

BIRD FRIENDLY APPARATUS WITH UV SPECTRAL PATTERNS

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PRIORITY

This patent application claims priority from provisional United States patent application number 63/610,952, filed December 15, 2023, entitled, "Bird Friendly Interlayer Film for Laminated Glass with UVA Spectral Patterns," and naming Douglas H. Axtell, Jason U. Wallace, Nicolas C. Davy, and Adrian Winoto as inventors, the disclosure of which is incorporated
10 herein, in its entirety, by reference.

BACKGROUND

Windows pose a significant hazard to birds, primarily because of their
15 reflective and transparent properties. Birds often cannot perceive clear glass as a barrier, leading them to fly into it. Reflections of the surrounding environment, such as trees, sky, or vegetation, create the illusion of an open pathway. Additionally, interior spaces visible through glass, such as plants or lighted areas, can attract birds, further increasing the risk of collisions. These
20 impacts frequently result in serious injury or death for the birds.

The problem is exacerbated during migration seasons when large numbers of birds travel through urban and suburban areas. Buildings with extensive glass façades, particularly those with large windows or reflective coatings, are especially hazardous. Research indicates that millions of birds
25 die annually in collisions with windows, making it a significant cause of bird mortality.

SUMMARY OF VARIOUS EMBODIMENTS

In accordance with one embodiment of the invention, a bird-friendly
30 interlayer includes a clear flexible substrate having a first surface and a

second surface. The bird-friendly interlayer also includes an ultraviolet absorbing material on the first surface of the substrate. The ultraviolet absorbing material is configured to produce one or more spectral patterns under ultraviolet illumination. The clear, flexible substrate is configured to
5 about a first substantially flat glass pane on the first surface and a second substantially flat glass pane on the second surface. The ultraviolet absorbing material may include a luminophore.

The ultraviolet absorbing material may include a first material of a contiguous ultraviolet absorbing coating having a first absorbance spectrum
10 covering a first surface of the substrate.

The ultraviolet absorbing material may include a second material having a second absorbance spectrum applied to the first material. The second material may have a pattern of ultraviolet absorbing features. The pattern of ultraviolet absorbing features and the contiguous ultraviolet
15 absorbing material may provide the one or more spectral patterns of ultraviolet wavelength contrast.

The substrate may be impregnated with an ultraviolet absorbing dye having a first absorbance spectrum throughout its bulk uniformly and contiguously. The ultraviolet absorbing material may include a first material
20 of a contiguous ultraviolet absorbing coating having a first absorbance spectrum covering a first surface of substrate. The ultraviolet absorbing material may also include a pattern of ultraviolet absorbing features having a second absorbance spectrum deposited on the ultraviolet absorbing material. The pattern of ultraviolet absorbing features and the contiguous ultraviolet
25 absorbing coating may provide the one or more spectral patterns of ultraviolet wavelength contrast.

The one or more ultraviolet absorbing coatings may include a luminophore. The ultraviolet absorbing dye and the ultraviolet absorbing coating may include luminophores.

The pattern of ultraviolet absorbing features and the contiguous ultraviolet absorbing coating may be deposited by a gravure cylinder.

The clear flexible substrate may include a first ultraviolet absorbing coating having a first ultraviolet absorption spectrum on the first surface. The clear flexible substrate may further include a second ultraviolet absorbing coating with a second ultraviolet absorption spectrum on a second surface. The second surface may be opposite the first surface. One or both of the first ultraviolet absorbing coatings or the second ultraviolet absorbing film may have a pattern.

10 In accordance with another embodiment of the invention, a bird friendly apparatus includes an outside layer having first outer surface and a first inner surface, an inside layer having a second inner surface and a second outer surface, and a clear flexible substrate having a first surface and a second surface. The first surface is coupled to the first inner surface of the outside layer, the second surface is coupled to the second inner surface of the inside layer, and the clear flexible substrate includes one or more ultraviolet absorbing coatings that produce spectral patterns under ultraviolet illumination.

20 The one or more ultraviolet absorbing coatings comprise a luminophore.

The one or more ultraviolet absorbing coatings may include a first material of a contiguous ultraviolet absorbing coating having a first absorbance spectrum covering a first surface of the substrate, and may include a second material having a second absorbance spectrum applied to the first material. The second material may have a pattern of ultraviolet absorbing features. The pattern of ultraviolet absorbing features and the contiguous ultraviolet absorbing material may provide the one or more spectral patterns of ultraviolet wavelength contrast.

