

A GLASS STRUCTURE

TECHNICAL FIELD

This invention relates generally to a glass structure that is anti-reflective and a method for forming the glass structure.

Background

Existing glass structures which coats a glass substrate with, for example anti-reflective coatings, are difficult to produce in large format and sizes. Further, the nature of typical coatings on glass substrates are easily damaged and do not offer protection to outdoor environment and weathering. Further, these coatings may even be easily damaged during application thereof to the glass substrate and when subjected to chemical oxidation and reduction. Even when not exposed to the elements, the anti-reflective properties of existent glass structures leaves much to be desired, lacks good stability and have reflectance of beyond 5%. Further, the coatings used for working towards the anti-reflectivity also does not provide a natural neutral color. The materials used for the coatings are also harmful to the environment, expensive and is inefficient to apply and process. Therefore, there exists a need for an improved release method/mechanism for addressing the foregoing problems.

Summary

In accordance with a first aspect of the invention, there is disclosed a glass structure comprising a glass substrate, a first dielectric layer formed over the glass substrate and having a high refractive index, a second dielectric layer formed over the first dielectric layer and having a low refractive index, a third dielectric layer formed over the second dielectric layer and having a high refractive index such that the second dielectric layer interposes the first dielectric layer and the third dielectric layer, and a fourth dielectric layer formed over the third dielectric layer and having a low refractive index such that the third dielectric layer interposes the second dielectric layer and the fourth dielectric layer.

In accordance with a second aspect of the invention, there is disclosed a glass structure forming method comprising forming a first dielectric layer formed having a high refractive index over a glass substrate by magnetron sputtering, forming a second dielectric layer having a low refractive index over the first dielectric layer by magnetron sputtering, forming
5 a third dielectric layer having a high refractive index over the second dielectric layer by magnetron sputtering such that the second dielectric layer interposes the first dielectric layer and the third dielectric layer, and forming a fourth dielectric layer having a low refractive index over the third dielectric layer by magnetron sputtering such that the third dielectric layer interposes the second dielectric layer and the fourth dielectric layer.

10

Brief Description of the Drawings

FIG. 1 shows an exemplary partial sectional view of a glass structure in accordance with an
15 aspect of the invention with various layers being formed on a glass substrate and capped with a protective layer;

FIG. 2 shows an exemplary partial sectional view of the glass structure of FIG. 1 without the protective layer; and

20

FIG. 3 shows an exemplary process flow of a glass structure forming method in accordance with another aspect of the invention for forming the glass structure of FIG. 1.

Detailed Description

An exemplary embodiment of the present invention, a glass structure 20 and a glass structure forming method 100 is described hereinafter with reference to FIG. 1 and FIG. 3.

5

The glass structure 20 comprises a glass substrate 22, a first dielectric layer 24 formed over the glass substrate 22 in a step 210 and having a high refractive index, a second dielectric layer 26 formed over the first dielectric layer 24 in a step 212 and having a low refractive index, a third dielectric layer 28 formed over the second dielectric layer 26 in a step 214 and
10 having a high refractive index such that the second dielectric layer 26 interposes the first dielectric layer 24 and the third dielectric layer 28, and a fourth dielectric layer 30 formed over the third dielectric layer 28 in a step 216 such that the third dielectric layer interposes the second dielectric layer and the fourth dielectric layer. The fourth dielectric layer 30 is formed with a low refractive index.

15

In preparation for the step 210, the glass substrate 22 is first cleaned and dried before being placed a coating zone of a magnetron sputtering system. Through the use of an intermediate frequency AC power supply on a rotary cathode, the first dielectric layer 24 is formed on the glass substrate 22 in the step 210. Each of the second dielectric layer 26, the third dielectric
20 layer 28 and the fourth dielectric layer 30 is formed, or plated, one layer atop the other, also through the application of an intermediate frequency AC power supply on the rotary cathode in the coating zone via magnetron sputtering.

