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(54) Title: DIELECTRIC MIRROR

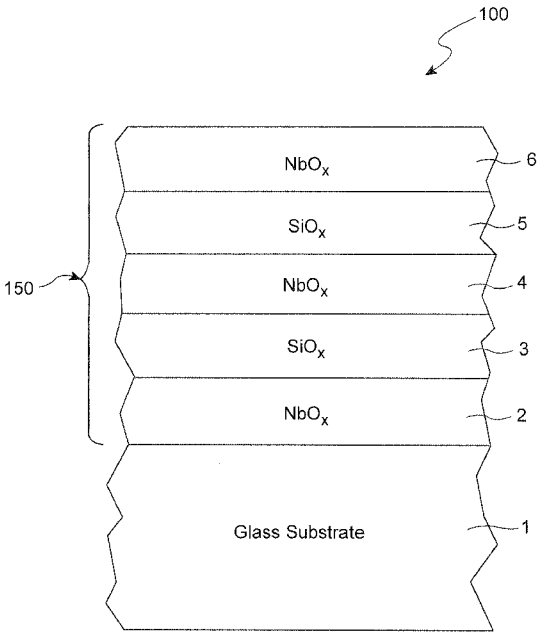

FIG. 1

(57) Abstract: A dielectric mirror includes a coating having alternating high and low index layers. The mirror coating has no metallic reflective layer, and may have film side and/or glass side visible reflection of from about 50-90% (more preferably from about 60-80% and most preferably from about 65-75%) and visible transmission of from about 10-50% (more preferably from about 20-40%, and most preferably from about 25-35%).

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TITLE OF THE INVENTION

DIELECTRIC MIRROR

FIELD OF THE INVENTION

[0001] Certain example embodiments of this invention relate to dielectric mirrors and/or methods of making the same. More particularly, certain example embodiments relate to dielectric mirrors having no metallic reflective layer and which realize film side and/or glass side visible reflection of from about 50-90% (more preferably from about 60-80% and most preferably from about 65-75%) and visible transmission of from about 10-50% (more preferably from about 20-40%, and most preferably from about 25-35%).

BACKGROUND AND SUMMARY OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0002] Mirrors have been in existence for years and have been used in many applications. Mirrors generally are either (a) first surface mirrors, where the mirror coating is provided between the viewer and the supporting glass substrate, or (b) second surface mirrors, where the supporting glass substrate is interposed between the viewer and the mirror coating. See, for example, U.S. Patent Nos. 7,276,289 and 7,678,459; U.S. Publication Nos. 2006/0077580; 2007/0178316; 2008/0073203; 2008/0164173; 2010/0229853; 2011/0176212; and 2011/0176236. The entire contents of each of these patent documents are hereby incorporated herein by reference.

[0003] Mirrors often require the use of a metallic (e.g., Al or Ag) reflective layer. However, it would be desirable if mirrors could be provided without the need for a metallic reflective layer.

[0004] Certain example embodiments of this invention relate to dielectric mirrors and/or methods of making the same. More particularly, certain example embodiments relate to dielectric mirrors having no metallic reflective layer (e.g., no Ag layer and no Al layer) and which are nonetheless capable of realizing film side and/or glass side visible reflection of from about 50-90% (more preferably from about 60-80% and most preferably from about 65-75%) and visible transmission of from about 10-50% (more preferably from about 20-40%, and most preferably from about

25-35%). The dielectric mirrors may be first or second surface mirrors in certain example embodiments, given good performance regarding both glass side reflection and film side reflection. The mirrors may or may not be heat treated (e.g., thermally tempered and/or thermally bent) in certain example embodiments. In certain example instances, such dielectric mirrors may be used in consumer, commercial and/or digital signage applications such as picture frames, bathroom mirrors, TVs, and/or electronic devices.

[0005] In certain example embodiments of this invention, there is provided a dielectric mirror including a glass substrate supporting a coating, the coating comprising moving away from the glass substrate: a first transparent dielectric high refractive index layer comprising niobium oxide, the first transparent dielectric high refractive index layer having a thickness of from about 70-140 nm; a second transparent dielectric low refractive index layer comprising silicon oxide, the second transparent dielectric low refractive index layer having a thickness of from about 30-140 nm; a third transparent dielectric high refractive index layer comprising niobium oxide; a fourth transparent dielectric low refractive index layer comprising silicon oxide; a fifth transparent dielectric high index layer comprising niobium oxide; wherein the first transparent dielectric high index layer comprising niobium oxide is at least 10 nm thicker than one or both of the third transparent dielectric high refractive index layer comprising niobium oxide and/or the fifth transparent dielectric high index layer comprising niobium oxide; wherein the coating does not contain any metallic reflective layer; and wherein the dielectric mirror has a visible film side reflectance and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

[0006] In certain example embodiments of this invention, there is provided a mirror including a substrate (e.g., glass substrate) supporting a coating, the coating comprising moving away from the substrate: a first dielectric layer having a thickness of from about 70-140 nm and a refractive index (n) of from about 2.15 to 2.5; a second dielectric layer comprising silicon oxide; a third dielectric layer having a refractive index of from about 2.15 to 2.5; a fourth dielectric layer comprising silicon oxide; a fifth dielectric layer having a refractive index of from about 2.15 to 2.5; wherein the first dielectric layer is at least 10 nm thicker than one or both of the third dielectric layer and/or the fifth dielectric layer; wherein the coating does not contain any metallic reflective layer; and wherein the mirror has a visible film side reflectance

and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIGURE 1 is a cross sectional view of a dielectric mirror according to an example embodiment of this invention;