The substrate may be impregnated with an ultraviolet absorbing dye having a first absorbance spectrum throughout its bulk uniformly and contiguously. The ultraviolet absorbing material may include a first material of a contiguous ultraviolet absorbing coating having a first absorbance
5 spectrum covering a first surface of substrate. A pattern of ultraviolet absorbing features may have a second absorbance spectrum deposited on the ultraviolet absorbing material. The pattern of ultraviolet absorbing features and the contiguous ultraviolet absorbing coating may provide the one or more spectral patterns of ultraviolet wavelength contrast.

10 The one or more ultraviolet absorbing coatings may include a luminophore. The ultraviolet absorbing dye and the ultraviolet absorbing coating may include luminophores.

The clear flexible substrate may include a first ultraviolet absorbing coating having a first ultraviolet absorption spectrum on the first surface, and
15 may include a second ultraviolet absorbing coating with a second ultraviolet absorption spectrum on a second surface. The second surface being may be opposite the first surface. One or both of the first ultraviolet absorbing coatings or the second ultraviolet absorbing film may have a pattern.

The ultraviolet absorbing coatings may include a luminophore which
20 emits light that is waveguided to the edges of the apparatus. The edges of the apparatus may be fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator.

The ultraviolet absorbing dye and coating comprise luminophores which emit light that may be waveguided to the edges of the apparatus. The
25 edges of the apparatus may be fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator.

The outside layer may be a submillimeter thick piece of glass ranging in thickness from 30 microns to 20 millimeters. The spectral patterns under

ultraviolet illumination may be on the first surface of the clear flexible substrate to be as close as possible to the outside surface of the apparatus.

In accordance with another embodiment of the invention, a bird-friendly integrated glass unit includes an outer pane of laminated glass that includes an outside layer having first outer surface and a first inner surface, an inside layer having a second inner surface and a second outer surface, and a clear flexible substrate having a first surface and a second surface. The first surface is coupled to the first inner surface of the outside layer, the second surface is coupled to the second inner surface of the inside layer, the clear flexible substrate includes one or more ultraviolet absorbing coatings that produce spectral patterns under ultraviolet illumination. The bird-friendly integrated glass unit also includes a gap filled with vacuum, air, or inert gas, and an inner pane of glass. The outer pane of glass and the inner pane of glass are secured together in an air-tight manner.

In accordance with another embodiment of the invention, a bird-friendly integrated glass unit includes an outer pane of laminated glass that includes an outside layer having first outer surface and a first inner surface, an inside layer having a second inner surface and a second outer surface, and a clear flexible substrate having a first surface and a second surface. The first surface is coupled to the first inner surface of the outside layer, the second surface is coupled to the second inner surface of the inside layer, and the clear flexible substrate includes a film of an ultraviolet absorbing dye and a film comprising luminophores which emit light that is waveguided to edges of the laminated glass. The films of the ultraviolet absorbing dye and the coating are configured to provide bird-friendly patterns.

The edges of the laminated glass are fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator. The bird-friendly integrated glass unit also includes an inner pane of glass, and a gap between the outer pane of laminated glass and the inner pane of

glass. The bird-friendly integrated glass unit also includes electrical contacts to harvest the electrical power generated from the laminated glass that incorporates bird-friendly patterns and functions as a luminescent solar concentrator. The gap is evacuated or filled with air, or inert gas, and the
5 outer pane of laminated glass and the inner pane of gas are secured to each other in an air-tight manner.

The outside layer may be a submillimeter thick piece of glass ranging in thickness from 30 microns to 10 millimeter. The inner pane of glass is secured to the outer pane of laminated glass in an air-tight manner.

10 In accordance with yet another embodiment of the invention, a method to make a bird-friendly integrated glass unit includes applying a first ultraviolet (UV) material to a first side of a clear flexible substrate to form a first side of an interlayer. The UV material is a UV radiation absorber.

The method also includes adhering the first side of the interlayer to an
15 inner surface of a first outside layer. The first outside layer has an outer surface opposite the inner surface.

The method also includes adhering a second side of the interlayer to an inner surface of an inside layer, the second surface of the inside layer being opposite the first surface.