25

Preferably, each of the first dielectric layer 24 and the third dielectric layer 28 is being
25 formed from one of NbOx, for example NbO, NbO₂ or Nb₂O₅, ZrOx, for example ZrO or Zr₂O₃, and TiOx, for example, TiO or TiO₂. Each of the first dielectric layer 24 and the third dielectric layer 28 has a refractive index of between and including 2.0 and 2.3. The first dielectric layer 24 is formed with a thickness of between and including 5 nm and 100 nm. However, it is preferred that the thickness of the first dielectric layer 24 be from 8 nm
30 to 30 nm, and more preferably be from 10 nm and 20 nm. This enables the first dielectric layer 24 to function as a coupler between the glass substrate 22 and subsequent layers to be

formed thereonto. Further, the first dielectric layer 24 also functions substantially to adjust the colour reflective properties of the glass structure 20 and to function substantially as a barrier to block the diffusion of alkali metal ions in glass to the subsequent layers of the glass structure and to enhance firmness between the layers of the glass structure 20. The
 5 third dielectric layer 28 is formed with a thickness of between and including 50nm and 150nm. However, it is preferred that the thickness of the third dielectric layer 28 be from 80 nm to 140 nm, and more preferably from 100 to 113 nm. The third dielectric layer 28 functions to adjust optical interference and reflection color of the glass structure 20.

10 Preferably, each of the second dielectric layer 26 and the fourth dielectric layer 30 being formed from SiO₂. The second dielectric layer 26 has a thickness of between and including 10nm and 100nm. However, it is preferred that the thickness of the second dielectric layer 26 be from 20 nm to 40 nm, and more preferably from 25 nm to 37 nm. The second dielectric layer 26 functions to adjust the optical interference and appearance color of the
 15 glass structure 20.

The fourth dielectric layer 30 has a thickness of between and including 30nm and 100nm. However, it is preferred that the thickness of the fourth dielectric layer 30 be from 40 nm to 100 nm, and more preferably from 50 nm to 80 nm. The fourth dielectric layer 30 functions
 20 also to adjust the optical interference and colour appearance of the glass structure 20.

Preferably, the glass substrate 22 further comprises a protective layer 32 formed over the fourth dielectric layer 30 in a step 218. The protective layer 32 is preferably formed from at least one of TiO₂, ZrO₂, Si₃N₄ and SiC with a thickness of between and including 2nm to
 25 30nm, preferably by via magnetron sputtering over the fourth dielectric layer 30 in the coating zone. At least one of ZrO₂, Si₃N₄ and SiC or the like scratch resistant material is chosen for forming the protective layer 32 due to not only their scratch resistant property, but also due to their abrasion resistant and corrosion resistant properties as well. It is preferred that the thickness of the glass substrate be from 4 nm to 15 nm, and more
 30 preferably from 5 to 10 nm. The main function of the protective layer 32 enables the glass structure 20 to be used and exposed to outdoor environment, to prevent scratches and

chemical corrosion to the dielectric layers, and to the coating layer scratches, chemical corrosion and other defects, to maintain optical and aesthetic integrity of the glass structure 20 during transportation and installation thereof.

- 5 It is preferred that the third dielectric layer 28 is thicker than the first dielectric layer 24 and the fourth dielectric layer 30 is thicker than the second dielectric layer 26. Further preferably, each of the first dielectric layer 24, the second dielectric layer 26, the third dielectric layer 28 and the fourth dielectric layer 30 is at least one of formed by magnetron sputtering, formed from inorganic, and preferably non-metallic, material and is Au and Ag free. Preferably, the largest production planar dimensions that can be achievable by the glass substrate are 3300mm*6000mm.

