TRANSPARENT CONDUCTIVE OXIDE HAVING AN EMBEDDED FILM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The invention relates to coated articles having a low emissivity and neutral color.

Description of Related Art

[0002] Transparent conductive oxides ("TCOs") are applied to the substrate to provide the coated article with lower emissivity and lower sheet resistance. This makes TCOs particularly useful in electrodes (for example solar cells) or heating layers, activing glazing units or screens. TCOs are usually applied by vacuum deposition techniques, such as magnetron sputtering vacuum deposition ("MSVD"). Generally a thicker TCO layer provides a lower sheet resistance. The thickness of the TCO, however, impacts the color of the coated article. Therefore, there is a need to adjust the coloring effect caused by TCO layers. There is also a need to minimize the thickness of a TCO layer so as to minimize the impact the TCO has on the color of the coated article while still maintaining the required sheet resistance.

[0003] Coating stacks may corrode over time. To protect from this, protective overcoats can be applied to coatings. For example, titanium dioxide films disclosed in U.S. Patent Numbers 4,716,086 and 4,786,563 are protective films that provide chemical resistance to a coating. Silicon oxide disclosed in Canadian Patent Number 2,156,571, aluminum oxide and silicon nitride disclosed in U.S. Patent Numbers. 5,425,861; 5,344,718; 5,376,455; 5,584,902 and 5,532,180; and in PCT International Patent Publication No. 95/29883 are also protective films that provide chemical resistance to a coating. This technology could be advanced by more chemically and/or mechanically durable protective overcoats.

SUMMARY

[0004] A coated article includes a substrate, an underlayer over the substrate. The underlayer includes a first layer. The first layer contains a high refractive index material. A second layer is positioned over at least a portion of the first layer. The second layer contains a low refractive index material. A transparent conductive film positioned over at least a portion of the underlayer. The coated article has a sheet resistance of at least 5 Ω/□ and at most 25 Ω/□. The coated article has a color with an a* of at least -9 and at most 1, a b* of at least -9 and at most 1.

[0005] Optionally, the coated article can have a protective layer over at least a portion of the transparent conductive oxide layer. The protective layer includes a first protective film over at least a portion of the transparent conductive oxide layer, and a

transparent conductive oxide is applied over at least a portion of the second underlayer film at the transparent conductive oxide film thickness.

[0008] A coated article including a substrate. An underlayer is positioned over at least a portion of the substrate. The underlayer includes at least a first underlayer film over at least a portion of the substrate, and an optional second underlayer film over at least a portion of the first underlayer film. The first underlayer film contains a first high refractive index material. The optional second underlayer film contains a first low refractive index layer. A transparent conductive oxide layer is positioned over at least a portion of the first or optional second underlayer film. A second high refractive index material is embedded within the transparent conductive oxide layer. The coated article has a sheet resistances of at least 5 Ω/□ and at most 25 Ω/□. The sheet resistance is at least 35% higher than without the second high refractive index material embedded within the transparent conductive oxide layer.

[0008a] In one aspect, the present disclosure relates to a coated article comprising

a substrate,

an underlayer over at least a portion of the substrate, the underlayer comprising

a first underlayer film wherein the first underlayer film comprises a first high refractive index material, and

a second underlayer film over at least a portion of the first underlayer film wherein the second underlayer film comprises a low refractive index material, and wherein the first high refractive index material has a refractive index greater than the first low refractive index material,

a transparent conductive oxide layer over at least a portion of the underlayer and

an embedded film embedded within the transparent conductive oxide layer wherein the embedded film comprises a second high refractive index material, and wherein the second high refractive index material has a refractive index greater than the first low refractive index material.

[0009] Optionally, the coated article can have a protective layer over at least a portion of the transparent conductive oxide layer. The protective layer includes a first protective film over at least a portion of the transparent conductive oxide layer, and a second protective film over at least a portion of the first protective film. The second protective film is the outer-most film in the coating stack, and includes a mixture of titania and alumina. Optionally, the protective layer can include a third protective film positioned between the first protective film and a second protective film.

