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(54) Title: TRANSPARENT ARTICLE HAVING PROTECTIVE SILICON NITRIDE FILM

(57) Abstract

Transparent articles comprising transparent, nonmetallic substrate and a transparent film stack is sputter deposited on the substrate. The film stack is characterized by including at least one infrared reflective metal film, a dielectric film over the metal film, and a protective silicon nitride film of 10 Å to 150 Å in thickness over the said dielectric film. The dielectric film desirably has substantially the same index of refraction as does silicon nitride and is contiguous with the silicon nitride film.

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TRANSPARENT ARTICLE HAVING PROTECTIVE SILICON NITRIDE FILM

FIELD OF THE INVENTION

This invention is directed to transparent coatings for substrates and particularly to transparent coatings that are physically and chemically resistant.

BACKGROUND OF THE INVENTION

Glass and similar transparent substrates can be coated with transparent films to alter the optical properties of the glass. High visible transmittance, low emissivity coatings are characterized by their ability to transmit visible light while minimizing the transmittance of other wavelengths of light, particularly light in the infrared spectrum. This characteristic is useful for minimizing radiative heat transfer without impairing visibility, and coatings of this type find utility in architectural glass or automobile windows. It is often desired to maintain reflectance relatively consistent throughout the visible spectrum so that the coating has a "neutral" color; that is, colorless.

Generally speaking, coatings on glass that are provided for high transmittance and low emissivity comprise a stack of films having one or more thin metallic films with high infrared reflectance and low transmissivity that are disposed between antireflective dielectric layers that commonly are metal oxide films. The metal oxide layers serve to reduce visible reflection of the film stack to enhance transmittance, and are characterized by relatively high indices of refraction, commonly on the order of 1.9 or more.

Thin, transparent metal films of silver, copper and the like are susceptible to corrosion (e.g., staining) when they are brought into contact, under moist or wet conditions, with various staining agents such as atmosphere-carried chlorides, sulfides, sulfur dioxide and the like. Films of this type commonly are employed on inner surfaces of multi-pane glass units so that the films are maintained in a dry condition by desiccants or the like that remove moisture from the interpane spaces.

Staining can occur when coated panes of glass are stored for later fabrication into insulating glass units.

Film stacks frequently are isolated from contact with the environment, and a film stack of the type described may be positioned on one of the inner surfaces of a multipane insulating glass unit. However, when glass panes bearing coating stacks are transported or assembled into multipane units, they often are subjected to relatively harsh conditions which may cause physical marring of the film stacks.

Film stacks commonly are provided on glass sheets on a commercial production basis through the use of magnetron sputtering techniques such as those described in Chapin, U.S. patent 4,166,018.

Gillery, et al. U.S. patent 4,786,563 suggests the use of a thin overcoat of titanium dioxide as a protective layer. Titanium oxide overcoats may be particularly prone to scratching or abrasion during shipping and washing operations, however, rendering the glass panes commercially unsuitable for use. O'Shaughnessy, et al. U.S. patent 5,296,302 corrects the problem by providing a protective overcoat of an oxide such as zinc oxide, the latter being relatively very thin in comparison to other films in the stack, and protective overcoats of this type having thicknesses in the range of 10-40 Å are disclosed.

High transmittance, low emissivity film stacks of the type described in U.S. patent 5,296,302, despite their excellent resistance to scratching, nonetheless have experienced problems in connection with the tarnishing or other discoloration of the reflective metal layers, which commonly are silver. Moreover, since the sputter deposition of certain films such as titanium oxide proceeds more slowly than zinc oxide, for example, it would be desirable to avoid the presence of titanium oxide films of thicknesses greater than, for example, 30Å.

It would be desirable to provide such film stacks with protection not only against physical damage (e.g., scratching) but also against tarnishing or discoloration of the metal reflective layers employed in such film stacks.