[0008] FIGURE 2 is a modeled wavelength (nm) versus visible transmission (Ts), film side reflection (BRs), glass side reflection (Ra) graph illustrating optical characteristics of a dielectric mirror according to an example of the Fig. 1 embodiment; and

[0009] FIGURE 3 is a modeled angle (degrees) versus glass side reflective a* and b* color values graph, illustrating angular distribution of reflected colors of a dielectric mirror according to the example of the Fig. 1 embodiment.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0010] Referring now more particularly to the drawings in which reference numerals indicate like parts/materials throughout the several views.

[0011] Fig. 1 is a cross sectional view of a dielectric mirror 100 according to certain example embodiments of this invention. The mirror includes a dielectric coating 150 which is on a glass substrate 1. Glass substrate 1 may be soda-lime-silica based glass or any other suitable type of glass, and may be from about 1-10 mm thick, more preferably from about 2-6 mm thick, in example embodiments of this invention. Alternatively, substrate 1 may be of quartz, silicon, or the like. The mirror coating 150 includes high index transparent dielectric layers 2, 4 and 6 of or including niobium oxide (e.g., Nb_2O_5, NbO_2 and/or NbO) and low index transparent dielectric layers 3 and 5 of or including silicon oxide (e.g., SiO_2 which may or may not be doped with aluminum and/or nitrogen). In certain example embodiments, one or both of the silicon oxide layers 3 and/or 5 may be doped with other material such as from about 1-8% aluminum and/or from about 1-10% nitrogen. One or more of layers 2, 4 and 6 may also be doped with other material in certain example instances. In the Fig. 1 embodiment, layer 6 is the outermost layer of the coating 150 and may be exposed to air. Each of layers 2-6 is considered "transparent" because each of these layers,

standing alone, is substantially transparent to visible light (e.g., at least about 50% transparent, more preferably at least about 60% or 70% transparent to visible light).

[0012] High index transparent dielectric layers 2, 4 and 6 of or including niobium oxide may have a refractive index (n) of from about 2.15 to 2.5, more preferably from about 2.2 to 2.4, and most preferably from about 2.25 to 2.35 (at 550 nm). In certain alternative embodiments, the niobium oxide may be replaced with titanium oxide (e.g., TiO_2), zirconium oxide, hafnium oxide (e.g., HfO_2), cerium oxide (e.g., CeO_2), zinc sulfide, or bismuth oxide (e.g., Bi_2O_3) in one or more of high index layers 2, 4 and/or 6. Low index transparent dielectric layers 3 and 5 of or including silicon oxide may have a refractive index (n) of from about 1.4 to 1.7, more preferably from about 1.4 to 1.6, and most preferably from about 1.45 to 1.55 (all refractive index n values herein are measured at 550 nm).

[0013] Transparent dielectric layers 2-6 are preferably deposited by sputtering in example embodiments of this invention. For example, transparent dielectric layers 2, 4 and 6 of or including niobium oxide may be sputter deposited via at least one sputtering target of or including Nb, via sputtering in an atmosphere including a mixture of argon and reactive oxygen gases. And for example, transparent dielectric layers 3 and 5 of or including silicon oxide may be sputter deposited via at least one sputtering target of or including Si or SiAl, via sputtering in an atmosphere including a mixture of argon and reactive oxygen gases. Rotation C-Mag sputtering targets, or other types of targets, may be used. In sputtering operations, sufficient reactive oxygen gas may be used to achieve the refractive index values discussed herein. Ceramic targets may alternatively be used to sputter deposit one or more of these layers. While layers 2-6 are preferably deposited via sputtering, it is possible that they may be deposited via other techniques in alternative embodiments of this invention. While mirror coating 150 consists of five layers in the Fig. 1 embodiment, it is possible that additional layers may be provided in alternative embodiments.

[0014] Dielectric mirror 100, in the Fig. 1 embodiment and in other example embodiments, contains no metallic reflective layer (e.g., no Ag layer and no Al layer), but is nonetheless capable of realizing film side and/or glass side visible reflection of from about 50-90% (more preferably from about 60-80% and most preferably from about 65-75%) and visible transmission of from about 10-50% (more preferably from about 20-40%, and most preferably from about 25-35%). The high reflectance values are achieved, despite no metallic reflective layers, by way of the large refractive index

differences between adjacent layers in the coating 150 in combination with the layer thickness values discussed herein. In certain example embodiments, the glass side reflectance (reflectance measured from the glass 1 side of the mirror) and the film side reflectance (reflectance measured from the film 150 side of the mirror) may be substantially symmetric (e.g., the glass side reflectance and film side reflectance of the mirror may differ by no more than about 10%). The refractive index and thickness values herein may also be tailored to allow transmitted and reflected color values (e.g., a* and/or b* color values) to be substantially neutral. The dielectric mirrors 100 may be first or second surface mirrors in certain example embodiments. The dielectric mirror 100 may be used, for example, as a beamsplitter. The mirrors 100 may or may not be heat treated (e.g., thermally tempered and/or thermally bent) in certain example embodiments. In certain example instances, such dielectric mirrors 100 may be used in consumer, commercial and/or digital signage applications such as picture frames, bathroom mirrors, TVs, and/or electronic devices. Theses mirrors may be used for electronic mirrors or hidden TVs for consumers, security, commercial, and/or digital signage applications. In certain electronic applications, when the display is on, the screen image can be viewed through the glass 1, and when the display is off the mirror 100 has the appearance of a mirror, given the reflectance and visible transmission values of the mirror discussed herein.