[0010] A coated article including a substrate. An underlayer is positioned over at least a portion of the substrate. The underlayer includes at least a first underlayer film over at least a portion of the substrate, and an optional second underlayer film over at least a portion of the first underlayer film. The first underlayer film contains a first high refractive index material. The optional second underlayer film contains a first low refractive index layer. A first transparent conductive oxide layer is positioned over at least a portion of the first or optional second underlayer film. An embedded film is positioned over at least a portion of the first transparent conductive oxide layer. The embedded film has a second high refractive index material. A second transparent conductive oxide layer is positioned over at least a portion of the second transparent conductive oxide layer. The coated article has a sheet resistances of at least 5 Ω/□ and at most 25 Ω/□. The sheet resistance is at least 35% higher than without the embedded film.

[0010a] In another aspect, the present disclosure relates to a coated article comprising

a substrate;

an underlayer over at least a portion of the substrate, wherein the underlayer comprises a first underlayer film and a second underlayer film over at least a portion of the first underlayer film, wherein the first underlayer film comprises a first high refractive index material, wherein said second underlayer film comprises a first low refractive index material, wherein the first high refractive index material has a refractive index greater than the first low refractive index material;

a first transparent conductive oxide layer over at least a portion of the underlayer,

an embedded film over at least a portion of the first transparent conductive oxide layer, wherein the embedded film comprises a second high refractive index material, and wherein the second high refractive index material has a refractive index greater than the first low refractive index material; and

a second transparent conductive oxide layer over at least a portion of the embedded film.

[0011] Optionally, the coated article can have a protective layer over at least a portion of the transparent conductive oxide layer. The protective layer includes a first protective film over at least a portion of the transparent conductive oxide layer, and a

is applied over at least a portion of the substrate in an atmosphere that comprises between 0 % and 2.0 % oxygen.

[0018a] In another aspect, the present disclosure relates to a method of reducing the sheet resistance of a coated article comprising

(a) applying a first underlayer film over at least a portion of a substrate, wherein the first underlayer film comprises a first high refractive index material;

(b) applying a second underlayer film over at least a portion of the first underlayer film, wherein the second underlayer film comprises a first low refractive index material;

(c) applying a first transparent conductive oxide layer over at least a portion of the second underlayer film;

(d) applying an embedded film over at least a portion of the first transparent conductive oxide layer, wherein the embedded film comprises a second high refractive index material, and wherein the second high refractive index material has a refractive index greater than the first low refractive index material; and

applying a second transparent conductive oxide layer over at least a portion of the embedded film.

[0019] A coated article having reduced absorption, resistance or emissivity comprising a transparent conductive oxide layer made by the following steps. A substrate is provided. A transparent conductive oxide layer is applied over at least a portion of the substrate in an atmosphere that comprises between 0 % and 2.0 % oxygen.

BRIEF DESCRIPTION OF THE DRAWING(S)

[0020] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0021] Figs. 1a, 1b, 1c and 1d are side views (not to scale) of coatings incorporating a feature of the invention;

[0022] Figs. 2a, 2b, 2c, 2d and 2e are side views of other coatings (not to scale) incorporating a feature of the invention;

[0023] Figs. 3a, 3b, 3c, 3d, 3e are side views of other coatings (not to scale) incorporating a feature of the invention;

[0024] Figs. 4a and 4b are side views of other coatings (not to scale) incorporating a feature of the invention;

[0025] Figs. 5a and 5b are side views of other coatings (not to scale) incorporating a feature of the invention;

[0026] Figs. 6a, 6b, 6c, 6d, 6e, 6f, 6g, and 6h are side views of other coatings (not to scale) incorporating a feature of the invention;

[0027] Fig. 7 is a graph showing the sheet resistance of ITO versus thickness for samples that had the surface of the ITO transparent conductive oxide layer heated to specified temperatures.

[0028] Figs. 8a-c are XRD graphs showing the crystallization of tin-doped indium oxide transparent conductive oxide layers.

[0029] Fig. 9 shows the sheet resistance of a gallium-doped zinc oxide transparent conductive oxide layer as deposited and have being heated.

[0030] Fig. 10 shows the sheet resistance of aluminum-doped zinc oxide transparent conductive oxide layer as deposited and have being heated.

[0031] Fig. 11 is a graph showing the effect of the underlayer on the color of a substrate having a 170 nm thick tin-doped indium oxide transparent conductive oxide layer.