SUMMARY OF THE INVENTION

We have found that application of a thin sputtered-on film of a compound of silicon and nitrogen such as silicon nitride as a protective film in a film stack provides the underlying metal (e.g., silver) metal film(s) with excellent resistance to

corrosion while at the same time providing the underlying stack with resistance to physical marring, all without substantial effect upon optical properties of the stack. Preferably, the film directly beneath the silicon nitride protective film is a dielectric film having an index of refraction substantially the same as that of silicon nitride, that is, about 2.0 ± 0.1. The film directly beneath the silicon nitride film may be of a metal oxide such as an oxide of zinc or tin or alloys thereof, these oxides having substantially the same index of refraction. In this manner, the optical properties of a given film stack may be adjusted by adjusting the thickness of the contiguous, combined zinc oxide/silicon nitride films. Desirably, the silicon nitride film is at least 10 Å thick, and is present at a thickness less than 150 Å, preferably not greater than 100 Å and most preferably not greater than about 50 Å. Although the film stack may have thin (usually not greater than about 20Å) sacrificial or shielding films of titanium compounds such as titanium oxide, the stack desirably is free of titanium-containing films having thicknesses greater than about 30Å.

In one embodiment, the invention comprises a transparent support such as glass having a transparent film stack sputter deposited upon it, the film stack comprising a reflective metal film, a dielectric film over the metal film, and a thin (10Å - 150Å) protective silicon nitride film over the dielectric film. In another embodiment, the invention relates to a transparent article having a pair of reflective metal films separated by a dielectric film, the film stack including an outer dielectric film and a thin protective film of silicon nitride over the outer dielectric film. Desirably, the dielectric film immediately beneath the protective silicon nitride film is a metal oxide film such as zinc oxide or tin oxide that has an index of refraction substantially the same as that of the silicon nitride so that the outer dielectric film and the silicon nitride film can be treated as a single film for adjusting optical properties of the stack.

DESCRIPTION OF THE DRAWING

Figure 1 is a schematic view of a substrate coated with a film stack of the invention according to one embodiment of the invention; and

Figure 2 is a schematic view of a substrate coated with a film stack according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to Figure 1, a transparent article 10 is shown as comprising a glass sheet 12 bearing a film stack 14. The film stack 14 may be manufactured by any convenient method, but magnetron sputtering techniques of the type described in U.S. patent 4,166,018, the teachings of which are incorporated herein by reference, are preferred. In this method, the glass sheet 12 is transported through a series of low pressure zones in which the various films which make up the film stack 14 are sequentially applied. Metallic films are sputtered from metallic sources or "targets". Metal oxide or metal nitride films may be formed by sputtering the metal in a reactive oxygen or nitrogen atmosphere, or by first sputtering the metal on a substrate to form a film and then subjecting the metal film to a reactive atmosphere of oxygen or nitrogen. If desired, two or more contiguous films of different metal oxides may be used instead of a single metal oxide film. Magnetron sputtering techniques are well known in the art and need not be described here in detail.

With reference to Figure 1, upon the surface 13 of the glass pane 12 is sputter deposited a first antireflective film 16 of sufficient thickness to reduce or eliminate any reflectance which may arise from the interface between the following metal film 18 and the glass substrate 12. Appropriate metal oxides for use in film 16 include zinc oxide, tin oxide, indium oxide, bismuth oxide, titanium oxide, hafnium oxide, and zirconium oxide, and combinations thereof, but in a particularly preferred embodiment, the inner metal oxide film 16 is formed of zinc oxide at a thickness in the range of 120-700 Å, and preferably in the range of 300-700 Å.

Following sputter deposition of the metal oxide film 16, a reflective metal film 18 such as silver, gold, copper or aluminum is sputter deposited, the metal preferably being silver deposited at a thickness in the range of about 70Å to about 150 Å with a thickness of about 110 Å being most preferred. The resulting metallic silver film, if not protected, will react with such reactive gasses as oxygen if not protected. Hence, directly upon the metal film 18 is sputter deposited a thin sacrificial metal film (referred to herein as a "shielding" film) such as titanium, the metal film 20 serving to shield and thus protect the underlying silver film 18 during the sputter deposition, in this example, of a following metal oxide film 22 and thus preventing the silver film from becoming oxidized. The resulting film 20 thus is formed directly by the

application of a thin film of titanium metal directly to the reflective silver film 18, followed by oxidation of the titanium film. When the overlying metal oxide film 22 is applied by sputtering a metal in a reactive oxygen atmosphere, the titanium metal film oxidizes to form a titanium oxide and thus serves to shield the underlying silver film. Applying a shielding titanium film at about 20 Å has been found to work well and, as mentioned, leads to the formation of a titanium oxide film 20.

