herein by reference.

With respect to the electrochromic element **134**, the various layers or components typically affect the light that is viewed through the electrochromic element **134**. The rear element **114** can have a transflective coating, such that the rear element **114** can have an optical configuration that reflects at least a portion of light incident from at least one side, and transmits at least a portion of light incident from at least one side. Typically, the light viewed through the rear element **114** can be attenuated, but can compensate for adverse attenuation effects of other components of the electrochromic element **134**. The transflective elements can be substantially color neutral to reduce adverse color rendering effects of the emitted light. Exemplary transflective elements are disclosed in U.S. Provisional Patent Application No. 60/587,113, entitled "HIGH BRIGHTNESS DISPLAY IN MIRROR," U.S. Pat. No. 7,502,156, entitled "VARIABLE REFLECTANCE MIRRORS AND WINDOWS," U.S. Pat. No. 7,679,809, entitled "VARIABLE REFLECTANCE MIRRORS AND WINDOWS," U.S. Patent Application Publication No. 2009/0296190, entitled "REARVIEW MIRROR ASSEMBLIES WITH ANISOTROPIC POLYMER LAMINATES," and U.S. Patent Application Publication No. 2010/0165437, entitled "VARIABLE REFLECTANCE MIRRORS AND WINDOWS," the entire references hereby being incorporated herein by reference.

Generally, the electrochromic medium **126** can be adapted to be in the high transmittance state, the low transmittance state, and transmittance states intermediate thereto. When the electrochromic medium **126** is in the high transmittance state and the display device **136** is OFF, the user can view a reflection from the reflector. If the display device **136** is ON and the electrochromic medium **126** is in the high transmittance state, the electrochromic medium **126** may slightly attenuate the emitted light. There is, however, greater attenuation of the emitted light when the electrochromic medium is in the low transmittance state. In embodiments where the electrochromic system **138** is configured for a given color, the high transmittance state may define the reference color condition that the low transmittance states are compared against. The electrochromic medium **126** can include one or more components to reduce adverse affects of color rendering on light viewed through the electrochromic medium **126**.

The front element **112** may also have one or more coating layers, which may include a transparent electrode, which typically has a lower reflectivity than the coating on the rear element **114**. The light viewed through the front element **112** may be attenuated by the coating layers on the front element **112**, however, the transmittance properties of these coating layers may be controlled to compensate for adverse attenuation effects of other components of the electrochromic element **134**. The transparent electrode on the front element **112** generally has a substantially neutral color to reduce adverse color rendering effects of the emitted light.

Thus, there typically is a change in intensity and/or hue (e.g., h_{ab}) of light viewed directly from the display device **136** as compared to light viewed through the electrochromic element **134**, either due to the electrochromic medium **126**, substrates, coatings, or a combination thereof. Such a change in intensity and/or hue is generally greater when the electrochromic medium **126** is in the low transmittance state (or intermediate states) as compared to when the electrochromic medium **126** is in the high transmittance state.

In various examples described herein, references are made to the spectral properties of models of electrochromic systems constructed or modeled in accordance with the parameters specified in each example. In discussing colors, it is useful to refer to the Commission Internationale de I'Eclairage's (CIE) 1976 CIELAB Chromaticity Diagram (commonly referred to as the L*a*b* chart). The technology of color is relatively complex, but a fairly comprehensive discussion is given by F. W. Billmeyer and M. Saltzman in *Principles of Color Technology,* 2nd Edition, J. Wiley and Sons Inc. (1981), and the present disclosure, as it relates to color technology and terminology, generally follows that discussion, the entire reference hereby incorporated herein by reference. In describing the invention we will use three different color spaces, which includes the CIELAB color space, $Y_{x,y}$ color space, and the $Y_{u',v'}$ color space. On the L*a*b* chart, L* defines lightness, a* denotes the red/green value, and b* denotes the yellow/blue value. Typically the electrochromic medium **126** has a transmission spectra at each particular voltage that may be converted to a three number designation, their L*a*b* values. To calculate a set of color coordinates, such as L*a*b* values, from the spectral transmission or reflectance, two additional items are generally needed. One is the spectral power distribution of the light source or illuminant. The present disclosure uses CIE Standard Illuminant A to simulate light from automobile headlamps and uses CIE Standard Illuminant D_{65} to simulate daylight. The second item is the spectral response of the observer. The present disclosure can use the 2 degree CIE standard observer. The illuminant/observer combination generally used for mirrors is then represented as A/2 degree and the combination generally used for windows is represented as $D_{65}/2$ degree. The value C*, which is also described below, is equal to the square root of $(a^*)^2+(b^*)^2$, and hence, provides a measure for quantifying color neutrality. To further describe the invention, the CIELAB color space, in particular, the values of L*, C^*_{ab} (chroma), and h_{ab} (hue) can be referenced (FIG. **10**). According to one embodiment, a hue or h_{ab} can be a range or variation of colors within a particular color region (FIG. **13**). In the u',v' color space we introduce the value ($\Delta E_{u',v'}$), defined as the square root of $(\Delta u')^2+(\Delta v')^2$, wherein Δu' and Δv' are the differences in the u' and v' for a display element (e.g., one or more primaries) viewed through the electrochromic element **134** in approximately the high and low transmission (or intermediate) states, respectively.

The display device **136** can be configured to project a display element in a plurality of colors. Thus, the primaries can project the display element. When the display element is viewed through the electrochromic device **134** when in the high transmittance state, the user perceives the display element in one or more colors (e.g., the first hue) h_{ab}. When the electrochromic device **134** is driven to a lower transmittance state, the attenuation characteristics of the electrochromic medium **126** change, which may alter the perceived color of the display element when viewed through the electrochromic device **134** (e.g., a second hue) h_{ab}', as compared to when the electrochromic element **134** is in the high transmittance state. As described in greater detail herein, the electrochromic element **134**, the display device **136**, or a combination thereof, can be configured to reduce the change in color (Δh_{ab}) (e.g., a change in the first and second hues) of the emitted light perceived by the user when the electrochromic device **134** alters between the high transmittance state and a lower transmittance state.

This hue change of the display element is quantified as Δh_{ab}. The Δh_{ab} of the display element (or the primaries) from the display device **136** when viewed through the electrochromic device **134** is controlled by the components in the electrochromic medium **126**, the components of the front and rear elements **112**, **114**, the light emitted by the display device **136**, or a combination thereof, as described in greater detail herein. Such control can reduce the perceived color change or reduce the change in h_{ab} (or the change in hue (Δh_{ab})) of the display element when the electrochromic device is driven from the high transmittance state to a state of lower transmittance.

FIG. **11** exemplary illustrates various h_{ab} for a display element in Example **14** having a green hue, a display element having a yellow hue, and a display element having a red hue. The h_{ab} of the display element can be controlled to reduce a change in h_{ab} between transmittance states by active control of the display device **136** (e.g., altering light emitted by a light source **140** therein), the components of the electrochromic element **134**, or a combination thereof. Typically, the difference between the h_{ab} values of the display element **136** when viewed through the electrochromic medium **126** when in approximately the high transmittance state and in approximately the low transmittance state are reduced. As described herein, reducing the change in h_{ab} of a display element from the display device **136** when viewed through the electrochromic element **134** from its high transmittance state to its low transmittance state can be achieved by selecting one or more components in the electrochromic element **134** and/or by altering the light by the display device **136** emitted to compensate for the influence of the electrochromic medium **126** on the emitted light.

With respect to both FIGS. **11** and **14**, line **200** (FIG. **11**) can represent a primary that is light having a yellow hue, which is emitted by the display device **136** and viewed by a user through the electrochromic element **134** when the electrochromic medium **126** is in approximately the high transmittance state. Line **202** (FIG. **11**) can represent the primary that is light having the yellow hue, which is emitted by the display device **136** and viewed by a user through the electrochromic element **134** when the electrochromic medium **126** is in an intermediate transmittance state, and line **204** (FIG. **11**) can represent the primary that is light having the yellow hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in approximately the low transmittance state. When considering lines **200**, **202**, and **204** with respect to FIG. **11**, the color perceived by the user maintains the yellow hue even as the transmittance state of the electrochromic medium **126** is altered between the high and low transmittance states. Thus, a change in h_{ab} between lines **200** and **204** is a value (approximately forty-five degrees (45°)) that remains approximately representative of light having the yellow hue, rather than having a larger change in h_{ab}, such that the perceived light no longer has a yellow hue (e.g., has a green hue).

Similarly, in regards to both FIGS. **11** and **14**, line **206** (FIG. **11**) can represent a primary that is light having a red hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in approximately the high transmittance state. Line **208** (FIG. **11**) can represent the primary that is light having the red hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in the intermediate transmittance state, and line **210** (FIG. **11**) can represent the primary that is light having the red hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in approximately the low transmittance state. When considering lines **206**, **208**, and **210** with respect to FIG. **11**, the color perceived by the user maintains the red hue even as the transmittance state of the electrochromic medium **126** is altered between the high and low transmittance states. Thus, a change in h_{ab} between lines **206** and **210** is a value (approximately fifteen degrees (15°)) that remains approximately representative of light having the red hue, rather than having a larger change in h_{ab}, such that the perceived light no longer has a red hue.

Another example with respect to both FIGS. **11** and **14**, is line **212** (FIG. **11**) representing a primary that is light having a green hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in approximately the high transmittance state. Line **214** (FIG. **11**) can represent the primary that is light having the green hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in an intermediate transmittance state, and line **216** (FIG. **11**) can represent the primary that is light having the green hue, which is emitted by the display device **136** and viewed through the electrochromic element **134** when the electrochromic medium **126** is in approximately the low transmittance state. When considering lines **212**, **214**, and **216**, with respect to FIG. **11**, the color perceived by the user maintains the green hue even as the transmittance state of the electrochromic medium **126** is altered between the high and low transmittance states. Thus, a change in h_{ab} between lines **212** and **216** is a value (approximately twenty-five degrees (25°) that remains approximately representative of light having the green hue, rather than having a larger change in h_{ab}, such that the perceived light no longer has a green hue.

Typically, the reduced change in h_{ab} as the transmittance state is altered is independent of a C* value. In further regards to FIG. **11**, lines **200**, **202**, **204**, **206**, **208**, **210**, **212**, **214**, and **216** illustrates the hue (angle) in addition to a chroma (i.e., the length of the line).

According to one embodiment, primaries emitted by the display device **136** can include at least one red primary, one green primary, and one blue primary light. Typically, the display device **136** can be configured to emit one primary or combine two or more primaries to emit light of another color. Alternatively, the primaries can include at least one red, at least one green, at least one blue, and at least one yellow. The display device **136** can be configured as a white light source with variable filters (e.g., typical LCD), or can have a plurality of light sources **140** that emit light at various wavelengths, as described above.

With continued reference to the L*a*b* color space, the display device **136** can be configured to emit at least a first primary and a second primary. The first and second primaries, as viewed through the electrochromic medium **126** in an approximately the high transmittance state (e.g., a first hue h_{ab}), in approximately the low transmittance state (e.g., a second hue h_{ab}'), and all intermediate transmittance states exhibit a change in h_{ab} (Δh_{ab}) (e.g., a change in the first and second hues) of less than approximately thirty one degrees (31°).

The change in h_{ab} between approximately the high transmittance state and approximately the low transmittance state for both the first and second primaries can be less than approximately twenty-five degrees (25°), according to one embodiment. However, the change in h_{ab} between approximately the high and low transmittance states for both the first and second primaries can be less than approximately fifteen degrees (15°). Typically, the first and secondary primaries have different hues, such as, but not limited to, the first primary being light having a red hue and the second primary being light having a green hue (FIG. **13**). In such an embodiment, the change in h_{ab} between approximately the high and low transmittance states for light having a red hue can range from approximately twenty-three degrees (23°) to approximately thirteen degrees (13°), and the change in h_{ab} for light having a green hue can range from approximately thirty-one degrees (31°) to approximately fourteen degrees (14°) (FIGS. **17A-17I**).