[0015] In certain example embodiments of this invention, transparent dielectric layer 2 of or including niobium oxide may be from about 70-140 nm thick, more preferably from about 80-130 nm thick, even more preferably from about 90-120 nm thick, with an example thickness being about 105 nm. In certain example embodiments of this invention, transparent dielectric layer 4 of or including niobium oxide may be from about 20-90 nm thick, more preferably from about 30-80 nm thick, even more preferably from about 40-65 nm thick, with an example thickness being about 52 nm. Similarly, in certain example embodiments of this invention, transparent dielectric layer 6 of or including niobium oxide may be from about 20-90 nm thick, more preferably from about 30-80 nm thick, even more preferably from about 40-70 nm thick, with an example thickness being about 54 nm. To realize the desired reflectance and transmission values herein, niobium oxide based layer 2 is preferably substantially thicker than each of niobium oxide based layers 4 and 6. For example, in certain example embodiments, niobium oxide based layer 2 is at least about 10 nm thicker (more preferably at least about 25 nm thicker, and most

preferably at least about 40 nm thicker) than one or both of niobium oxide based layers 4 and/or 6.

[0016] In certain example embodiments of this invention, transparent dielectric layer 3 of or including silicon oxide may be from about 30-140 nm thick, more preferably from about 40-120 nm thick, even more preferably from about 60-120 nm thick, even more preferably from about 75-100 nm thick, with an example thickness being about 88 nm. Similarly, in certain example embodiments of this invention, transparent dielectric layer 5 of or including silicon oxide may be from about 30-140 nm thick, more preferably from about 40-120 nm thick, even more preferably from about 60-120 nm thick, even more preferably from about 75-100 nm thick, with an example thickness being about 88 nm. Thus, the silicon oxide based layers 3 and 5 may be of substantially the same thickness in certain example embodiments (i.e., the thickness of silicon oxide based layers 3 and 5 differs by no more than about 20 nm, more preferably by no more than about 10 nm, in certain example embodiments). And in certain example embodiments, one or both of silicon oxide based layers 3 and/or 5 are at least about 10 nm (more preferably at least about 15 nm) thinner than niobium oxide based layer 2, and is/are at least about 10 nm (more preferably at least about 20 nm) thicker than niobium oxide based layer(s) 4 and/or 6.

[0017] An example dielectric mirror 100 was made as follows:

glass substrate 1
niobium oxide layer 2: 105 nm thick
silicon oxide layer 3: 88 nm thick
niobium oxide layer 4: 53 nm thick
silicon oxide layer 5: 88 nm thick
niobium oxide layer 6: 53 nm thick

[0018] Optical properties of this example mirror are shown in Figs. 2-3. Fig. 2 is a modeled wavelength (nm) versus visible transmission (Ts), film side reflection (BRs), glass side reflection (Ra) graph illustrating optical characteristics of this example dielectric mirror; and Fig. 3 is a modeled angle (degrees) versus glass side reflective a* and b* color values graph, illustrating angular distribution of reflected colors of this example dielectric mirror. The following visible optical values (L*, visible transmission values (TY or TaY), visible reflectance values (film side RfY or

BRa, glass side RgY or Ra), and visible transmissive/reflective color values a* and b*) were measured:

Table 1

	a*	b*	L*	Y
Transmission:	-0.53	+0.17	62.42	30%
Glass side reflectance (Rg):	-0.04	-0.08	86.88	70%
Film side reflectance (Rf):	-1.28	+0.01	85.85	68%

[0019] Thus, it can be seen from the above Table 1 that the dielectric mirror had a visible transmission of 30%, a visible glass side reflectance of 70%, and a visible film side reflectance of 68% (the glass side and film side reflectance was substantially the same). It can also be seen that the mirror had neutral (from -2 to +2) glass side and film side reflective color values a* and b*. These were measured in accordance with Ill. C, 2 degree. And it can be seen in Fig. 3 that the angular distribution of the reflected a* and b* color values showed no large fluctuations at angles from about 0-30 degrees.

[0020] An advantage of the mirror is that ultraviolet (UV) transmission at 385 nm is at least about 70%, more preferably at least about 75%, and most preferably at least about 80% or 85%, as shown in Fig. 2 (note the Ts curve in Fig. 2 at 385 nm), although the visible transmission is less than about 40%, more preferably less than about 35% as also shown in Fig. 2. This high UV transmission, coupled with the low visible transmission and high reflectance values, allows the mirror to be particularly suited for certain applications where high UV is desired.

[0021] While a layer, layer system, coating, or the like, may be said to be "on" or "supported by" a substrate, layer, layer system, coating, or the like, other layer(s) may be provided therebetween. Thus, for example, the coatings or layers described above may be considered "on" and "supported by" the substrate and/or other coatings or layers even if other layer(s) are provided therebetween.