In the embodiment depicted in Figure 1, the next film to be applied is a dielectric antireflective film that is desirably a metal oxide and most desirably has an index of refraction substantially identical to that of silicon nitride. The indices of refraction of silicon nitride and zinc oxide or tin oxide, for example, are substantially identical. The dielectric antireflective film 22 may have a thickness in the range of 150-350 Å.

Finally, over the antireflective dielectric film 22 is sputter deposited a thin film 24 of silicon nitride, the latter desirably being sputter deposited from a silicon target (suitably doped to render it conductive) in a nitrogen atmosphere. The thin silicon nitride film can be present in any thickness which does not unduly interfere with the optical properties of the sheet, and silicon nitride thicknesses in the range of about 10Å to about 150 Å are appropriate. It is generally desired that the silicon nitride film not be thicker than about 50Å.

If the silicon nitride film 24 and the underlying dielectric layer 22 have substantially the same index of refraction and are contiguous, then these two films can be treated as a single film 26 for the purpose of determining and adjusting the optical properties of the film stack 14. That is, the relative thicknesses of the films 22 and 24 in this instance will have little, if any, effect upon the optical properties of the film stack; rather, it is the thickness of these films combined that can be adjusted to provide the desired optical properties. The combined thickness of the films 22 and 24 in this instance desirably will be in the range of about 250 to about 400 Å. For film stacks having only a single reflective metal film such as the stack depicted in Figure 1, a combined thickness of films 22 and 24 of 300 - 350 Å is preferred, whereas for film stacks using two or more metal reflective layers such as the stack depicted in Figure 2, a combined thickness of films 22′ and 24′ of 275 - 325 Å is preferred.

Referring now to Figure 2, an embodiment similar to that of Figure 1 is shown except that the series of films 18, 20 and 22 are repeated, although not necessarily at the same thickness. Elements similar to those shown in Figure 1 are given the same numbers, primed.

In Figure 2, a transparent support 12′ such as glass is provided with a first dielectric antireflective film 16′ followed by an infrared reflective metal film 18′ such as silver. Atop the silver film is sputter deposited a thin titanium metal shielding film which is subsequently oxidized to titanium oxide, then the next antireflective dielectric film 28, in the form of, for example, zinc oxide is applied. Thereafter, a metal film 30 is applied that is similar to film 18′, followed by a titanium shielding film which is oxidized subsequently to titanium oxide and designated 32, followed by the dielectric antireflective film such as a zinc oxide film 22′. Over the dielectric film 22′ is placed a thin silicon nitride protective film designated 24′.

Although it is desired that the silicon nitride film 24, 24′ be the outermost or overcoat film of the film stack, it may on occasion be desirable to add a subsequent thin, highly scratch-resistant film 34 such as a film of zinc oxide as reported in U.S. patent 5,296,302, the teachings of which are incorporated herein by reference. The latter film 34 desirably is applied at a thickness in the range of about 10 to about 40 Å and does not significantly affect the optical properties of the remainder of the stack. The overcoat 34, although desirably of zinc oxide, may be formed of an oxide of a metal selected from the group consisting of tin, indium, bismuth and alloys thereof.

Film stacks of the type depicted in Figures 1 and 2 may be sputter deposited to form the sequential films of the type and thicknesses set out in the following Tables 1 and 2. Zinc oxide was sputter deposited from a zinc target in an atmosphere containing oxygen, and silicon nitride was sputter deposited from a doped silicon target in an atmosphere containing nitrogen. Of course, additional films such as titanium nitride, titanium, stainless steel and other metals, and oxides of metals can be employed as desired, but it is desired that the films listed in Tables 1 and 2 be contiguous to each other.