The display device **136** can be further configured to emit a third primary, wherein a change in h_{ab} of the third primary between when the electrochromic medium **126** is in approximately the high transmittance state (e.g., a first hue h_{ab}) and in approximately the low transmittance state (e.g., a second hue h_{ab}') can be less than approximately forty-one degrees (41°). Alternatively, the change in h_{ab} of the third primary can be less than approximately thirty-five degrees (35°), the change in h_{ab} of the third primary can be less than approximately twenty degrees (20°), or the change in h_{ab} of the third primary can be less than approximately ten degrees (10°). According to one embodiment, the third primary can be a different color than the first and second primaries, such as, but not limited to, light having a blue hue (FIG. **13**). In such an embodiment, the change in h_{ab} for light having a blue hue can range from approximately forty-one degrees (41°) to approximately zero degrees (0°) (FIGS. **17A-17I**).

Additionally and alternatively, the display device **136** can be configured to emit a fourth primary. In such an embodiment, a change in h_{ab} of the fourth primary when the electrochromic medium **126** is in approximately the high transmittance state and in approximately the low transmittance state can be less than approximately fifty-five degrees (55°). It should be appreciated that additional primaries beyond four, or alterative primaries, can be used in a manner as taught herein for embodiments in which such an approach would be advantageous.

Alternatively, the change in h_{ab} between approximately the high and low transmittance states for the fourth primary can be less than approximately fifty degrees (50°), the change in h_{ab} for the fourth primary can be less than approximately forty degrees (40°), or the change in h_{ab} for the fourth primary can be less than approximately thirty degrees (30°). A further alternative can be wherein the differences in h_{ab} for the fourth primary can be less than approximately fifteen degrees (15°).

Typically, the fourth and any additional primaries are different colors, such as, but not limited to, the fourth primary being light having a yellow hue (FIG. **13**). As described above, hues other than those of the primaries can be obtained by mixing of two or more primaries. In this manner, a yellow hue can be obtained, for example, by the mixing of red and green primaries at a suitable ratio. An amber hue can also be obtained by the mixing of primaries, for example red and green in a ratio slightly different than that for yellow. In such an embodiment, the change in h_{ab} between the approximately high and approximately low transmittance states for light having a yellow hue can range from approximately fifty-five degrees (55°) to approximately twenty-seven degrees (27°) and the change in h_{ab} between the approximately high and approximately low transmittance states for light having an amber hue can range from approximately fifty-five degrees (55°) to approximately nine degrees (9°) (FIGS. **17**A-**17**I).

According to one embodiment, the rear view mirror **110** can include the electro-optic device having the front element **112** that includes the first and second surfaces **112***a,* **112***b,* the rear element **114** having a third and fourth surfaces **114***a,* **114***b,* and the electro-optic medium **126** in optical communication between the front element **112** and the rear element **114**, wherein the electro-optic medium **126** can be configured to dynamically adjust between a high transmittance state and a low transmittance state. The rear view mirror **110** can further include the display device **136** in optical communication with the electro-optic device. The display device **136** can include the at least one light source **100**, and the display device **136** can be configured to emit at least a first primary and a second primary. The first and second primaries can each have a first hue (h_{ab}) when viewed through the electro-optic element **134** in approximately the high transmittance state and a second hue (h_{ab}') when viewed through the electro-optic element **134** in approximately the low transmittance state, wherein a change in the first and second hues ((h_{ab}) is less than approximately thirty-one degrees (31°).

Another exemplary illustration in reduced color change is illustrated in FIGS. **15**A and **15**B, which shows color change in the $Y_{u',v'}$ color space. The $Y_{u',v'}$ color space is a color space adopted by CIE in **1976** as transformation of the **1931** CIE $Y_{x,y}$ color space, but which attempted perceptual uniformity. The insert triangle may represent a portion of the u',v' color space addressable by the display device **136** (i.e., the color gamut), which illustrates the subset of color capability of a particular embodiment of a RGB display. This chart illustrates the color changes of emitted light having a plurality of hues as the electrochromic medium **126** is altered between the high transmittance state and the low transmittance state. The magnitude of color changes of a prior art electrochromic medium may be considered less desirable by the viewer.

The lines of FIG. **15**A directly compare the change in color for an embodiment of the present invention described in Example **12** with the change in color of a prior art configuration described in Example 1, wherein a display element of the display device **136** is viewed through the electrochromic element **134**, while the electrochromic medium **126** is in various transmittance states. Line **218** represents a display element having a red color of a prior art system at various transmittance states of the electrochromic system, and line **220** represents a display element having a red color in accordance with one embodiment of the present invention at various transmittance states. According to one embodiment, a display element can emit light, such as, but not limited to, and indicator light, a symbol, text, and image, emitted light viewed through one or more pixels, the like, or a combination thereof.

Line **222** represents a display element having a green color of a prior art system at various transmittance states of the electrochromic system, and line **224** represents a display element having a green color in accordance with one embodiment of the present invention at various transmittance states of the electrochromic system. Line **226** represents a display element having a blue color of a prior art system at various transmittance states of the electrochromic system **138**, and line **228** represents a display element having a blue color in accordance with one embodiment of the present invention at various transmittance states of the electrochromic system **138**. As shown in FIG. **15**, line **228** maintains the blue color, whereas line **226** extends towards a green region of the u',v' color space, and thus, illustrates an undesirable color change for a prior art system shown by line **226** compared to a system of the present invention as shown by line **228**.

With continued reference to FIG. **15**A, line **230** represents a display element having a yellow color of a prior art system at various transmittance states of the electrochromic system, and line **232** represents a display element having a yellow color in accordance with one embodiment of the present invention at various transmittance states of the electrochromic system **138**. Line **232** maintains the yellow color, whereas line **230** extends towards a green region of the u',v' color space, and thus, illustrates an undesirable color change for a prior art system shown by line **230** compared to a system of the present invention as shown by line **232**. Line **234** represents a display element having a amber color of a prior art system at various transmittance states of the electrochromic system **138**, and line **236** represents a display element having an amber color in accordance with one embodiment of the present invention at various transmittance states of the electrochromic system **138**. Line **236** maintains the amber color, whereas the line **234** extends towards a green region of the u',v' color space, and thus, illustrates an undesirable color change for a prior art system shown by line **234** compared to a system of the present invention as shown by line **236**. Line **238** represents a display element having a white color of a prior art system at various transmittance states of the electrochromic system, and line **240** represents a display element having a white color in accordance with one embodiment of the present invention at various transmittance states of the electrochromic system **138**. As shown by the comparison of lines in FIG. **15**A, the perceived color change of the emitted light is reduced as compared to the prior art. Thus, lines **220**, **224**, **228**, **232**, **236**, and **240** remain closer to their respective starting point (the point where the electrochromic system **138** is in its approximately high transmittance state) for each respective color, and remain closer to the starting color as the electrochromic system **138** changes from its high transmittance state to its low transmittance state, as compared to the prior art lines **218**, **222**, **226**, **230**, **234**, and **238**, which illustrate an undesirable color change in the prior art.

Continuing to reference the u',v' color space and FIG. **15**B, the first and second primaries viewed through the electrochromic medium **126** in approximately the high transmittance state and in approximately the low transmittance state exhibit a change in color ($\Delta E_{u',v'}$) of less than approximately 0.06. The color change, $\Delta E_{u',v'}$, for both the first and second primaries can be less than approximately 0.05, according to one embodiment. However, the color change, $\Delta E_{u,v'}$, for both the first and second primaries can be less than approximately 0.04. Typically, the first and second primaries have different colors, such as, but not limited to, the first primary being light having a red color and the second primary being light having a green color (FIG. **15**A).

The display device **136** can be further configured to emit a third primary, wherein a color change, $\Delta E_{u',v'}$, of the third primary when the electrochromic medium **126** is in approximately the high transmittance state and in approximately the low transmittance state is less than approximately 0.08. Alternatively, the color change, $\Delta E_{u',v'}$, of the third primary can be less than approximately 0.07, the color change, $\Delta E_{u',v'}$, of the third primary can be approximately 0.06, or the color change, $\Delta E_{u',v'}$, of the third primary can be less than approximately 0.05. According to one embodiment, the third primary can be a different color than the first and second primaries, such as, but not limited to, light having a blue color (FIG. **15**A).

The display device **136** can be configured to emit a fourth primary, according to one embodiment. In such an embodiment, a color change, $\Delta E_{u',v'}$, of the fourth primary when the electrochromic medium **126** is in approximately the high transmittance state and in approximately the low transmittance state is less than approximately 0.08, a color change, $\Delta E_{u',v'}$, of light having an amber color when the electrochromic medium 126 is in approximately the high transmittance state and in approximately the low transmittance state can be less than approximately 0.09, or a combination thereof.

Alternatively, the color change, $\Delta E_{u',v'}$, for at least one of the fourth and any additional primaries can be less than approximately 0.08, a color change, $\Delta E_{u',v'}$, for at least one of the fourth and any additional primaries can be less than approximately 0.07, a color change, $\Delta E_{u',v'}$, for at least one of the fourth and any additional primaries can be less than approximately 0.06, or a color change, $\Delta E_{u',v'}$, for at least one of the fourth and any additional primaries can be less than approximately 0.05. Accordingly to one embodiment, the fourth primary can be light having a yellow hue.

For purposes of explanation and not limitation, in operation, the electrochromic system **138** can be configured to emit light via the display device **136** through the layers of the electrochromic element **134** to display an image to the user or occupant of the motor vehicle. Further, the electrochromic system **138** can be configured to display this image in a manner viewable by the user without regard as to the transmittance states of the electrochromic medium **126**, and thus, any change in the perceived color of the displayed image is reduced, even though the transmittance level of the electrochromic medium **126** is being altered. The color change, $\Delta E_{u',v'}$, of the image viewed by the user is reduced even as the transmittance states of the electrochromic medium **126** is being altered, such that, in a non-limiting example, an image that appears yellow when the electrochromic medium **126** is in the high transmittance state does not appear green when the electrochromic medium **126** is in the low transmittance state.

In another embodiment, the color accuracy can be based upon light emitted from the display device **136** that is viewed through the electrochromic element **134** having a plurality of primary colors, as compared to a broadband source, such as daylight (e.g., Illuminat D_{65} or Illuminat A). Thus, coatings of the front and rear elements **112**, **114**, components of the electrochromic medium **126**, active control of the display device **136**, or a combination thereof can be adapted to compensate for adverse attenuation affects the electrochromic medium **126** has on the light viewed there through at various transmittance states. As described above, the display device **136** can be configured to at least partially compensate for adverse attenuation of the emitted light by other components of the electrochromic system **138**. When the display device **136** is configured to at least partially enhance the color accuracy (e.g., reduce a perceived color change), the display device **136** can be an LCD, wherein the backlighting source(s) and/or the filters (e.g., RGB, RGB-Yellow) are adapted to at least partially compensate for a color change that is a result of the emitted light viewed through the electrochromic medium **126**. Thus, the LCD can be enhanced to give color accuracy to two or more primaries. This tuning might include, but not limited to, modifying the instructions in video driver circuitry and/or programming to actively or passively compensate for the same color shift.

The backlighting and display filter of the display device **136**, the attenuation of the emitted light viewed through the electrochromic medium **134**, or a combination thereof, can affect color balance of the perceived light. Additionally or alternatively, an intensity and/or color of a backlighting light source of the display device **136** (e.g., RGB light source, white phosphor light source, etc.) can be configured to actively or passively compensate for attenuation of the emitted light viewed through the electrochromic medium **126**. The backlighting of the display device **136** can be, but is not limited to, direct lighting or edge lighting.