[0022] In example embodiments of this invention there is provided a dielectric mirror including a glass substrate supporting a coating, the coating comprising moving away from the glass substrate: a first transparent dielectric high refractive index layer comprising niobium oxide, the first transparent dielectric high refractive index layer having a thickness of from about 70-140 nm; a second transparent dielectric low refractive index layer comprising silicon oxide, the second transparent dielectric low refractive index layer having a thickness of from about 30-140 nm; a

third transparent dielectric high refractive index layer comprising niobium oxide; a fourth transparent dielectric low refractive index layer comprising silicon oxide; a fifth transparent dielectric high index layer comprising niobium oxide; wherein the first transparent dielectric high index layer comprising niobium oxide is at least 10 nm thicker than one or both of the third transparent dielectric high refractive index layer comprising niobium oxide and/or the fifth transparent dielectric high index layer comprising niobium oxide; wherein the coating does not contain any metallic reflective layer; and wherein the dielectric mirror has a visible film side reflectance and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

[0023] In the mirror of the immediately preceding paragraph, the first transparent dielectric high index layer comprising niobium oxide may be at least 10 nm thicker than both of the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high index layer comprising niobium oxide.

[0024] In the mirror of any of the preceding two paragraphs, the first transparent dielectric high index layer comprising niobium oxide may be at least 25 nm thicker than one or both of the third transparent dielectric high refractive index layer comprising niobium oxide and/or the fifth transparent dielectric high index layer comprising niobium oxide.

[0025] In the mirror of any of the preceding three paragraphs, the first transparent dielectric high index layer comprising niobium oxide may be at least 25 nm thicker than both of the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high index layer comprising niobium oxide.

[0026] In the mirror of any of the preceding four paragraphs, one, two or all three of the first, third and fifth layers may consist essentially of niobium oxide.

[0027] In the mirror of any of the preceding five paragraphs, the dielectric mirror may have a visible film side reflectance of from about 60-80% and a visible glass side reflectance of from about 60-80%.

[0028] In the mirror of any of the preceding six paragraphs, the dielectric mirror may have a visible transmission of from about 25-35%.

[0029] In the mirror of any of the preceding seven paragraphs, the third transparent dielectric high refractive index layer comprising niobium oxide may be from about 30-80 nm thick.

[0030] In the mirror of any of the preceding eight paragraphs, the fourth transparent dielectric low refractive index layer comprising silicon oxide may be from about 40-120 nm thick.

[0031] In the mirror of any of the preceding nine paragraphs, the fifth transparent dielectric high refractive index layer comprising niobium oxide may be from about 30-80 nm thick.

[0032] In the mirror of any of the preceding ten paragraphs, the coating may consist essentially of the first, second, third, fourth and fifth layers.

[0033] In the mirror of any of the preceding eleven paragraphs, the first transparent dielectric high refractive index layer comprising niobium oxide may directly contact the glass substrate.

[0034] In the mirror of any of the preceding twelve paragraphs, the second transparent dielectric low refractive index layer comprising silicon oxide may be located between and directly contacting the first transparent dielectric high refractive index layer comprising niobium oxide and the third transparent dielectric high refractive index layer comprising niobium oxide.

[0035] In the mirror of any of the preceding thirteen paragraphs, the fourth transparent dielectric low refractive index layer comprising silicon oxide may be located between and directly contacting the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high refractive index layer comprising niobium oxide.

[0036] In the mirror of any of the preceding fourteen paragraphs, the first, second, third, fourth, and fifth layers may be sputter-deposited layers.

[0037] In the mirror of any of the preceding fifteen paragraphs, each of the second and fourth transparent dielectric low refractive index layers comprising silicon oxide may be doped with aluminum and/or nitrogen.

[0038] In the mirror of any of the preceding sixteen paragraphs, the first, third, and fifth transparent dielectric high refractive index layers comprising niobium oxide may have a refractive index of from about 2.15 to 2.5, more preferably from about 2.2 to 2.4.

[0039] In the mirror of any of the preceding seventeen paragraphs, the second and fourth transparent dielectric low refractive index layers comprising silicon oxide may have a refractive index of from about 1.4 to 1.7, more preferably from about 1.4 to 1.6.

[0040] In the mirror of any of the preceding eighteen paragraphs, the second and fourth transparent dielectric low refractive index layers comprising silicon oxide may each be: (i) thinner than the first transparent dielectric high refractive index layer comprising niobium oxide, and (ii) thicker than both the third and fifth transparent dielectric high refractive index layers comprising niobium oxide.

[0041] In the mirror of any of the preceding nineteen paragraphs, the mirror may have an ultraviolet (UV) transmission at 385 nm of at least about 75%, more preferably of at least about 80%.

[0042] In the mirror of any of the preceding twenty paragraphs, the mirror may be heat treated (e.g., thermally tempered).

[0043] In the mirror of any of the preceding twenty-one paragraphs, the fifth layer may be the outermost layer of the coating.

[0044] In the mirror of any of the preceding twenty-two paragraphs, the mirror may have neutral glass side and/or film side reflective color values a* and b*, each of the glass side and/or film side reflective a* and b* values being from about -2 to +2.