In a first example of an aspect of the invention, a first high refractive index dielectric layer NbOx, for example NbO, NbO₂ or Nb₂O₅, forming the first dielectric layer 24 is plated to a thickness of 12nm on a 6 mm ultra-white glass substrate 22. Next, first low refractive index dielectric layer SiO₂ forming the second dielectric layer 26 is plated to a thickness of 35 nm on the first high refractive index dielectric layer. A second high refractive index dielectric layer NbOx, for example NbO, NbO₂ or Nb₂O₅, forming the third dielectric layer 28 is plated to a thickness of 113.5nm on the first low refractive index dielectric layer. Finally, a second low refractive index dielectric layer SiO₂ forming the fourth dielectric layer 30 is plated to a thickness of 70nm on the second high refractive index dielectric layer. A layer Si₃N₄ film forming the protective layer 32 with a thickness of 6nm is finally plated onto the second low refractive index dielectric layer. The above first example is preferably performed using the glass structure forming method 100. After completion of the glass structure forming method 100, the glass structure 20 obtained is an anti-reflective film glass structure with substantially reduced light reflectivity and improved transmittance as shown in the below table:

Project	Surface reflection				Transmittance			
Color space	Y%	L	a*	b*	Y%	L	a*	b*
Example 1	4.5	26.6	-0.4	-0.4	93.9	97.5	-0.2	0.3

In a second example of an aspect of the invention, a first high refractive index dielectric layer NbOx, for example NbO, NbO₂ or Nb₂O₅, forming the first dielectric layer 24 is plated to a thickness of 12nm on a 6 mm ultra-white glass substrate 22. Next, first low refractive index dielectric layer SiO₂ forming the second dielectric layer 24 is plated to a thickness of 35 nm on the first high refractive index dielectric layer. A second high refractive index dielectric layer NbOx, for example NbO, NbO₂ or Nb₂O₅ forming the third dielectric layer 28 is plated to a thickness of 113.5nm on the first low refractive index dielectric layer. Finally, a second low refractive index dielectric layer SiO₂ forming the fourth dielectric layer 30 is plated to a thickness of 65nm on the second high refractive index dielectric layer. A layer Si₃N₄ film forming the protective layer 32 with a thickness of 5nm is finally plated onto the second low refractive index dielectric layer. The above first example is preferably performed using the glass structure forming method 100. After completion of the glass structure forming method 100, the glass structure 20 obtained is an anti-reflective film glass structure with substantially reduced light reflectivity and improved transmittance as shown in the below table

Project	Surface reflection				Transmittance			
Color space	Y%	L	a*	b*	Y%	L	a*	b*
Example 2	4.78	26.1	-0.3	3.1	92.8	97.16	-9.4	0.6

The anti-reflective nature of the glass structure 20 according to an aspect of the invention as
aforescribed employs the glass structure forming method 100 for plating an antireflective
layers on a clean glass surface by magnetron sputtering. The anti-reflective layers comprise
a combination of high refractive index layers formed from NbOx, for example NbO, NbO₂
or Nb₂O₅, and low refractive index layers formed from SiO₂ and capped off with the
protective layer 32. The resultant glass structure 20 has a visible light reflectance of $\leq 5\%$,
and optically exhibiting natural colour rendering. The glass structure 20 has excellent
weatherability and can be used in outdoor or monolithic coated glass or as a glad on

structure on existent glass devices or panels which are being exposed to the outdoor environment. The glass structure forming method 100 also simplifies production preparation time, shortens production cycle and reducing cost while greatly improving production efficiency. The glass structure forming method 20 can enable the glass structure 20 to be used monolithically as well as forming part of other article and glass structures or interlayered with other glass products. The glass structure forming method 100 avoids organic chemical in the production process and materials used to thereby reduce pollutive impact on the environment. Further, the use of pure inorganic non-metallic materials enables a monolithic structure to be achieved for the glass structure 20 while improving weatherability thereof while enabling follow-up processing or deep-processing of the glass structure 20 subsequent to the glass structure forming method 100.

Aspects of particular embodiments of the present disclosure address at least one aspect, problem, limitation, and/or disadvantage associated with glass structure and method for forming thereof. While features, aspects, and/or advantages associated with certain embodiments have been described in the disclosure, other embodiments may also exhibit such features, aspects, and/or advantages, and not all embodiments need necessarily exhibit such features, aspects, and/or advantages to fall within the scope of the disclosure. It will be appreciated by a person of ordinary skill in the art that several of the above-disclosed structures, components, or alternatives thereof, can be desirably combined into alternative structures, components, and/or applications. In addition, various modifications, alterations, and/or improvements may be made to various embodiments that are disclosed by a person of ordinary skill in the art within the scope of the present disclosure, which is limited only by the following claims.