A magnitude of perceived color change can be approximately inversely proportional to a width of a color filter (e.g., full width/half max of the light distribution band) of the display device **136** (e.g., the display device **136** being a LCD), according to one embodiment. Typically, the width of the filter can correspond to the range of wavelengths that pass through the filter. Thus, if the backlight is monochromic, there can be substantially no shift in color and the filter can only attenuate. However, when the backlight of the display device **136** is configured to emit a plurality of primary colors, a wide filter in a particular wavelength range can be utilized in the display device **136**, which can allow for greater intensity, but reduced color accuracy, or narrow filters in a particular wavelength range can be utilized in the display device **136**, which can allow for reduced intensity, but increased color accuracy. Typically, LCDs have opted for greater intensity and reduced color accuracy. In this case, if the prior art electrochromic medium is used, there may be primaries that shift colors as the electrochromic medium shifts from high transmittance to low transmittance. However, even with the prior art electrochromic medium, the adverse effect the electrochromic medium may have on the light viewed there through may, at least partially, be compensated for by dynamically controlling how the light is emitted from the display device **136**.

According to one embodiment, using an RGB video display (e.g., the display device **136**) behind the electrochromic element **134** can compensate for adverse attenuation of the emitted light by adjusting a relative intensity of the red, green, and blue emitters in order to maintain better color rendering. For example, in the case of transmission that was greater for the blue region of the spectrum and lesser for the red region it may be desirable to decrease the intensity of the blue emitter and increase the intensity of the red emitter. This type of adjustment can be appropriate in this and other designs whether the spectral bias of the transmission is a gentle slope or one with more distance bands of transmission.

When the display device **136** is intended for use when the mirror element is dimmed, intensity adjustments may be made to compensate for any spectral bias from the coatings and, of, the activated electrochromic medium **126**. The intensity adjustment may be a function of the operating voltage of the electrochromic system **138**, and/or other feedback mechanism to match the relative RGB intensities appropriately for a given point in the color excursion of the electrochromic element **134**.

Optionally because tolerances of electrochromic element **134** construction can include, but are not limited to, cell spacing, sheet resistances of coatings, and drive circuit components, it can be difficult to determine precisely the point on the color excursion curve a device will be based on a look up table with respect to a voltage. Also, because the electrochromic element **134** can attain the low transmittance state at lower temperatures at a lesser voltage than when at a higher temperature, the characteristic of voltage may not adequately define the position on a color excursion curve for a particular device. For example, the outside electrochromic mirror **111***a*, **111***b* may be operating at a temperature that is sufficiently different than an inside mirror **110** to place it on a different location on the color excursion curve for a given voltage. In addition some components of the electrochromic medium **126** experience a shift in their spectral absorption characteristics with temperature. So, depending on the color accuracy required for a particular display application in various transmittance states, methods other than a voltage look up table may assist some embodiments to perform more optimally. A look up table containing both element voltage and current draw data, may, in some embodiments provide a more accurate sense of the transmitted color of the element. A circuit, such as those described in U.S. Pat. No. 6,222,177, entitled "ELECTROCHROMIC ELEMENT DRIVER WITH A NEGATIVE OUTPUT RESISTANCE," the entire reference hereby being incorporated herein by reference, may also, in some embodiments, improve the accuracy of any adjustments to a display.

With respect to FIGS. **21** and **22**, according to one embodiment, methods using an additional sensor **276** behind the electrochromic element **134** facing the rear of the vehicle can be used for attaining an accurate reading. If a glare sensor is in an electrochromic system **138** outside of the darkening region, such as the "chin" of an inside mirror **110** assembly, looking through a partially transmissive reflective ring bezel, or is in the bezel, another sensor just inside the darkening region can receive light from the same glare sources. When the two signals are compared, the degree of attenuation of the signal between the sources can, via a lookup table, or other algorithm, yield the position on a color excursion curve that would translate into an intensity adjustment of the colors in a display, such as an RGB display or other combinatorial color display. In another embodiment, a reflective region such as a dot can be placed on the first or second surface of an electrochromic system **138**, and a signal is emitted through the electrochromic element **134** from the rear of the electrochromic element **134** and the reflected signal measured. Based on the attenuation of that signal, the degree of dimming of the display device **136** can, and therefore its position on a color excursion curve, can be determined and, again, adjustments to the display device **136** can be made. The light signal reflected by the dot could be of a single spectral makeup, or it could be pulsed between signals of different make ups. If an RGB display were being adjusted, it could in some embodiments be advantageous to quickly pulse between at least one red light, at least one blue light, and at least one green light for the signal to the reflector of similar spectral characteristics used in the display device **136**, and adjust the RGB display based on the relative attenuation detected between those signals.

When used as an inside rearview mirror, the inside mirror assembly **110** can exhibit a high end reflectance of at least about sixty percent (60%) while also exhibiting a transmittance of at least five percent (5%) and at least the area in front of the display device **136**, according to one embodiment. The display device **136** can be an LCD that, together with the electrochromic element **134** can be configured to provide a luminosity when viewed through the electrochromic element **134** of at least about two hundred fifty candelas per meter squared (250 cd/m^2). Alternatively, depending upon the requirements, suitable luminosity can be at least about four hundred candelas per meter squared (400 cd/m^2), at least about five hundred candelas per meter squared (500 cd/m^2), at least about six hundred candelas per meter squared (600 cd/m^2), at least about seven hundred candelas per meter squared (700 cd/m^2), at least about one thousand candelas per meter squared (1,000 cd/m^2), at least about one thousand five hundred candelas per meter squared (1,500 cd/m^2), at least about two thousand seven hundred fifty candelas per meter squared (2,750 cd/m^2), at least about thirty-five hundred candelas per meter squared (3,500 cd/m^2), at least about five thousand candelas per meter squared (5,000 cd/m^2), and at least about eight thousand candelas per meter squared (8,000 cd/m^2).

Referring again to FIGS. **7A-7H**, the coatings of the third surface **114***a* can be sealably bonded to the coatings on the second surface **112***b* in a spaced-apart and parallel relationship by a seal member **116** disposed near the outer perimeter of both second surface **112***b* and third surface **114***a*. Seal member **116** may be any material that is capable of adhesively bonding the coatings on the second surface **112***b* to the coatings on the third surface **114***a* to seal the perimeter such that electrochromic material **126** does not leak from chamber **125**. Optionally, the layer of transparent conductive coating **128** and the layer of reflector/electrode **120** may be removed over a portion where the seal member is disposed (typically not the entire portion, otherwise the drive potential could not be applied to the two coatings). In such a case, seal member **116** can typically bond well to glass.

The performance requirements for a perimeter seal member **116** used in an electrochromic system **138** are similar to those for a perimeter seal used in an LCD. The seal should have good adhesion to glass, metals and metal oxides; can have low permeabilities for oxygen, moisture vapor, and other detrimental vapors and gases; and cannot interact with or poison the electrochromic or liquid crystal material it is meant to contain and protect. The perimeter seal can be applied by means commonly used in the LCD industry, such as by silk-screening or dispensing. Totally hermetic seals, such as those made with glass frit or solder glass, can be used, but the high temperatures involved in processing (usually near four hundred fifty degrees (450° C.)) this type of seal can cause numerous problems, such as glass substrate warpage, changes in the properties of transparent conductive electrode, and oxidation or degradation of the reflector. Because of their lower processing temperatures, thermoplastic, thermosetting, or UV curing organic sealing resins can be used. Because of their excellent adhesion to glass, low oxygen permeability and good solvent resistance, epoxy-based organic sealing resins can be used. These epoxy resin seals may be UV curing, or thermally curing, such as with mixtures of liquid epoxy resin with liquid polyamide resin or dicyandiamide, or they can be homopolymerized. The epoxy resin may contain fillers or thickeners to reduce flow and shrinkage such as fumed silica, silica, mica, clay, calcium carbonate, alumina, etc., and/or pigments to add color. Fillers pretreated with hydrophobic or silane surface treatments can be used. Cured resin crosslink density can be controlled by use of mixtures of mono-functional, di-functional, and multi-functional epoxy resins and curing agents. Additives such as silanes or titanates can be used to improve the seal's hydrolytic stability, and spacers such as glass beads or rods can be used to control final seal thickness and substrate spacing. Suitable epoxy resins for use in a perimeter seal member **116** include, but are not limited to: "EPON RESIN" 813, 825, 826, 828, 830, 834, 862, 1001F, 1002F, 2012, DPS-155, 164, 1031, 1074, 58005, 58006, 58034, 58901, 871, 872, and DPL-862 available from Shell Chemical Co., Houston, Tex.; "ARALITE" GY 6010, GY 6020, CY 9579, GT 7071, XU 248, EPN 1139, EPN 1138, PY 307, ECN 1235, ECN 1273, ECN 1280, MT 0163, MY 720, MY 0500, MY 0510, and PT 810 available from Ciba Geigy, Hawthorne, N.Y.; and "D.E.R." 331, 317, 361, 383, 661, 662, 667, 732, 736, "D.E.N." 431, 438, 439 and 444 available from Dow Chemical Co., Midland, Mich. Suitable epoxy curing agents include V-15, V-25, and V-40 polyamides from Shell Chemical Co.; "AJICURE" PN-23, PN-34, and VDH available from Ajinomoto Co., Tokyo, Japan; "CUREZOL" AMZ, 2MZ, 2E4MZ, C11Z, C17Z, 2PZ, 2IZ, and 2P4MZ available from Shikoku Fine Chemicals, Tokyo, Japan; "ERISYS" DDA or DDA accelerated with U-405, 24EMI, U-410, and U-415 available from CVC Specialty Chemicals, Maple Shade, N.J.; and "AMICURE" PACM, 352, CG, CG-325, and CG-1200 available from Air Products, Allentown, Pa. Suitable fillers include fumed silica such as "CAB-0-SIL" L-90, LM-130, LM-5, PTG, M-5, MS-7, MS-55, TS-720, HS-5, and EH-5 available from Cabot Corporation, Tuscola, Ill.; "AEROSIL" R972, R974, R805, R812, R812 S, 8202, US204, and US206 available from Degussa, Akron, Ohio. Suitable clay fillers include BUCA, CATALPO, ASP NC, SATINTONE 5, SATINTONE SP-33, TRANSLINK 37, TRANSLINK 77, TRANSLINK 445, and TRANSLINK 555 available from Engelhard Corporation, Edison, N.J. Suitable silica fillers are SILCRON G-130, G-300, G-100-T, and G-100 available from SCM Chemicals, Baltimore, Md. Suitable silane coupling agents to improve the seal's hydrolytic stability are Z-6020, Z-6030, Z-6032, Z-6040, Z-6075, and Z-6076 available from Dow Corning Corporation, Midland, Mich. Suitable precision glass microbead spacers are available in an assortment of sizes from Duke Scientific, Palo Alto, Calif.