[0045] In example embodiments of this invention, there is provided a mirror including a substrate supporting a coating, the coating comprising moving away from the substrate: a first dielectric layer having a thickness of from about 70-140 nm and a refractive index (n) of from about 2.15 to 2.5; a second dielectric layer comprising silicon oxide; a third dielectric layer having a refractive index of from about 2.15 to 2.5; a fourth dielectric layer comprising silicon oxide; a fifth dielectric layer having a refractive index of from about 2.15 to 2.5; wherein the first dielectric layer is at least 10 nm thicker than one or both of the third dielectric layer and/or the fifth dielectric layer; wherein the coating does not contain any metallic reflective layer; and wherein the mirror has a visible film side reflectance and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

[0046] In the mirror of the immediately preceding paragraph, (i) at least one of the first, third and fifth dielectric layers may comprise or consist essentially of niobium oxide, and/or (ii) at least one of the first, third and fifth dielectric layers may comprise or consist essentially of titanium oxide.

[0047] In the mirror of any of the preceding two paragraphs, the first dielectric layer may be at least 10 nm thicker than both of the third and fifth dielectric layers.

[0048] In the mirror of any of the preceding three paragraphs, the coating may consist essentially of the first, second, third, fourth and fifth layers.

[0049] In the mirror of any of the preceding four paragraphs, the second and fourth dielectric layers comprising silicon oxide may each be: (i) thinner than the first dielectric layer, and (ii) thicker than both the third and fifth dielectric layers.

[0050] In the mirror of any of the preceding five paragraphs, the mirror may have an ultraviolet (UV) transmission at 385 nm of at least about 75%, more preferably of at least about 80% or 85%.

[0051] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A dielectric mirror including a glass substrate supporting a coating, the coating comprising moving away from the glass substrate:

a first transparent dielectric high refractive index layer comprising niobium oxide, the first transparent dielectric high refractive index layer having a thickness of from about 70-140 nm;

a second transparent dielectric low refractive index layer comprising silicon oxide, the second transparent dielectric low refractive index layer having a thickness of from about 30-140 nm;

a third transparent dielectric high refractive index layer comprising niobium oxide;

a fourth transparent dielectric low refractive index layer comprising silicon oxide;

a fifth transparent dielectric high index layer comprising niobium oxide;

wherein the first transparent dielectric high index layer comprising niobium oxide is at least 10 nm thicker than one or both of the third transparent dielectric high refractive index layer comprising niobium oxide and/or the fifth transparent dielectric high index layer comprising niobium oxide;

wherein the coating does not contain any metallic reflective layer; and

wherein the dielectric mirror has a visible film side reflectance and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

2. The mirror of claim 1, wherein the first transparent dielectric high index layer comprising niobium oxide is at least 10 nm thicker than both of the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high index layer comprising niobium oxide.

3. The mirror of any preceding claim, wherein the first transparent dielectric high index layer comprising niobium oxide is at least 25 nm thicker than one or both of the third transparent dielectric high refractive index layer comprising niobium oxide and/or the fifth transparent dielectric high index layer comprising niobium oxide.

4. The mirror of any preceding claim, wherein the first transparent dielectric high index layer comprising niobium oxide is at least 25 nm thicker than both of the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high index layer comprising niobium oxide.

5. The mirror of any preceding claim, wherein the dielectric mirror has a visible film side reflectance of from about 60-80% and a visible glass side reflectance of from about 60-80%.

6. The mirror of any preceding claim, wherein the dielectric mirror has a visible transmission of from about 25-35%.

7. The mirror of any preceding claim, wherein the third transparent dielectric high refractive index layer comprising niobium oxide is from about 30-80 nm thick.

8. The mirror of any preceding claim, wherein the fourth transparent dielectric low refractive index layer comprising silicon oxide is from about 40-120 nm thick.

9. The mirror of any preceding claim, wherein the fifth transparent dielectric high refractive index layer comprising niobium oxide is from about 30-80 nm thick.

10. The mirror of any preceding claim, wherein the coating consists essentially of the first, second, third, fourth and fifth layers.

11. The mirror of any preceding claim, wherein the first transparent dielectric high refractive index layer comprising niobium oxide directly contacts the glass substrate.

12. The mirror of any preceding claim, wherein the second transparent dielectric low refractive index layer comprising silicon oxide is located between and

directly contacting the first transparent dielectric high refractive index layer comprising niobium oxide and the third transparent dielectric high refractive index layer comprising niobium oxide.

13. The mirror of any preceding claim, wherein the fourth transparent dielectric low refractive index layer comprising silicon oxide is located between and directly contacting the third transparent dielectric high refractive index layer comprising niobium oxide and the fifth transparent dielectric high refractive index layer comprising niobium oxide.

14. The mirror of any preceding claim, wherein the first, second, third, fourth, and fifth layers are sputter-deposited layers.

15. The mirror of any preceding claim, wherein each of the second and fourth transparent dielectric low refractive index layers comprising silicon oxide are doped with aluminum.

16. The mirror of any preceding claim, wherein the first, third, and fifth transparent dielectric high refractive index layers comprising niobium oxide have a refractive index of from about 2.15 to 2.5.

17. The mirror of any preceding claim, wherein the first, third, and fifth transparent dielectric high refractive index layers comprising niobium oxide have a refractive index of from about 2.2 to 2.4.

18. The mirror of any preceding claim, wherein the second and fourth transparent dielectric low refractive index layers comprising silicon oxide have a refractive index of from about 1.4 to 1.7.