Table 1

Material	Thickness, Å
Glass	
Zinc Oxide	370
Silver	110
Titanium*	20
Zinc Oxide	225
Silicon Nitride	100

Table 2

Material	Thickness, Å
Glass	
Zinc Oxide	120
Silver	110
Titanium*	20
Zinc Oxide	600
Silver	110
Titanium*	20
Zinc Oxide	230
Silicon Nitride	100

*Shielding film that is subsequently converted to titanium oxide

Film stacks of the type described, utilizing a silicon nitride protective overcoat having a thickness in the range of about 10Å to about 150Å, have been demonstrated to show superior results in comparison to film stacks of the type depicted in U.S. patent 5,296,302 with respect to resistance to discoloring of the metal films. In one series of tests, glass sheets with the film stacks of approximately the same constitution as shown in Tables 1 and 2 were subjected to severe weatherability tests: Racks of the coated glass sheets separated by small polystyrene beads were placed in an enclosed space and subjected to cycles of high humidity and temperature (each period being 16 hours at 90°F and 60% relative humidity) and relatively low temperature and humidity (8 hours at 65 - 70°F, 30% relative humidity). After 21 days (21 cycles), the film stacks having the silicon nitride overcoat were visibly

unchanged, whereas the other film stacks exhibited commercially unacceptable spotting associated with damage to the silver layers.

While a preferred embodiment of the present invention has been described, it should be understood that various changes, adaptations and modifications may be made therein without departing from the spirit of the invention and the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A transparent article comprising a transparent, non-metallic substrate and a transparent film stack sputter deposited upon the substrate, said film stack comprising, in sequence, a metal film, a dielectric film, and a protective film of silicon nitride.

2. The transparent article of claim 1 wherein the dielectric film has an index of refraction essentially the same as that of silicon nitride.

3. The transparent article of claim 2 wherein the combined thickness of said dielectric film and the silicon nitride overcoat ranges from 250 to 400 Å.

4. The transparent article of claim 2 wherein said dielectric film and the silicon nitride film are contiguous.

5. The transparent article of any one of claims 1 through 4 wherein said dielectric film is zinc oxide.

6. The transparent article of claim 1 wherein the metal film is silver.

7. A transparent article comprising a transparent, non-metallic substrate and a transparent film stack sputter deposited upon the substrate, said film stack comprising, in sequence, a dielectric film contiguous to the transparent substrate, a metal film, a shielding film contiguous to the metal film, a metal oxide film, and a protective film of from 10Å to 150 Å of silicon nitride contiguous to said metal oxide film.

8. The transparent article of claim 7 wherein the metal film is silver.

9. The transparent article of claim 7 wherein the index of refraction of the metal oxide film is essentially the same as silicon nitride.

10. The transparent article of claim 7 wherein the shielding film and the metal oxide film are contiguous.

11. The transparent article of claim 10 wherein the metal oxide film is zinc oxide.

12. A transparent article comprising a transparent, non-metallic substrate and a transparent film stack sputter deposited upon the substrate, said film stack comprising, in sequence, a metal film, a first shielding film contiguous to the metal film, a metal oxide film, and a protective overcoat of silicon nitride contiguous to the

metal oxide film and having a thickness of from 10Å to 150Å, the indices of refraction of the metal oxide film and the overcoat film being substantially the same.

13. The transparent article of claim 12 wherein the combined thickness of the second metal oxide film and the silicon nitride overcoat ranges from 300 to 350 Å.

14. The transparent article of claim 12 wherein the combined thickness of the third metal oxide film and the silicon nitride overcoat ranges from 275 to 325 Å.

15. The transparent article of claim 14 wherein the metal oxide film is an oxide of zinc or tin oxide or an alloy thereof.

16. A transparent article comprising a transparent, non-metallic substrate and a transparent film stack sputter deposited upon the substrate, said film stack comprising, in sequence, a dielectric base film deposited on the transparent substrate, a metal film, an intermediate dielectric film, a second metal film, an outer dielectric film, and a protective overcoat of silicon nitride having a thickness of from 10Å to 150Å.

17. The transparent article of claim 16 wherein the outer dielectric film has an index of refraction essentially the same as silicon nitride.

18. The transparent article of claim 17 wherein the outer dielectric film is zinc oxide.

19. The transparent article of claim 17 wherein the combined thickness of the outer dielectric film and the silicon nitride overcoat ranges from 250 to 400 Å.

20. The transparent article of any one of claims 12 and 16 wherein the film stack is free of a titanium containing film having a thickness greater than about 30Å.