The layer of a transparent electrically conductive material **128** can be deposited on the second surface **112***b* to act as an electrode. Transparent conductive material **128** may be any material which bonds well to front element **112**, is resistant to corrosion to any materials within the electrochromic system **138**, resistant to corrosion by the atmosphere, has minimal diffuse or specular reflectance, high light transmission, near neutral coloration, and good electrical conductance. Transparent conductive material **128** may be fluorine-doped tin oxide, doped zinc oxide, indium zinc oxide ($Zn_3In_2O_6$), indium tin oxide (ITO), ITO/metal/ITO (IMI) as disclosed in "Transparent Conductive Multilayer-Systems for FPD Applications," by J. Stollenwerk, B. Ocker, K. H. Kretschmer of LEYBOLD AG, Alzenau, Germany, the materials described in above-referenced U.S. Pat. No. 5,202,787, such as TEC 20 or TEC 15, available from Libbey Owens-Ford Co. of Toledo, Ohio, or other transparent conductors. Exemplary electrochromic systems are described in U.S. Pat. No. 7,688,495, entitled "THIN-FILM COATINGS, ELECTRO-OPTIC ELEMENTS AND ASSEMBLIES INCORPORATING THESE ELEMENTS," U.S. Patent Application Publication No. 2008/0302657, entitled "METHOD AND APPARATUS FOR ION MILLING," U.S. Patent Application Publication No. 2007/0201122, entitled "THIN-FILM COATINGS, ELECTRO-OPTIC ELEMENTS AND ASSEMBLIES INCORPORATING THESE ELEMENTS," and U.S. patent application Ser. No. 12,691,830, entitled "IMPROVED THIN-FILM COATINGS, ELECTRO-OPTIC ELEMENTS AND ASSEMBLIES INCORPORATING THESE ELEMENTS," the entire references hereby being incorporated herein by reference.

Generally, the conductance of transparent conductive material **128** will depend on its thickness and composition. IMI generally has superior conductivity compared with the other materials. Exemplary IMIs are described in U.S. Patent Application Publication No. 2007/0206263, entitled "ELECTRO-OPTICAL ELEMENT INCLUDING IMI COATINGS," the entire reference hereby incorporated herein by reference. IMI is, however, known to undergo more rapid environmental degradation and suffer from interlayer delamination. The thickness of the various layers in the IMI structure may vary, but generally the thickness of the first ITO layer ranges from about 10 Å to about 200 Å, the metal ranges from about 10 Å to about 200 Å, and the second layer of ITO ranges from about 10 Åto about 200 Å. If desired, an optional layer or layers of a color suppression material **130** may be deposited between transparent conductive material **128** and the second surface **112***b* to suppress the reflection of any unwanted portions of the electromagnetic spectrum. According to one embodiment, half-ware ITO having a thickness of approximately 1450 Å, or eighty percent (80%) ITO having a thickness of approximately 1150 Å can be utilized.

Examples of electrochromic systems, display devices, and/or mirrors and components thereof are described in Canadian Patent No. 1,300,945, entitled "AUTOMATIC REARVIEW MIRROR SYSTEM FOR AUTOMOTIVE VEHICLES," U.S. Pat. No. 6,700,692, entitled "ELECTROCHROMIC REARVIEW MIRROR ASSEMBLY INCORPORATING A DISPLAY/SIGNAL LIGHT," U.S. Pat. No. 5,940,201, entitled "ELECTROCHROMIC MIRROR WITH TWO THIN GLASS ELEMENTS AND A GELLED ELECTROCHROMIC MEDIUM," U.S. Pat. No. 5,928,572, entitled "ELECTROCHROMIC LAYER AND DEVICES COMPRISING SAME," U.S. Pat. No. 5,434,407, entitled "AUTOMATIC REARVIEW MIRROR INCORPORATING LIGHT PIPE," U.S. Pat. No. 5,448,397, entitled "OUTSIDE AUTOMATIC REARVIEW MIRROR FOR AUTOMOTIVE VEHICLES," U.S. Pat. No. 6,157,480, entitled "SEAL FOR ELECTROCHROMIC DEVICES," U.S. Pat. No. 6,170,956, entitled "REARVIEW MIRROR WITH DISPLAY," U.S. Pat. No. 5,808,778, entitled "ELECTRO-OPTIC REARVIEW MIRROR FOR AUTOMOTIVE VEHICLES," U.S. Pat. No. 6,356,376, entitled "ELECTROCHROMIC REARVIEW MIRROR INCORPORATING A THIRD SURFACE METAL REFLECTOR AND A DISPLAY/SIGNAL LIGHT," U.S. Pat. No. 6,512,624, entitled "ELECTROCHROMIC REAR-

VIEW MIRROR INCORPORATING A THIRD SURFACE PARTIALLY TRANSMISSIVE REFLECTOR," U.S. Pat. No. 7,009,751, entitled "ELECTROCHROMIC REARVIEW MIRROR INCORPORATING A THIRD SURFACE PARTIALLY TRANSMISSIVE REFLECTOR," U.S. Pat. No. 6,870,656, entitled "ELECTROCHROMIC REARVIEW MIRROR ELEMENT INCORPORATING A THIRD SURFACE REFLECTOR," U.S. Pat. No. 7,209,277, entitled "ELECTROCHROMIC REARVIEW MIRROR INCORPORATING A THIRD SURFACE REFLECTOR WITH AT LEAST ONE GRAPHICAL INDICIA," U.S. Pat. No. 7,417,781, entitled "ELECTROCHROMIC REARVIEW MIRROR INCORPORATING A THIRD SURFACE REFLECTOR," U.S. Pat. No. 6,020,987, entitled "ELECTROCHROMIC MEDIUM CAPABLE OF PRODUCNIG A PRE-SELECTED COLOR," U.S. Patent Application Publication No. 2009/0296190, entitled "REARVIEW MIRROR ASSEMBLIES WITH ANISOTROPIC POLYMER LAMINATES," U.S. Pat. No. 4,902,108, entitled "SINGLE-COMPARTMENT, SELF-ERASING, SOLUTION-PHASE ELECTROCHROMIC DEVICES, SOLUTIONS FOR USE THEREIN, AND USES THEREOF," U.S. Pat. No. 5,128,799, entitled "VARIABLE REFLECTANCE MOTOR VEHICLE MIRROR," U.S. Pat. No. 5,278,693, entitled, "TINTED SOLUTION-PHASE ELECTROCHROMIC DEVICES," U.S. Pat. No. 5,280,380, entitled "UV-STABILIZED COMPOSITIONS AND METHODS," U.S. Pat. No. 5,282,077, entitled "VARIABLE REFLECTANCE MIRROR," U.S. Pat. No. 5,294,376, entitled "FINISHER FOR AN IMAGE FORMING APPARATUS," U.S. Pat. No. 5,336,448, entitled "ELECTROCHROMIC DEVICES WITH BIPYRIDINIUM SALT SOLUTIONS," U.S. Pat. No. 5,818,625, entitled "DIMMABLE REARVIEW MIRROR INCORPORATING A THIRD SURFACE METAL REFLECTOR," U.S. Pat. No. 6,441,943, entitled " INDICATORS AND ILLUMINATORS USING A SEMICONDUCTOR RADIATION EMITTER PACKAGE," U.S. Pat. No. 6,521,916, entitled "RADIATION EMITTER DEVICES AND METHOD OF MAKING THE SAME," and U.S. Pat. No. 6,020,987, entitled "ELECTROCHROMIC MEDIUM CAPABLE OF PRODUCING A PRE-SELECTED COLOR," the entire references hereby being incorporated herein by reference.

Typically, thin silver or silver alloy layers are higher in blue-green transmission and lower in blue-green light reflection which imparts a yellow hue to the reflected image. For purposes of explanation and not limitation, a 2000 Å ITO underlayer of approximately ¾ wave in thickness can supplement the reflection of blue-green light which results in a more neutral hue in reflection. Other odd quarter wave multiples (e.g., ¼, 5/4, 7/4, etc.) can also be effective in reducing reflected hue. It should be noted that other transparent coatings, such as (F)SnO or (AL)ZnO, or a combination of dielectric, semi-conductive, or conductive coatings, can be used to supplement blue-green reflection and produce a more neutral reflected hue in the same manner.

Referring to FIG. **3** for one embodiment of the present invention, a reflector/electrode that is made from a single layer of a reflective silver or silver alloy **121** is provided that is in contact with at least one solution-phase electrochromic material. The layer of silver or silver alloy covers at least part of the entire third surface **114***a* of second element **114**. The reflective silver alloy means a homogeneous or non-homogeneous mixture of silver and one or more metals, or an unsaturated, saturated, or supersaturated solid solution of silver and one or more metals. The thickness of reflective layer **121** ranges from about 50 Å to about 2000 Å, or from about 200 Å to about 1000 Å. If reflective layer **121** is disposed directly to the glass surface, the glass surface can be treated by plasma discharge to improve adhesion. Examples of coatings and electrochromic systems are described in U.S. Pat. No. 7,746,534, entitled "THIN-FILM COATINGS, ELECTRO-OPTIC ELEMENTS AND ASSEMBLIES INCORPORATING THESE ELEMENTS," the entire reference hereby being incorporated herein by reference.

In another embodiment, the reflector/electrode **120** shown in FIG. **4** has at least two layers (**121** and **122**), where at least one layer of a base material **122** covers substantially the entire portion of the third surface **114***a* and at least one layer of a reflective material **121** covers the inner section of the third surface **114***a*, but does not cover the peripheral edge portion **125** where seal member **116** is disposed. Peripheral portion **125** may be created by masking that portion of layer **122** during deposition of the layer of reflective material **121**, or the layer of reflective material may be deposited over the entire third surface and subsequently removed or partially removed in the peripheral portion. The masking of layer **122** may be accomplished by use of a physical mask or through other well-known techniques, such as photolithography and the like. Alternatively, layer **122** may be partially removed in the peripheral portion by a variety of techniques, such as, for example, by etching (laser, chemical, or otherwise), mechanical scraping, sandblasting, or otherwise. Laser etching can be used because of its accuracy, speed, and control. Partial removal is preferably accomplished by laser etching in a pattern where enough metal is removed to allow the seal member **116** to bond directly to the third surface **114***a* while leaving enough metal in this area such that the conductance in this area is not significantly reduced.

In addition, an optional intermediate layer of a conductive material **123** may be placed over the entire area of third surface **114***a* and disposed between the reflective layer **121** and the base layer **122**, or it may be placed only under the area covered by layer **121**, (e.g., not in peripheral edge portion **125**). If this optional intermediate layer is utilized, it can cover the entire area of third surface **114***a* or it may be masked or removed from the peripheral edge portion as discussed above.

An optional flash over-coat layer **124** may be coated over the reflective layer **121**. The reflective layer **121**, the optional intermediate layer **123**, and the base layer **122** can have properties similar to that described herein, except that the layer of reflective material **121** need not bond well to the epoxy seal, since it is removed in the peripheral portion where the seal member **116** is placed. Because the interaction with the epoxy seal is removed, silver metal itself, in addition to the alloys of silver described herein, will function as the reflective layer. Alternatively, an adhesion promoter can be added to the sealing material which enhances adhesion to silver or silver alloys and the reflective layer can be deposited over most of the third surface including substantial portions under the seal area. Such adhesion promoters are disclosed in U.S. Pat. No. 6,157,480, entitled "IMPROVED SEAL FOR ELECTROCHROMIC DEVICES," the entire reference hereby being incorporated herein by reference.

Referring now to FIGS. **5**A and **5**B, an improved mechanism for applying a drive potential to the layer of transparent conductive material **128** is shown. Electrical connection between the power supply and the layer of transparent conductive material **128** is made by connecting the buss bars (or clips **119***a*) to the area of reflector/electrode **120***a*, such that the drive potential travels through the area of reflector/

electrode **120***a* and conductive particles **116***b* in sealing member **116** before reaching the transparent conductor **128**. The reflector/electrode must not be present in area **120***c,* so that there is no chance of current flow from reflector/electrode area **120***a* to **120***b*. This configuration is advantageous in that it allows connection to the transparent conductive material **128** nearly all the way around the circumference, and therefore improves the speed of dimming and clearing of the electrochromic media **126**.