19. The mirror of any preceding claim, wherein the second and fourth transparent dielectric low refractive index layers comprising silicon oxide have a refractive index of from about 1.4 to 1.6.

20. The mirror of any preceding claim, wherein the second and fourth transparent dielectric low refractive index layers comprising silicon oxide are each: (i) thinner than the first transparent dielectric high refractive index layer comprising niobium oxide, and (ii) thicker than both the third and fifth transparent dielectric high refractive index layers comprising niobium oxide.

21. The mirror of any preceding claim, wherein the mirror has an ultraviolet (UV) transmission at 385 nm of at least about 75%.

22. The mirror of any preceding claim, wherein the mirror has an ultraviolet (UV) transmission at 385 nm of at least about 80%.

23. The mirror of any preceding claim, wherein the mirror is thermally tempered.

24. The mirror of any preceding claim, wherein the mirror has neutral glass side reflective color values a* and b*, each of the glass side reflective a* and b* values being from about -2 to +2.

25. The mirror of any preceding claim, wherein the mirror has neutral film side reflective color values a* and b*, each of the film side reflective a* and b* values being from about -2 to +2.

26. A mirror including a substrate supporting a coating, the coating comprising moving away from the substrate:

a first dielectric layer having a thickness of from about 70-140 nm and a refractive index (n) of from about 2.15 to 2.5;

a second dielectric layer comprising silicon oxide;

a third dielectric layer having a refractive index of from about 2.15 to 2.5;

a fourth dielectric layer comprising silicon oxide;

a fifth dielectric layer having a refractive index of from about 2.15 to 2.5;

wherein the first dielectric layer is at least 10 nm thicker than one or both of the third dielectric layer and/or the fifth dielectric layer;

wherein the coating does not contain any metallic reflective layer; and

wherein the mirror has a visible film side reflectance and/or a visible glass side reflectance of from about 50-90%, and visible transmission of from about 20-40%.

27. The mirror of claim 26, wherein at least one of the first, third and fifth dielectric layers comprises niobium oxide.

28. The mirror of any of claim 26, wherein at least one of the first, third and fifth dielectric layers comprises titanium oxide.

29. The mirror of any of claims 26-28, wherein the first dielectric layer is at least 10 nm thicker than both of the third and fifth dielectric layers.

30. The mirror of any of claims 26-29, wherein the coating consists essentially of the first, second, third, fourth and fifth layers.

31. The mirror of any of claims 26-30, wherein the second and fourth dielectric layers comprising silicon oxide are each: (i) thinner than the first dielectric layer, and (ii) thicker than both the third and fifth dielectric layers.

32. The mirror of any of claims 26-31, wherein the mirror has an ultraviolet (UV) transmission at 385 nm of at least about 75%.

33. The mirror of any of claims 26-32, wherein the mirror has neutral glass side and/or film side reflective color values a* and b*, each of the glass side and/or film side reflective a* and b* values being from about -2 to +2.