Claims

1. A glass structure comprising:
 - a glass substrate;
 - a first dielectric layer formed over the glass substrate and having a high refractive index;
 - a second dielectric layer formed over the first dielectric layer and having a low refractive index;
 - a third dielectric layer formed over the second dielectric layer and having a high refractive index such that the second dielectric layer interposes the first dielectric layer and the third dielectric layer; and
 - a fourth dielectric layer formed over the third dielectric layer and having a low refractive index such that the third dielectric layer interposes the second dielectric layer and the fourth dielectric layer.
2. The glass substrate as in claim 1, each of the first dielectric layer and the third dielectric layer being formed from one of NbO, NbO₂, Nb₂O₅, ZrO, Zr₂O₃, TiO and TiO₂, and having a refractive index of between and including 2.0 and 2.3.
3. The glass substrate as in claim 1, the first dielectric layer having a thickness of between and including 5 nm and 100nm and the third dielectric layer having a thickness of between and including 50nm and 150nm.
4. The glass substrate as in claim 1, each of the second dielectric layer and the fourth dielectric layer being formed from SiO₂.
5. The glass substrate as in claim 1, the second dielectric layer having a thickness of between and including 10nm and 100nm and the fourth dielectric layer having a thickness of between and including 30nm and 100nm.

6. The glass substrate as in claim 1, further comprising a protective layer formed over the fourth dielectric layer.
7. The glass substrate as in claim 6, the protective layer being formed from at least one of TiO₂, ZrO₂, Si₃N₄ and SiC.
8. The glass substrate as in claim 6, the protective layer having a thickness of between and including 2nm to 30nm.
9. The glass substrate as in claim 1, the third dielectric layer being thicker than the first dielectric layer and the fourth dielectric layer being thicker than the second dielectric layer.
10. The glass substrate as in claim 1, each of the first dielectric layer, the second dielectric layer, the third dielectric layer and the fourth dielectric layer being at least one of formed by magnetron sputtering, formed from inorganic non-metallic material and is Au and Ag free.
11. A glass structure forming method comprising:
 - forming a first dielectric layer formed having a high refractive index over a glass substrate by magnetron sputtering;
 - forming a second dielectric layer having a low refractive index over the first dielectric layer by magnetron sputtering;
 - forming a third dielectric layer having a high refractive index over the second dielectric layer by magnetron sputtering such that the second dielectric layer interposes the first dielectric layer and the third dielectric layer; and
 - forming a fourth dielectric layer having a low refractive index over the third dielectric layer by magnetron sputtering such that the third dielectric layer interposes the second dielectric layer and the fourth dielectric layer.

12. The method as in claim 11, each of the first dielectric layer and the third dielectric layer being formed from one of NbO, NbO₂, Nb₂O₅, ZrO, Zr₂O₃, TiO and TiO₂, and having a refractive index of between and including 2.0 and 2.3, wherein the first dielectric layer has a thickness of between and including 5 nm and 100nm and the third dielectric layer has a thickness of between and including 50nm and 150nm.
13. The method as in claim 11, each of the second dielectric layer and the fourth dielectric layer being formed from SiO₂, wherein the second dielectric layer has a thickness of between and including 10nm and 100nm and the fourth dielectric layer has a thickness of between and including 30nm and 100nm.
14. The method as in claim 11, further comprising:
forming a protective layer formed over the fourth dielectric layer by magnetron sputtering, the protective layer being formed from at least one of TiO₂, ZrO₂, Si₃N₄ and SiC, and having a thickness of between and including 2nm to 30nm.
15. The method as in claim 11, the third dielectric layer being thicker than the first dielectric layer and the fourth dielectric layer being thicker than the second dielectric layer, wherein each of the first dielectric layer, the second dielectric layer, the third dielectric layer and the fourth dielectric layer being at least one of formed from inorganic non-metallic material and is Au and Ag free.