In such a configuration, sealing member **116** comprises a typical sealing material, (e.g., epoxy **116***a,* with conductive particles **116***b* contained therein). The conductive particles may be small, such as, for example, gold, silver, copper, etc., coated plastic with a diameter ranging from about 5 microns to about 80 microns, in which case there should be a sufficient number of particles to ensure sufficient conductivity between the reflector/electrode area **120***a* and the transparent conductive material **128**. Alternatively, the conductive particles may be large enough to act as spacers, such as, for example, gold, silver, copper, etc., coated glass or plastic beads. The reflector/electrode **120** is separated into two distinct reflector/electrode areas (**120***a* and **120***b,* separated by an area **120***c* devoid of reflector/electrode). There are many methods of removing the reflector/electrode **120** from area **120***c,* such as, for example, chemical etching, laser ablating, physical removal by scraping, etc. Deposition in area **120***c* can also be avoided by use of a mask during deposition of reflector/electrode. Sealing member **116** with particles **116***b* contacts area **120***a* such that there is a conductive path between reflector/electrode area **120***a* and the layer of transparent conductive material **128**. Thus, electrical connection to the reflector/electrode area **120***b* that imparts a potential to the electrochromic medium is connected through clips **119***b* to the electronic circuitry at reflector/electrode area **120***d* (FIG. **5**B). No conductive particles **116***b* can be placed in this reflector/electrode area **120***b* because of the possibility of an electrical short between reflector/electrode area **120***b* and the layer of transparent conductive material **128**. If such an electrical short occurred, the electrochromic system **138** would not operate properly. Additionally, no conductive seal **116***b* should be present in area **120***b*.

Layer **121** may be made of any of the reflective materials described above and can be made of silver or a silver alloy. The thickness of reflective layer **121** in the arrangement shown in FIG. **7**A can be between 30 Å and 800 Å. The thickness of layer **121** will depend on the desired reflectance and transmittance properties. For an inside rearview mirror, layer **121** can have a reflectance of at least sixty percent (60%) and a transmittance through window 146 of ten percent (10%) to fifty percent (50%). For an outside mirror, the reflectance can be above thirty-five percent (35%) and the transmittance can be approximately ten percent (10%) to fifteen percent (15%), and/or at least twenty percent (20%) for those regions that are in front of one of the lights of a signal light.

Window **146** in layer **121** may be formed by masking window area **146** during the application of the reflective material. At this same time, the peripheral region of the third surface **114***a* may also be masked so as to prevent materials such as silver or silver alloy (when used as the reflective material) from being deposited in areas to which seal **116** must adhere, so as to create a stronger bond between seal **116** and coating **172** or element **114**. Additionally, an area in front of sensor **160** (FIG. **2**) may also be masked.

The masking of window **146** in layer **121** may be a discrete mask such that none of the material of layer **121** is deposited within window area **146**, or a gradient mask may be utilized, which gradually reduces the amount of the material of layer **121** from the periphery of window **146** to its center. The extent of the gradient masking may vary considerably such that virtually none of the material of layer **121** is provided over much of the display area of window **146** with just gradient edges surrounding window **146** to a configuration whereby all of window **146** is covered with at least some portion of the material of layer **121**. Alternative constructions are illustrated in FIGS. **6**, **7**B-**7**H, **8**, and **9**A-**9**G. It should be noted that the optical constants of materials vary somewhat with deposition method and conditions employed. These differences can have a substantial effect on the actual optical values and optimum thicknesses used to attain a value for a given coating stack.

Another embodiment is illustrated in FIG. **35**, wherein the electrochromic device **138** (e.g., a multi-zone mirror element) can be structured with a stack **278** having an upper reflecting layer **284**, the thickness of which is not substantially uniform but rather slightly variable. In the following description, therefore, a reference is made to elements of the general thin-film structure of the embodiment of the electrochromic element **134**, as illustrated in FIG. **35**, and the differences in thin-film structure are emphasized. The electrochromic element **134**, as illustrated in FIG. **35**, can also include a supporting base **286**, which has a base layer **288**, an ITO layer **290**, an opaque region **292**, a transflective region **294**, and a transition region **296**.

The properties of the stack are summarized in the table of FIG. **36** as a function of a one-dimensional position (corresponding to the y-axis of FIG. **35**) along the third surface **114***a* of the electrochromic element **134**. The electrochromic element **134** can include three metallic layers that change in thickness, which can be positioned across the third surface **114***a*. Such metallic layers can include, but are not limited to, a layer of Chromium **280**, a layer of Ruthenium **282**, and a layer of silver alloy **284**. The essentially opaque area can be seen to extend approximately between the positions identified as −0.75 in and 5 in across the substrate. The transflective display area, extending approximately between the positions of −5 in and 1.75 in, utilizes only three of the five layers listed in table of FIG. **36**. In this embodiment, the graded Chromium opacifying layer **280**, deposited on the supporting base that can include a glass substrate and a base bi-layer of TiO_2 and ITO, asymptotically extends into the transflective display area. A flash opacifying layer **282** of Ruthenium, deposited above the Chromium layer **280**, extends asymptotically into the transflective display area beyond the extent of the Chromium layer **280**. The fairly complicated thickness profile of an upper continuous reflecting layer **284** of silver alloy assures a substantially linear change in reflectance between the opaque area and display area.

Yet another alternative embodiment represents a modification of the electrochromic system **138** of FIG. **35** by employing a non-uniform reflective layer **284**. Such an embodiment may generally achieve an approximately uniform reflectance in excess of at least fifty percent (50%) across the surface of the mirror element and a transmittance levels below approximately five percent (5%) in the opaque area and below approximately fifty percent (50%) in the transflective area. In a specific embodiment, an approximately uniform reflectance of about sixty-five percent (65%) across the surface of the mirror element may be achieved, while simultaneously keeping transmittance level well below a half percent (0.5%) in the opaque area and above twenty percent (20%) in the transflective area. The geometry of thin-film layers comprising a thin-film stack that may be deposited on the third surface to achieve such properties, as described in the table of FIG. **37**.

With respect to FIG. **38**, another exemplary embodiment of the electrochromic system **138** is illustrated. In such an embodiment, at least one of the front element **112** and the rear element **114** can include an approximately 1.6 mm glass substrate. A TiO_2 layer **298** can be approximately 144 Å thick, and an ITO layer **300** can be approximately 180 Å thick. A silver alloy layer **302** can be approximately 240 Å thick, and additionally or alternatively, include approximately seven percent (7%) gold. The cell spacing filled with the electrochromic medium **126** can be approximately 160 microns, and the ITO layer **304** can be approximately 1450 Å thick. An appliqué layer **306** can be on the fourth surface **114***b*. Various exemplary characteristics of the electrochromic system **138** are described in the table of FIG. **39**.

By way of explanation and not limitation, the electrochromic medium **126** can include at least one solvent, at least one anodic electroactive material, and at least one cathodic electroactive material. One or more of the solvent, the anodic electroactive material, and the cathodic electroactive material can be adapted to reduce a perceived color change of light viewed there through (e.g., be approximately neutral). Examples of such electrochromic mediums are described in U.S. Patent Application Publication No. 2010/0073754, entitled "ULTRAVIOLET LIGHT STABILIZING COMPOUNDS AND ASSOCIATED MEDIA AND DEVICES," U.S. Pat. No. 7,428,091, entitled "SEMICONDUCTOR DEVICE HAVING DELAY DRIFT COMPENSATION CIRCUIT THAT COMPENSATES FOR DELAY DRIFT CAUSED BY TEMPERATURE AND VOLTAGE VARIATIONS IN CLOCK TREE," and U.S. Pat. No. 7,256,924, entitled "MULTI-CELL ELECTROCHROMIC DEVICES," the entire references hereby being incorporated herein by reference. Other examples are discussed in U.S. Pat. No. 6,141,137, entitled "ELECTROCHROMIC MEDIA FOR PRODUCING A PRESELECTED COLOR," and U.S. Pat. No. 6,037,471, entitled "ELECTROCHROMIC COMPOUNDS," the entire references hereby being incorporated herein by reference.

As described above, the components of the electrochromic element **134** can be selected to reduce adverse attenuation effects of the electrochromic medium **126** in various transmittance states. For purposes of explanation and not limitation, the below Examples 1-17, referenced in the tables of FIGS. **17**A-**17**I, describe various electrochromic solutions, which can be adapted to at least partially reduce a perceived color change of light viewed through the electrochromic element **134**, as described above.

EXAMPLE #1

Prior Art

In a flask, under a nitrogen purge, is added 567.5 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. LED backlighting is placed behind the elements and they are then darkened at various potentials and color measurements are taken. The construction of the electrochromic transflective mirror element, configured with LED backlighting, for Examples 1-13, is described below.

EXAMPLE #2

In a flask, under a nitrogen purge, is added 510.7 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 132.3 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #3

In a flask, under a nitrogen purge, is added 499.4 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 158.8 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)- ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tretrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #4

In a flask, under a nitrogen purge, is added 499.4 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 158.8 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #5

In a flask, under a nitrogen purge, is added 521.6 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 105.8 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #6

In a flask, under a nitrogen purge, is added 533.0 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 79.4 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl)hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,779.8 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #7

In a flask, under a nitrogen purge, is added 437.2 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 254.8 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1724.2 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #8

In a flask, under a nitrogen purge, is added 382.6 milligrams of 5,10-dimethyl-5,10-dihydrophenazine, 382.2 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1724.2 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #9

In a flask, under a nitrogen purge, is added 685.8 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 181.3 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1646.3 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #10

In a flask, under a nitrogen purge, is added 563.5 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 367.5 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1646.3 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 20.6 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #11

In a flask, under a nitrogen purge, is added 563.5 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 367.5 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1646.3 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 41.2 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #12

In a flask, under a nitrogen purge, is added 586.0 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 382.2 milligrams of 5,10-dineopentyl-5,10- dihydro-2,7-[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1629.6 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 82.4 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #13

In a flask, under a nitrogen purge, is added 1,339.5 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 509.6 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7-[2-(ethyl)hexyl] phenazine, 32.6 milligrams of 1,1',2,2',3,3',4,4',5,5'- decamethyl ferrocene, 1354.7 milligrams of TINUVIN 384™ (Ciba Geigy), 35.2 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.48 milligrams of dibutyl tin diacetate and 82 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 3259.3 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 165.2 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 360 milligrams of LUPRANATE™ (BASF) and 116 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #14

In a flask, under a nitrogen purge, is added 1,172.1 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 764.4 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7-[2-(ethyl)hexyl] phenazine, 32.6 milligrams of 1,1',2,2',3,3',4,4',5,5'- decamethyl ferrocene, 1354.7 milligrams of TINUVIN 384™ (Ciba Geigy), 35.2 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.48 milligrams of dibutyl tin diacetate and 82 grams of propylene carbonate. This solution is stirred and heated at 85° C.

for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 3259.3 milligrams of 1,1'-di (octyl)-4,4'-dipyridinium bis tetrafluoroborate, 165.2 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 360 milligrams of LUPRANATE™ (BASF) and 116 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken. The construction of the electrochromic transflective mirror element, configured with LED backlighting, for Examples 14-16, is described below.