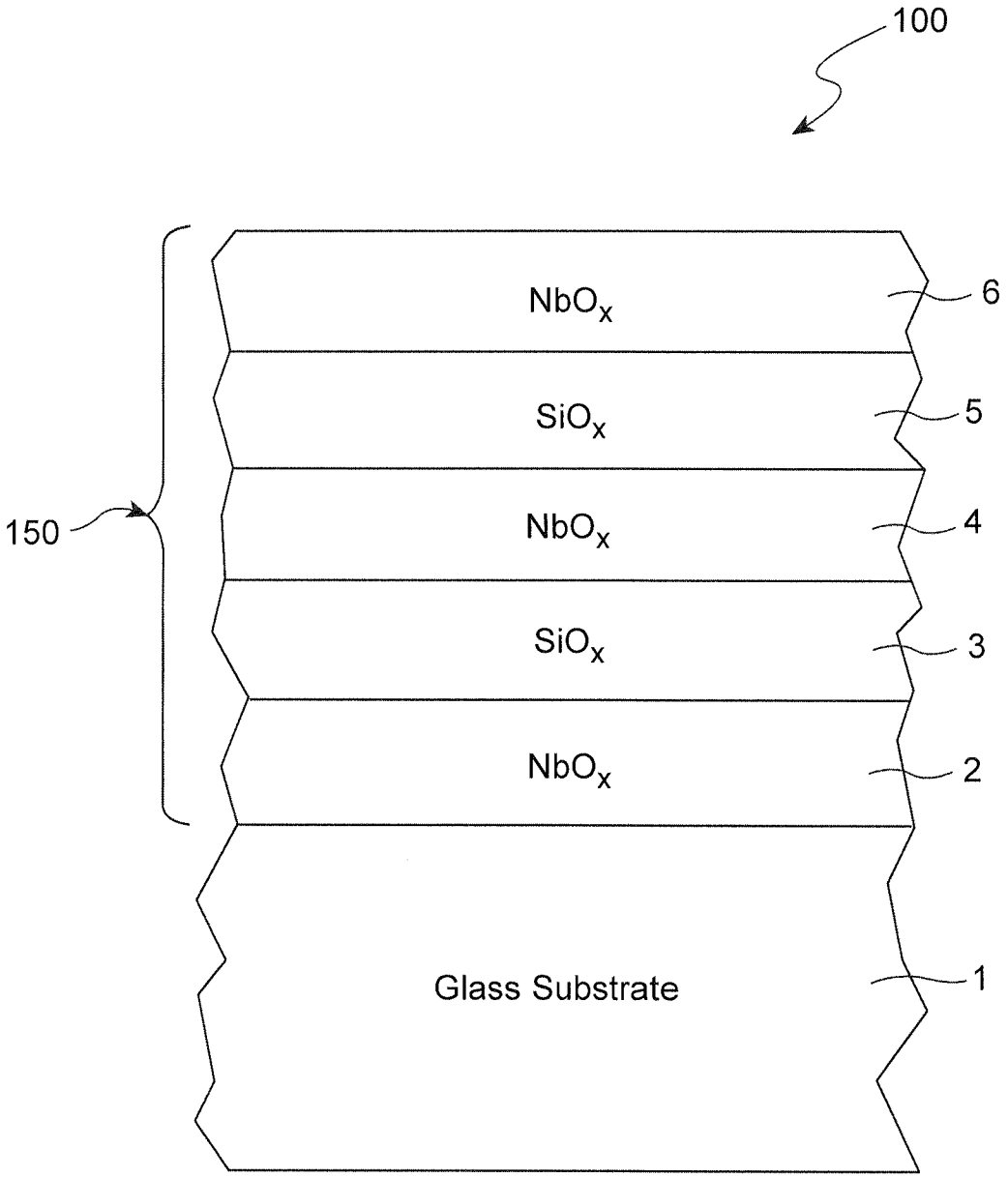

FIG. 1

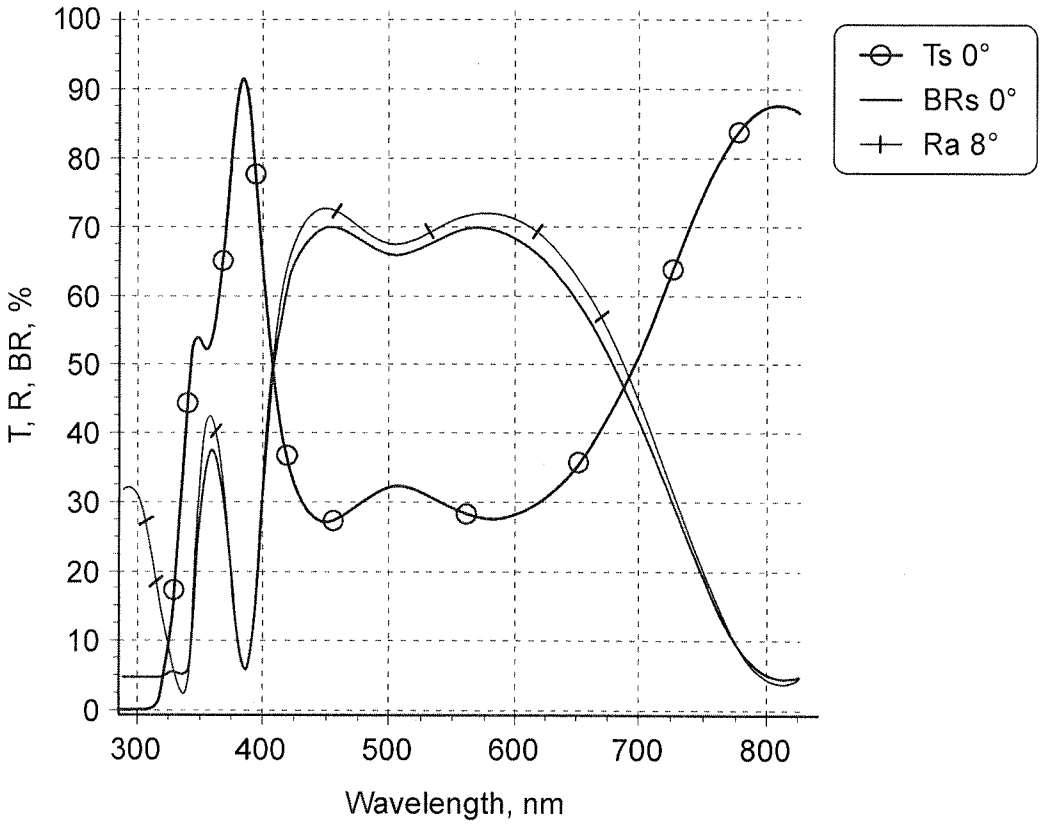
Ts 0°
BRs 0°
Ra 8°
T, R, BR, %
Wavelength, nm
100
90
80
70
60
50
40
30
20
10
0
300
400
500
600
700
800