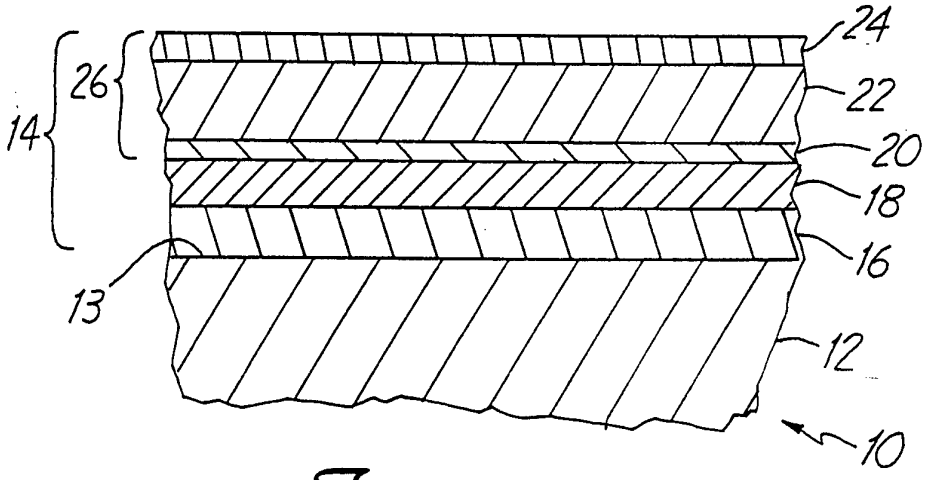


Fig. 1

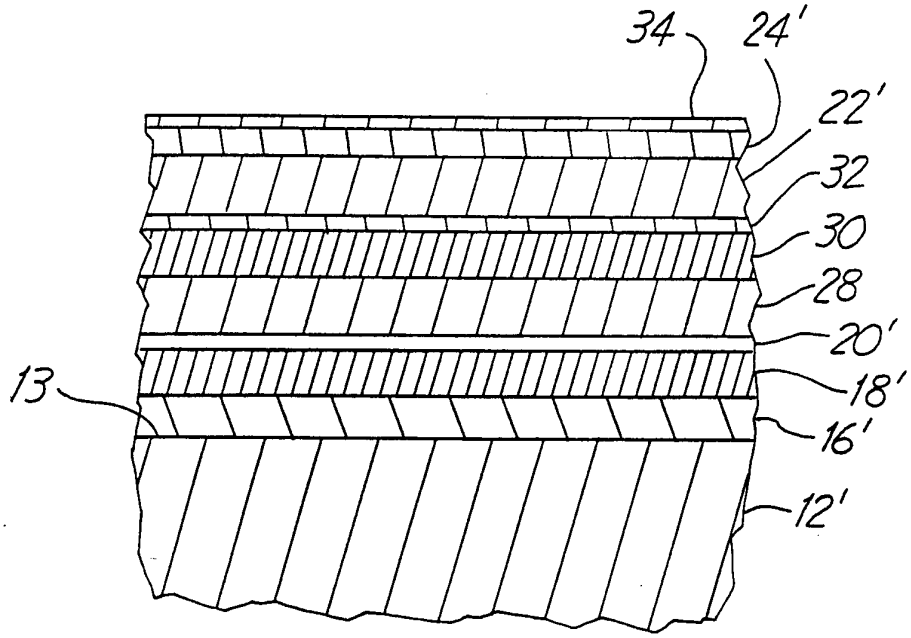


Fig. 2

INTERNATIONAL SEARCH REPORT

Intern. ..onal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C03C17/36 G02B1/10

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)
IPC 6 C03C

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,93 20256 (CARDINAL IG COMPANY) 14 October 1993 cited in the application see page 3, paragraph 3 - page 8, paragraph 3 ---	1-20
A	EP,A,0 456 488 (THE BOC GROUP, INC.) 13 November 1991 see page 3, line 50 - line 55 ---	1-4,7,9, 12-14, 16,17,19
A	DATABASE WPI Section Ch, Week 7220 15 May 1972 Derwent Publications Ltd., London, GB; Class L, AN 72-32369t & JP,A,47 016 315 (NIPPON SHEET GLASS CO LTD) see abstract --- -/--	1,7,12, 16

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[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
25 July 1995	22. 08. 95

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INTERNATIONAL SEARCH REPORT

Intern. nal Application No
PCT/US 95/05440

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern. ional Application No
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