EXAMPLE #15

In a flask, under a nitrogen purge, is added 1,339.5 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 509.6 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7-[2-(ethyl)hexyl] phenazine, 32.6 milligrams of 1,1',2,2',3,3',4,4',5,5'- decamethyl ferrocene, 1354.7 milligrams of TINUVIN 384™ (Ciba Geigy), 35.2 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.48 milligrams of dibutyl tin diacetate and 82 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 3259.3 milligrams of 1,1'-di (octyl)-4,4'-dipyridinium bis tetrafluoroborate, 165.2 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 360 milligrams of LUPRANATE™ (BASF) and 116 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #16

In a flask, under a nitrogen purge, is added 1,255.8 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 637.0 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7-[2-(ethyl)hexyl] phenazine, 32.6 milligrams of 1,1',2,2',3,3',4,4',5,5'- decamethyl ferrocene, 1354.7 milligrams of TINUVIN 384™ (Ciba Geigy), 35.2 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.48 milligrams of dibutyl tin diacetate and 82 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 3259.3 milligrams of 1,1'-di (octyl)-4,4'-dipyridinium bis tetrafluoroborate, 165.2 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 360 milligrams of LUPRANATE™ (BASF) and 116 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken.

EXAMPLE #17

In a flask, under a nitrogen purge, is added 608.5 milligrams of 5,10-dineopentyl-5,10-dihydrophenazine, 396.9 milligrams of 5,10-dineopentyl-5,10-dihydro-2,7[2-(ethyl) hexyl] phenazine, 16.3 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocene, 677.3 milligrams of TINUVIN 384™ (Ciba Geigy), 17.6 grams of 1:10 2(hydroxy)-ethyl methacrylate: methacrylate copolymer, 0.24 milligrams of dibutyl tin diacetate and 41 grams of propylene carbonate. This solution is stirred and heated at 85° C. for 2 hours to dissolve. To a second flask, that is being purged with nitrogen, is added 1,668.6 milligrams of 1,1'-di(octyl)-4,4'-dipyridinium bis tetrafluoroborate, 82.4 milligrams of 1,1',2,2',3,3',4,4',5,5'-decamethyl ferrocinium tetrafluoroborate, 180 milligrams of LUPRANATE™ (BASF) and 58 grams of propylene carbonate. This solution is stirred at room temperature to dissolve. The solutions are combined and mixed thoroughly. This solution is de-gassed under vacuum and then 137 micron transflective mirror elements are vacuum-filled with this solution. These mirror elements are heated to 85° C. for 2 hours to cure the polyurethane gel and then are wired to a variable voltage power supply. The transmittance of the devices is altered at various potentials and color measurements are taken. The construction of the electrochromic transflective mirror element, configured with LED backlighting, for Example 17, is described below.

For the above Examples 1-13 electrochromic cells were constructed as follows. A layer of ITO of approximately 145 nm thickness was deposited on sheets of approximately 1.6 mm soda lime float glass prior to being cut to the shape of an inside automotive mirror. Layers of TiO_2 of approximately 45 nm and ITO of approximately 22 nm were successively deposited forming a bi-layer on sheets of 1.6 mm soda lime float glass prior to being cut to the shape of an inside automotive mirror. On the pieces of glass having the coatings of TiO_2 and ITO, additional coatings were deposited having a somewhat complicated profile as described below. Onto the TiO_2/ITO bi-layer, a layer of chrome was deposited. This layer had a thickness of approximately 50 nm outside of the region in front of the display device and was not deposited in front of the display device. Onto the chrome layer and additional layer of ruthenium was deposited. This layer had a thickness of approximately 5.0 nm outside the region in front of the display and was not deposited in front of the display device. Next, a layer of silver/gold alloy (93% silver/7% gold) was deposited. This layer had a thickness of approximately 9 nm outside the region in front of the display device and a thickness of approximately 16 nm in front of the display device . In addition, there was a gradient to the layers of chrome, ruthenium, and silver/gold alloy between the areas in front of the display device and away from the display device such that the reflectance difference between the two areas are not readily discernable to an observer. The techniques for obtaining a gradient with good aesthetic transition are in accordance with the teachings of U.S. Patent Application Publication No. 2009/0207513, entitled, "MULTI-ZONE MIRRORS." Reference can also be made to FIGS. **35** and **36** and the accompanying text. On the ITO coated side of the piece of glass (i.e., surface two in the completed element), a bead of epoxy containing spacers was deposited, this was laid up onto the second piece such that the coated surfaces face one another (i.e., the reflective surface would be the third surface of the electrochromic element) and so that an opening remained to facilitate the vacuum fill of the electrochromic medium, such that there remained an offset between the glass pieces allowing for electrical connection. The epoxy was cured and the elements were then filled with the electrochromic medium (fluid/gel) systems described in Examples 1-13 and plugged with a UV cured material.

For the above Examples 14-16 electrochromic cells were constructed as follows. A layer of ITO of approximately 115 nm thickness was deposited on sheets of approximately 1.6 mm soda lime float glass prior being cut to the shape of an inside automotive mirror. Layers of TiO_2 of approximately 45 nm and ITO of approximately 22 nm were successively deposited forming a bi-layer on separate sheets of 1.6 mm soda lime float glass prior to being cut to the shape of an inside automotive mirror. On the piece of glass having the coatings of TiO_2/ITO bi-layer an additional coating of silver/gold alloy (93% silver/7% gold) was deposited to a thickness of approximately 23 nm. Onto the ITO coated side of the piece of glass (i.e., surface two in the completed element), a bead of epoxy containing spacers was deposited, this was laid up to the second piece such that the reflective surfaces faced one another (i.e., the reflective surface would be the third surface of the electrochromic element) and so that an opening remained to facilitate the vacuum fill of electrochromic medium and such there remained an offset between the glass pieces allowing for electrical connection. The epoxy was cured and the elements were then vacuum backfilled with the electrochromic medium (fluid/gel) systems described in Examples 14-16 and plugged with a UV cured material.

For the above Example 17 electrochromic assembly was constructed as follows. A layer of ITO of approximately 115 nm was deposited on sheets of approximately 1.6 mm soda lime float glass prior to being cut to the shape of an inside automotive mirror. Onto the ITO coated side of one of the pieces of glass (i.e., surface two of the completed element), a bead of epoxy containing spacers was deposited, this was laid up onto the second similar piece so that the coated surfaces faced one another and so that there was an opening remained to facilitate the vacuum fill of the electrochromic medium, such that there remained an offset between the glass pieces allowing for electrical connection. The epoxy was cured and the element was then vacuum backfilled with the electrochromic medium (fluid/gel) system described in Example 17 and plugged with a UV cured material. An anisotropic polymer film "DBEF-Q" available from 3M corporation was also cut to mirror shape. The DBEF-Q film was then laminated (i.e., at approximately 105° C. at approximately 190 psig) between the electrochromic element described above and an approximately 1.1 mm piece of soda lime glass cut to the shape of an inside mirror in accordance with teachings found in U.S. Patent Application Publication No. 2010/0110553, entitled "REARVIEW MIRROR ASSEMBLIES WITH ANISOTROPIC POLYMER LAMINATES," the entire reference hereby being incorporated herein by reference. This additional glass had coatings on the surface that is in contact with the DBEF-Q film. The coating deposited on the glass surface was a layer of TiO_2 of approximately 55 nm and a layer of ITO of approximately 5 nm was deposited onto the layer of TiO_2 forming a bi-layer. A layer of chrome of approximately 50 nm was deposited onto the TiO_2/ITO bi-layer in the areas that are not in front of the display device. This layer of chrome has a graded thickness in the area around the display. The DBEF-Q film was oriented such that its polarization of high transmittance was lined up with the polarization of the display device in accordance with teachings found in the above-referenced U.S. Patent Application Publication No. 2010/0110553.

Photopic measurements wherein described were taken with equipment known commonly in the industry as MacBeth Color Eye 7000A Spectrophotometer, Ocean Optics USB 4000 Spectro radiometer and Photo Research PR-705 Spectro radiometer. The Photopic instrument incident angle is orientated perpendicular to the mirror front surface at normal zero degrees (0°) horizontal, zero degrees (0°) vertical of a distance approximately fourteen inches (14 in) away from the front surface of the mirror. Individual colors were produced with standard LED light source NICHIA™ NSSW064A shined through the display LTA035B3J1F which is fully driven in color modes red, green, blue, amber, and yellow. LTA035B3J1F is a normally white Active Matrix TFT display and the white state is considered non-driven from the display point of view.

The above embodiments and examples are particularly well suited for primaries that have relatively broad widths. Many displays are often constructed with light sources and liquid crystals optimized for high brightness. As stated above this generally requires that the red, green, and blue primaries have a relatively wide bandwidth to maximize the light transmittance. When coupled with a white light source this approach can lead to displays with high light intensity levels. The trade-off is lower color accuracy of the display due to the wide band widths of the primaries. The electrochromic chemistry discussed and defined above with respect to the electrochromic element provides relatively uniform light attenuation during the darkening excursions (e.g., lowering the transmittance state) of the electrochromic media. This allows the electrochromic system to maintain color accuracy in the high transmittance, low transmittance, and the intermediate states.

FIG. **23** illustrates the transmittance of the electrochromic system **138** with various applied potentials. The 0.0 V curve is the high transmittance case while the 1.2 V curve is the low transmittance state. The intermediate states are noted with the applied potentials (i.e., the 0.5 V curve, the 0.6 V curve, the 0.7 V curve, and the 0.8 V curve). The data of FIG. **23** was simulated using thin film models. The electrochromic element **134** was modeled with two 1.6 mm thick pieces of glass. The ITO layer on the second surface **112*b*** was 145 nm thick (½ wave), the transflective electrode on the third surface **114*a*** has a 45 nm TiO_2 layer directly on the glass, an 18 nm ITO layer on the TiO_2 layer and a 25 nm silver gold alloy layer on the ITO layer. The electrochromic model was set at 190 microns and the optical constants of the fluid are comparable to the prior art reference in Example 1 above. As shown in FIG. **23**, the transmittance spectra has varying transmittance versus wavelength at the different applied potentials. The non-equivalent transmittance spectra result in non-uniform modulation of the RGB primaries resulting in color shifts, as discussed in detail herein.

As can be seen from FIG. **23**, it does not appear that dual or more primaries can be selected that will maintain color accuracy since the change in transmittance with applied potential changes dramatically with wavelength. However, in accordance with an embodiment of the present invention, an alternate approach to broad primaries is to use narrow primaries. Some types of LEDs provide a narrow wavelength distribution. For the examples below the wavelength bandwidth for the primaries was set to 5 nm or less full width half max. It should be appreciated that alternate wavelength bandwidths are possible. The exemplary color below is in the u',v' system with an approximately 10 degree observer.

The use of narrow primaries is not a universal solution. For the electrochromic system **138** having the characteristics of FIG. **23**, we have determined that only a very narrow set of primary combinations can preserve color accuracy during the darkening excursion for an electrochromic system **138** or other electro-optic system. The table of FIG. **24** and the chart of FIG. **25** illustrate the color $\Delta E_{u',v'}$ values between the high transmittance states and the intermediate states. The primary pairs or triplets in this example are a sample of the possible primary combinations wavelength pairs. These are meant to be representative of the high $\Delta E_{u',v'}$ values that will arise with random pairings of primaries.

A method was developed to determine viable primaries whose relative intensities do not change to a large extent during the darkening excursion. The ratio of intensities of potential primary pairs can be calculated for the high and low transmittance states and then compared. By way of explanation and not limitation, the intensity ratio was calculated for 400 nm to every wavelength from 401 nm to 675 nm for each nanometer wavelength. The calculations were then repeated for 405, 410, . . . 500 nm instead of the 400 nm primary. FIGS. **26** and **27** (same information on different vertical scales) show the calculated difference in intensities for the high and low transmittance states. Suitable primaries are obtained when the difference is approximately zero.

As can be determined from FIGS. **26** and **27**, the vast majority of potential primary pairs have intensity ratio differences that are relatively high. In order to have relatively low $\Delta E_{u',v'}$ values over the darkening excursion, the difference in the intensity ratios can be less than 0.75. Alternatively, the differences in the intensity ratio can be less than 0.50 or less than 0.25. It can be beneficial to select primary pairs wherein the intensity ratio differences are near zero. For this condition the primary pairs are most stable and will be more robust in practice.