FIG. 2

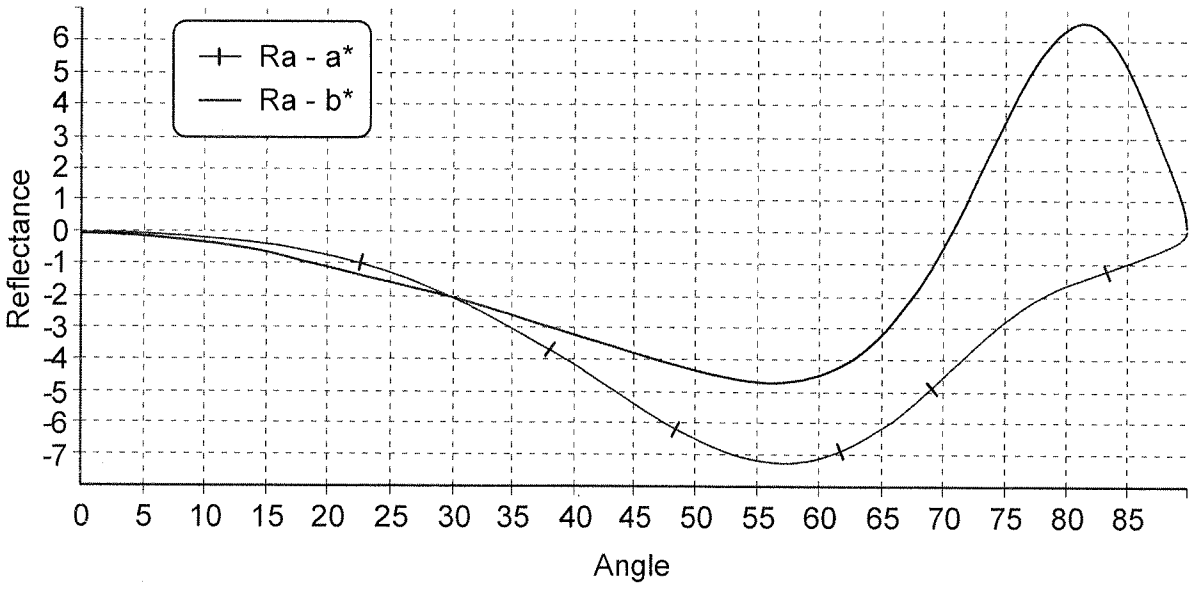
Ra - a*
Ra - b*
Reflectance
Angle
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/015290

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03C17/34 C03C17/36 G02B5/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C03C G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/146709 A1 (OHTA TATSUO [JP] ET AL) 7 August 2003 (2003-08-07) abstract paragraphs [0004] - [0011], [0054] - [0080] table 7 figure 1 -----	1-33
A	US 5 372 874 A (DICKEY ERIC R [US] ET AL) 13 December 1994 (1994-12-13) abstract column 4, line 25 - line 49 column 5, line 15 - column 6, line 18 ----- -/--	1-33

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2014	23/04/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Heer, Stephan

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/015290

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2002/001724 A1 (ANDERSON CHARLES-EDWARD [FR] ET AL) 3 January 2002 (2002-01-03) abstract paragraphs [0004] - [0007], [0013] - [0015] -----	1-33
A	US 2007/127126 A1 (TERADA YOSHIYUKI [JP]) 7 June 2007 (2007-06-07) abstract examples 2-2 table 7 figure 18 -----	1-33
A	EP 1 923 362 A1 (ASAHI GLASS CO LTD [JP]) 21 May 2008 (2008-05-21) abstract table 3 paragraphs [0115] - [0120] figures 4-11 -----	1-33
A	EP 1 942 356 A1 (CENTRAL GLASS CO LTD [JP]) 9 July 2008 (2008-07-09) abstract paragraphs [0015] - [0035] examples 1-12 -----	1-33

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/015290

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003146709 A1	07-08-2003	CN 1405580 A	26-03-2003
		EP 1286184 A2	26-02-2003
		KR 20030013317 A	14-02-2003
		TW 565709 B	11-12-2003
		US 2003146709 A1	07-08-2003
US 5372874 A	13-12-1994	AT 160107 T	15-11-1997
		CA 2067765 A1	01-03-1992
		DE 69128192 D1	18-12-1997
		DE 69128192 T2	28-05-1998
		EP 0498884 A1	19-08-1992
		JP H05502310 A	22-04-1993
		US 5372874 A	13-12-1994
		WO 9204185 A1	19-03-1992
US 2002001724 A1	03-01-2002	AT 192125 T	15-05-2000
		AT 258539 T	15-02-2004
		CA 2170192 A1	24-08-1996
		DE 69607878 D1	31-05-2000
		DE 69607878 T2	18-01-2001
		DE 69631439 D1	04-03-2004
		DE 69631439 T2	02-12-2004
		EP 0728712 A1	28-08-1996
		EP 0911302 A2	28-04-1999
		ES 2147903 T3	01-10-2000
		ES 2214759 T3	16-09-2004
		FI 960827 A	24-08-1996
		FR 2730990 A1	30-08-1996
		JP 4226666 B2	18-02-2009
		JP H08337441 A	24-12-1996
		JP 2009084143 A	23-04-2009
		US 5891556 A	06-04-1999
		US 6238781 B1	29-05-2001
		US 6337124 B1	08-01-2002
		US 2001002295 A1	31-05-2001
		US 2002001724 A1	03-01-2002
US 2007127126 A1	07-06-2007	CN 1979230 A	13-06-2007
		JP 2007183525 A	19-07-2007
		TW I404979 B	11-08-2013
		US 2007127126 A1	07-06-2007
		US 2010188737 A1	29-07-2010
EP 1923362 A1	21-05-2008	EP 1923362 A1	21-05-2008
		JP 5076897 B2	21-11-2012
		US 2008199670 A1	21-08-2008
		WO 2007020792 A1	22-02-2007
EP 1942356 A1	09-07-2008	EP 1942356 A1	09-07-2008
		TW I321552 B	11-03-2010
		US 2009237782 A1	24-09-2009
		WO 2007049478 A1	03-05-2007