FIG. **28** shows the color for optimal primary pairs and triplets whose color is stable over the darkening excursion of the electrochromic medium **126**. Pairs **405/565**, **405/630**, **460/550**, **460/635** and triplets **405/565/630** and **460/550/635** exhibit small $\Delta E_{u',v'}$ values over the darkening excursion. The table of FIG. **29** shows the $\Delta E_{u',v'}$ values for these primary combinations.

The color gamut for the **460/550/635** triplet is shown in FIG. **30**. The triangle defines the attainable colors possible with this primary system. The dots (or "x") represent colors attained by adjusting the intensity levels of the primaries. The table of FIG. **31** illustrates the relative intensities of the primaries, an average $\Delta E_{u',v'}$, and the maximum $\Delta E_{u',v'}$ for the points shown in FIG. **30**.

The color stability for this technique can be dependent on the transmittance characteristics of the electrochromic medium **126** and the width of the primaries. Depending on the transmittance spectra versus applied potential one or more primary combinations may be viable for a given system.

Additionally or alternatively, the coatings or stacks of the electrochromic element **134** can be configurable to compensate for the adverse affects on color rendering that are caused by the light viewed through other components of the electrochromic element **134**. Exemplary coating stacks are described in U.S. Provisional Patent Application Ser. No. 60/779,369, entitled "COATINGS AND REARVIEW ELEMENTS INCORPORATING THE COATINGS," U.S. Provisional Patent Application Ser. No. 60/810,921, entitled "ELECTROCHROMIC REARVIEW MIRROR ASSEMBLY INCORPORATING A DISPLAY/SIGNAL LIGHT," and U.S. Provisional Patent Application Ser. No. 60/888,686, entitled "ELECTRO-OPTIC ELEMENT WITH IMPROVED TRANSPARENT CONDUCTOR," the entire references hereby incorporated herein by reference.

One exemplary stack can have a reflectance of approximately sixty percent to sixty-five percent (60%-65%), a transmittance of approximately twenty percent to twenty-five percent (20%-25%) and a non-opaque coating, such that a bright display device can be in optimal communication behind the rear element **114** without utilizing a hard mask. The exemplary stack can have a display zone with a reduced reflectance to increase transmittance, and an opaque appliqué. Another exemplary stack has a transflective region and a non-transflective, hard masked region. Yet another exemplary state has a reflectance display zone of approximately sixty-five percent (65%) and a non-display, opaque area.

To increase the dynamic range, a control circuit constructed in accordance with the present invention utilizes two or more different current ranges for driving the LED display depending upon whether nighttime or daytime conditions are present. An exemplary control circuit for performing this function is shown in FIG. **18**. As illustrated, the circuit includes a control circuit **900**, which may include a microprocessor also functioning as an inside mirror control circuits, which is coupled to an ambient light sensor **932**, a glare sensor **934**, and an electrochromic element **920** having a construction similar to those disclosed above. Thus, control circuit **900** may perform various control functions for controlling the reflectivity of electrochromic mirror element **920** in response to light levels sensed by ambient sensor **932** and glare sensor **934**.

One of the purposes of the circuit shown in FIG. **18** is to control the brightness of one or more LEDs **902** of an indicator, signal light, or display. In general, the brightness of light emitted from an LED is a function of the current flowing through the LED. Control circuit **900** controls the amount of current flowing through LED **902** by generating a pulse-width modulated signal **904** that is provided through a resistor **906** to the base of a current-sourcing transistor **908**. The source of transistor **908** is coupled to LED **902** and the drain is coupled to ground via a resistor **910**. The drain of transistor **908** is selectively coupled to ground via another current path through a resistor **912** and a switching transistor **914**. The resistance of second resistor **912** is preferably significantly less than the resistance of resistor **910** such that when switching transistor **914** is conducting, the amount of current flowing through sourcing transistor **908** and LED **902** is significantly increased. The conducting status of switching transistor **914** is controlled in accordance with a day/night signal **916** issued from control circuit **900** and supplied to the base of transistor **914** via a resistor **918**.

Although the above-described circuit is utilized for controlling one or more LEDs of a display, a similar arrangement may be configured for controlling the brightness of various other forms of displays that may be utilized within a rearview mirror assembly or other vehicle accessory.

The various embodiments of the electrochromic medium **126** of the present invention taught above enable neutral and stable color in the high transmittance state, the low transmittance state, and the intermediate states for transmitted light. In some embodiments it may also beneficial for the electrochromic system **138** to have neutral reflected color in the high reflectance state, the low reflectance state, and the intermediate states. The neutral reflected color provides a desirable aesthetic appearance of the mirror as well as rendering the true colors of the objects in the reflected images. As described above, the electrochromic system **138** can be configured to reduce a perceived color change of transmitted light as the electrochromic medium **126** alters between transmittance states. Generally, the reflected light can be ambient light that is light other than the light emitted from the display device **136**. The electrochromic system **138** can also be configured to reduce a perceived color change of reflected light as the electrochromic medium **126** alters between transmittance states.

The reflected color is based on the summation of the reflectance of the light at each optical interface in the electrochromic system **138**. Each surface of the glass is an optical interface. The reflectance at each surface is determined by the refractive index of the incident media, the refractive index of the exit media, and any coating present on the surfaces. For the first surface **112***a,* the incident media is air, and the exit media is the substrate, (i.e., glass and typically no coatings are present). For the second surface **112***b,* the incident media is glass, the exit media is the electrochromic medium **126**, and there may be coatings present, such as ITO or an IMI stack. The third surface **114***a* has the electrochromic medium **126** as the incident media, the glass as the exit media, and in some embodiments, the transflective reflector electrode. The fourth surface **114***b* typically has glass as the incident media, air as the exit media, and no coatings. In other embodiments, the first surface **112***a* and fourth surface **114***b* may have one or more coatings present, or the third surface **114***a* can have a transparent electrode and the transflective coating may be present on the fourth surface **114***b*. The reflectance at each interface will vary with properties of the bounding media and any coatings present. The light from each interface adds together for each wavelength and the resultant spectrum determines the intensity of the light and the color.

When the electrochromic element **134** is in the high transmittance and reflectance state, the reflectance spectrum can be typically dominated by the reflectance of the transflector coating. In intermediate transmittance or reflectance states the reflectance can be dominated by the light from different interfaces depending on the specific absorption properties of the electrochromic medium **126**. When the electrochromic element **134** is in approximately the fully low transmittance state, with a minor contribution of light from the reflector on either the third surface **114***a* or the fourth surface **114***b* reaching the observer, the appearance of the electrochromic system **138** is due mainly to a combination of light from the first and second surfaces **112***a,* **112***b* of the front substrate **112**. With no coating on the first surface **112***a,* about four percent (4%) reflectance of relative uniform intensity across the visible spectrum from the uncoated glass interface is obtained. Reflected color is therefore primarily due to thin film interference effects from the transparent electrode on the second surface **112***b*.

The reflected color of the transparent conducting oxide or transparent electrode (IMI) on the second surface **112***b,* in one embodiment, can be due primarily from the thickness of the layer. As the thickness of the TCO is increased, the color changes. The color can be further altered by adding additional layers either above or below the TCO. A portion of the above referenced patents teach methods for reducing the color of TCO and other coatings. Materials used for transparent second surface conductive electrodes are typically materials with an approximately 1.8 index of refraction, or greater. The color impact of these conductive electrode materials can be reduced by using half wave thickness multiples, using the thinnest layer possible (or a layer with reduced thickness) for the application or by the use of one of several "non-iridescent glass structures." Non-iridescent structures will typically use either a high and low index layer under the conductive coating (see, for example, U.S. Pat. No. 4,377,613, entitled "NON-IRIDESCENT GLASS STRUCTURES," and U.S. Pat. No. 4,419,386, entitled "NON-IRIDESCENT GLASS STRUCTURES,"), or an intermediate index layer (see U.S. Pat. No. 4,308,316, entitled "NON-IRIDESCENT GLASS STRUCTURES," or U.S. Pat. No. 5,395,698, entitled "NEUTRAL, LOW EMISSIVITY COATED GLASS ARTICLES AND METHOD FOR MAKING,") or graded index layer (see U.S. Pat. No. 4,440,822, entitled "NON-IRIDESCENT GLASS STRUCTURES") to reduce color impact. IMI transparent electrodes are also referenced in a portion of the above referenced patents, wherein the reflected color in the dark state and how to alter it is addressed.

As noted above, the reflectance of the electrochromic element **134** in the low transmittance state is affected by the thickness of the TCO and whether other layers are present in the coating stack. As a result of the absorption in ITOs or other TCOs being fairly low, there is little color change in the bright state of the mirror due to thickness changes in the layer. Similarly, in a window, the ITO does not contribute substantially to the transmitted color nor is color tuning by adjusting the ITO a primary option for altering the reflected or transmitted color. In other embodiments, the absorption or transmittance characteristics of the TCO or IMI coating may be adjusted or tuned to specifically help address a deficiency due to the characteristics of another component, as discussed in greater detail herein.

Another design attribute desirable in some embodiments of the electrochromic system **138** is to have a very low reflectance in the low transmittance state as well as a neutral color. This can result in an increased or maximum dynamic range for the mirror elements. The table of FIG. **34**A depicts the dark state reflectance values, color, and C* values for the electrochromic device **138** as a function of the ITO thickness calculated using thin film models. In this example, the electrochromic medium **126** is set to be substantially opaque. When the electrochromic medium **126** is not completely opaque, the reflected light from the mirror coating can add to the reflectance in FIG. **34**A. As depicted, the low transmittance state reflectance can reach a minimum at about 140 to 150 nm or a ½ wave coating with a design wavelength of 550 nm. As the thickness deviates from this half wave thickness, the low transmittance state reflectance rises and the dynamic range decreases. The reflected color varies with the thickness of the ITO coating. The C* values vary also with the thickness. The most neutral color happens with a thickness less than that of a common half wave thickness (130 nm versus 150 nm).

An exemplary illustration of reflected color change of the electrochromic system **138** is illustrated in FIG. **16**A, which corresponds to Example 14 with neutral chemistry and that includes an approximately 130 nm thickness ITO coating on the second surface **112***b*. This curve illustrates the perceived color change as the electrochromic medium **126** is altered from approximately the high transmittance state to approximately the low transmittance state. The curves remaining proximate the origin with a low C* value through the darkening curve and a particularly low C* value in the fully low transmittance state. This can be compared to the prior art curves illustrated in FIG. **16**B which corresponds to Example 1 with the prior art electrochromic medium and a 150 nm ITO coating on the second surface. FIG. **16**B has an increased perceived color change of the reflected light when the electrochromic medium is altering between the high transmittance state and the low transmittance state relative to FIG. **16**A. The C* of the reflected light for the electrochromic system **138** can be less than approximately twenty (20), at one or more of the reflectance and/or transmittance states. Alternatively, the C* of the reflected light for the electrochromic system **138** can be less than approximately fifteen (15), or less than approximately ten (10) at one or more of the reflectance and/or transmittance states. Thus, the reflective components of the electrochromic element **134** can be substantially color neutral.

The above example demonstrates that the thickness of a single transparent conducting oxide layer (e.g., ITO) can be selected to have a beneficial effect on the reflected color of the electrochromic system **138**. The following examples in Table **34**B were calculated using thin film models. The optical constants of an electrochromic medium similar to Example 14 were used, which corresponds to an approximately fully opaque fluid. The optical contributions from the reflector electrode are therefore eliminated and do not contribute to the reflected color. Examples of three different coating stacks (color suppression) to provide neutral reflected color are presented. In each case the ITO thickness is at 149 nm, but the use of the various color suppression techniques work equally well for other thicknesses of ITO or other transparent conducting oxides.

In other embodiments, it may be advantageous to have a reflectance in the low reflectance state higher than that demonstrated by that attainable by the ITO layer within the thickness ranges described above. The electrochromic element **134** may be operated with applied potential values that do not allow the electrochromic medium **126** to attain its fully opaque state or the cell spacing of the electrochromic element **134** may be altered such that some desired level of reflectance from the reflector is obtained. Alternately, as described above, the transparent electrode stack comprising an IMI, a TCO layer, or the like may be modified to adjust the low end reflectance value. In particular, an additional layer or layers may be placed above or below the ITO or the TCO layer. In the table of FIG. **33** a single layer is placed below the ITO layer at a quarter wave thickness. It should be appreciated by other thicknesses may be chosen as needed without deviating from the spirit of the invention. The reflectance increases with increasing refractive index values. In other embodiments it may be advantageous to both increase the low end reflectance and have a relatively neutral color in the low reflectance state. In the table of FIG. **34**B it is illustrated that for the different three layer stacks, the low end reflectance is altered while maintaining a neutral reflected color.

By way of explanation and not limitation, the electrochromic system **138** can be used as an auto-dimming rearview mirror in a motor vehicle. Alternatively, the electrochromic system **138** can be used as a dimming mirror in other environments. In an exemplary embodiment of a motor vehicle, the electrochromic system **138** can be configured to dim as a function of ambient and glare light. Further, the display device **136** can be configured to emit light (e.g., the one or more primaries projecting the display element), such as, but not limited to, text, symbol, or image in a plurality of colors while the electrochromic element **134** is in any transmittance state. Thus, the display device **136** can be configured to emit light to project images associated with warning systems, navigational systems, or other suitable systems integrated with the motor vehicle. The reduced perceived color change of the emitted light by a user as the transmittance state of the electrochromic medium **126** alters can be advantageous, so that the plurality of colors emitted by the display device **136** that can form the text, the image, and/or the symbols can be perceived approximately the same by the user without regard to the transmittance state of the electrochromic medium **126**. Thus, the electrochromic medium **126**, chamber **125**, and other elements of the electrochromic element **134** can extend over the display device **136**, and the electrochromic medium **126** does not have to be in a high transmittance state when the display device **136** is emitting light to the user.

By integrating a personal computer with a telematics system such as that disclosed in U.S. Pat. No. 6,980,092, entitled "VEHICLE REARVIEW MIRROR ASSEMBLY INCORPORATING A COMMUNICATION SYSTEM," of which the entire reference is hereby incorporated herein by reference, the computer monitor may be used for displaying various forms of information including e-mail messages and pages, turning indicators for navigational systems; service reminders based on speed and mileage; vehicle heading; school, hospital zone warnings, weather, traffic, and emergency vehicle warnings; night vision displays; advertisements; stock quotes; and other information. Textual messages and other alphanumeric data and/or symbols may be superimposed over the video images displayed on the display device. If the vehicle is equipped with appropriate rear vision cameras, such as disclosed and described in U.S. patent application Ser. No. 09/001,855, entitled "VEHICLE VISION SYSTEM," and U.S. Pat. No. 6,550,949, entitled "SYSTEMS AND COMPONENTS FOR ENHANCING REAR VISION FROM A VEHICLE," the entire references hereby being incorporated herein by reference, coupling such cameras to the display device **136** would allow a video display of a view at the rear of the vehicle to assist drivers while connecting the vehicle to a trailer and for proportional steering with respect to the trailer. Other graphics relating to the connection of the vehicle to a trailer may also be displayed.

It should be appreciated by those skilled in the art that embodiments described herein that include a display can also be applied with equal efficacy to imaging embodiments. For display embodiments, the system is configured to substantially maintain color accuracy for the RGB (or other) color primaries emitted by a display behind the electro-optic device as it darkens or brightens (e.g., clears). For imaging embodiments, the direction of the light is reversed; however, the function of the electro-optic device to reduce alteration of color primaries is substantially identical (FIG. **42**). An example of using electrochromic devices as variable optical density filters and variable apertures is disclosed in U.S. Pat. No. 6,963,437, entitled "DEVICES INCORPORATING ELECTROCHROMIC ELEMENTS AND OPTICAL SENSORS," which is hereby incorporated herein by reference. Most imaging devices use standard RGB filters to divide incoming light into primaries compatible with digital encoding. The human eye, equivalently, breaks light into three primaries for the case of color vision based on the cone receptors in the retina. The rods, responsible for black and white vision, function more as color insensitive densitometers.

In one embodiment, an imaging sensor can be behind the electro-optic device such as, but not limited to, a transflective, electrochromic mirror. Such a device can be configured to be used for in cabin imaging of a vehicle for safety features such as, but not limited to, determining occupancy of the vehicle, attentiveness of the driver, sleepy driver detection, the like, or a combination thereof. It can be desirable for the color of the image captured by the sensor not to change significantly as the electrochromic mirror darkens to reduce glare.

In another embodiment, a variable attenuator can be in front of an imaging sensor in order to reduce saturation of the device by high light levels. The variable attenuator can be configured to function as a neutral density filter in that the action of the device would vary the light intensity at the sensor without changing the relative ratio of the primaries to each other. Thus, the action of the electro-optic based attenuator can be configured to reduce a shift of the color of the image. This embodiment could also be applied to eye glasses. Thus, the tint of the glasses can be electronically controlled in order to control the intensity of light passing through the lenses. In this example, as before, the device can be configured to reduce the color shift caused by darkening of the electro-optic device in order to maintain color accuracy when viewing the environment through the glasses. Such electronically dimmable eye glasses could function simply as variable tint sunglasses or this function could be applied to more advanced applications such as the so-called "augmented reality" glasses. Augmented reality glasses superimpose an electronically generated (display) image on top of the image of the environment viewed by the user similar to a head-up display in a car or aircraft. For this application, the control of environmental light intensity reaching the eye could be electronically attenuated in order to maintain adequate brightness and contrast of the electronically displayed image being overlaid on the user's view. The electro-optic device can be configured so the attenuation of the light does not substantially cause color shift.

The action of a variable attenuator might be substantially uniform across its field of view as is the case for the neutral density filter described above or it might be non-uniform. An example of a non-uniform attenuator is an irising filter that can be configured to function as a variable aperture for imaging. To generate an irising effect the outer perimeter of the variable attenuator can darken faster than the central zone. This can be controlled in several ways. A higher potential can be applied to the perimeter zones relative to the central zone. This can mean discrete bands of controlled potential or a potential gradient between the perimeter and the center of the EC cell (FIG. **43**A). Alternatively, controlling cell spacing in the electro-optic device such that the central zones have smaller cell spacing than the outer zones can be used to create the aperture (FIG. **43**B).

A method for compensating a displayed image for small color shifts caused by changes in the transmittance of an electro-optic device has been disclosed herein. This method is also applicable to imaging devices utilizing variable transmittance electro-optic filters and/or variable electro-optic apertures. Corrections can be made to the pixel color at the imaging sensor based on known color deviations caused by the electro-optic device during its transition from fully clear to fully darkened including intermediate levels. These corrections can, for example, be applied digitally during image processing based on correction functions for the primaries or alternatively look-up tables.

Modifications of the invention will occur to those skilled in the art and to those who make or use the invention. Therefore, it is understood that the embodiments shown in the drawings and described above are merely for illustrative purposes and not intended to limit the scope of the invention, which is defined by the following claims as interpreted according to the principles of patent law, including the doctrine of equivalents.

The invention claimed is:

1. An electrochromic system comprising:

an electrochromic element comprising:

a front element comprising first and second surfaces;

a transparent electrode on said second surface;

a rear element comprising third and fourth surfaces, wherein said front and rear elements are sealably bonded together in a spaced-apart relationship to define a chamber, such that said second surface and said third surface face one another; and

an electrochromic medium contained in said chamber, wherein said electrochromic medium is adapted to be in at least a high transmittance state and a low transmittance state,

wherein light passing through said electrochromic element has at least a first primary and a second primary, and said first and said second primaries each have a first hue (h_{ab}) when passing through said electrochromic medium in said high transmittance state and a second hue (h_{ab}') when passing through said electrochromic element in approximately said low transmittance state, wherein a change in said first and second hues (Δh_{ab}) for both said first and second primaries is less than approximately 31 degrees,

wherein a ratio of intensities of said first and second primaries remains approximately constant.

2. The electrochromic system of claim **1**, wherein a change of the ratio of intensities of said first and second primaries is between about 0.25 and 1.

3. The electrochromic system of claim **1**, wherein a change of the ratio of intensities of said first and second primaries is between about 0.50 and 1.

4. The electrochromic system of claim **1**, wherein a change of the ratio of intensities of said first and second primaries is between about 0.75 and 1.

5. The electrochromic system of claim **1**, and further comprising a display device in optical communication with said electrochromic element, wherein said display device comprising at least one light source, and wherein said display device being configured to emit at least said first and second primaries.

6. The electrochromic system of claim **1**, wherein each of said first and second primaries has a first color (u',v') when passing through at least a portion of said electrochromic element in approximately said high transmittance state and a second color (u',v')' when passing through at least a portion of said electrochromic element in approximately said low transmittance state, and a difference in said first and second colors ($\Delta E_{u',v'}$) for said first and second primaries is less than approximately 0.06.

7. The electrochromic system of claim **1**, wherein said first primary is light having a red hue and said second primary is light having a green hue.

8. The electrochromic system of claim **1**, wherein a third primary having a first hue (h_{ab}) when passing through at least a portion of said electrochromic element in approximately said high transmittance state and a second hue (h_{ab}') when received through said electrochromic element in approximately said low transmittance state, and a change in said first and second hues (Δh_{ab}) is less than approximately 41 degrees.

9. The electrochromic system of claim **8**, wherein said third primary has a first color (u',v') when passing through at least a portion of said electrochromic element in approximately said high transmittance state and a second color (u',v')' when received through said electrochromic element in approximately said low transmittance state, and a difference in said first and second colors ($\Delta E_{u',v'}$) for said third primary is less than approximately 0.05.

10. The electrochromic system of claim **8**, wherein said third primary is light having a blue hue.

11. The electrochromic system of claim 1 further comprising a reflector electrode on said third surface, wherein said transparent electrode is selected to have a beneficial effect on the reflected color of said electrochromic element, such that during a color excursion the reflected C* remains below approximately 20.

12. The electrochromic system of claim 1, wherein said first primary is a narrow bandwidth emission having a central wavelength of 405 nm.

13. The electrochromic system of claim 12, wherein said secondary primary is a narrow bandwidth emission having a central wavelength of 565 nm.

14. The electrochromic system of claim 12, wherein said secondary primary is a narrow bandwidth emission having a central wavelength of 630 nm.

15. The electrochromic system of claim 14, wherein light passing through said electrochromic element further has a third primary which is a narrow band emission having a central wavelength of 565 nm.

16. The electrochromic system of claim 1, wherein said first primary is a narrow bandwidth emission having a central wavelength of 460 nm.

17. The electrochromic system of claim 16, wherein said secondary primary is a narrow bandwidth emission having a central wavelength of 550 nm.

18. The electrochromic system of claim 16, wherein said secondary primary is a narrow bandwidth emission having a central wavelength of 635 nm.

19. The electrochromic system of claim 18, wherein light passing through said electrochromic element further has a third primary which is a narrow bandwidth emission having a central wavelength of 550 nm.

20. The electrochromic system of claim 1, wherein said first and second primaries have narrow wavelength bandwidths of 5 nm or less full width half max.

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