20 The interlayer is sandwiched between the outside layer and inside layer to form an integrated glass unit.

The first ultraviolet (UV) material may be a luminophore.

The method may further include applying a second UV material to the first UV layer. The second UV material may include a pattern of shapes
25 comprising at least one of bird silhouettes, logos, stripes, grids, crosshatches, squares, dots, or other shapes.

At least one of the first UV material or the second UV material may be applied a film. The at least one of the first UV material or the second UV material applied as thin films may be applied by a gravure printing process.

The outside layer and the inside layer may include a glass material. The method may further include securing an inner pane of glass to the outer surface of the inside layer of the integrated glass unit in an air-tight manner.

In accordance with yet another embodiment of the invention, a method
5 to make a bird-friendly apparatus includes applying a first ultraviolet (UV) material to a first side of a clear flexible substrate to form a first side of an interlayer, the first UV material being a UV radiation absorber, and applying a second ultraviolet (UV) material to a second side of the clear flexible substrate to form a second side of the interlayer, the second UV material
10 being a UV radiation absorber. The interlayer has the first ultraviolet (UV) material on the first side and the second ultraviolet (UV) material on the second side of the interlayer.

A third ultraviolet (UV) material may be applied to the first ultraviolet (UV) material or the second ultraviolet (UV) material. The method may
15 further include adhering the first side of the interlayer to an inner surface of an outside layer. The outside layer may have an outer surface opposite the inner surface.

The method may further include adhering the second side of the interlayer to an inner surface of an inside layer. The inside layer may have an
20 outer surface opposite the inner surface. The interlayer may be sandwiched between the outside layer and inside layer in an air-tight manner to form an integrated glass unit.

The clear flexible substrate may include a film of polyvinyl butyral (PVB), thermoplastic polyurethane (TPU), or ethylene vinyl acetate (EVA).
25 The clear flexible substrate may include a film of polyethylene, polypropylene, or polyester.

BRIEF DESCRIPTION OF THE DRAWINGS

Those skilled in the art should more fully appreciate advantages of various embodiments of the invention from the following “Description of Illustrative Embodiments,” discussed with reference to the drawings
5 summarized immediately below.

FIG. 1A schematically illustrates an exploded view of laminated glass showing the various layers involved in the formation in accordance with illustrative embodiments.

FIG. 1B schematically illustrates an example of a laminated glass
10 having two UV materials with each UV material having different wavelengths in accordance with illustrative embodiments.

FIG. 1C illustrates a portion of a roll coating process in accordance with illustrative embodiments.

FIG. 2 shows human color sensitivity to illustrate how a 80nm change
15 in absorption would be perceived in accordance with illustrative embodiments.

FIG. 3A shows the absorption spectra of two different dyes in accordance with illustrative embodiments.

FIG. 3B shows a combined absorption of two different in accordance
20 with illustrative embodiments.

FIG. 4A shows a pairing of absorption spectra of two UV-absorbing materials with high visible transparency (no absorption longer than 420 nm) in accordance with illustrative embodiments.

FIG. 4B shows another pairing of absorption spectra of two UV-
25 absorbing materials with high visible transparency (no absorption longer than 420 nm) in accordance with illustrative embodiments.

FIG. 4C schematically illustrates the effect of overlapping two filters comprising different materials in accordance with illustrative embodiments.

FIG. 5A shows a two dye system with significantly different peak absorptions in accordance with illustrative embodiments.

FIG. 5B shows a three dye system which could provide 3-D shading and color in accordance with illustrative embodiments.

5 FIG. 6A shows a 3-D drawing without shading in accordance with illustrative embodiments.

FIG. 6B shows how shading with two different colors can more readily portray 3-D shapes in accordance with illustrative embodiments.

10 FIG. 7A schematically shows a cross-section view of laminated glass using a bird-friendly interlayer in accordance with illustrative embodiments.

FIG. 7B schematically shows a view of a bird-friendly coating on an interlayer in accordance with illustrative embodiments.

FIG. 7C schematically shows a top view of various different patterns that can be made as examples in accordance with illustrative embodiments.

15 FIG. 7D schematically shows a cross-section view of laminated glass using another embodiment of a bird-friendly interlayer in accordance with illustrative embodiments.

20 FIG. 7E schematically shows a top view of various different patterns that can be made as embodiments of this disclosure in accordance with illustrative embodiments.

FIG. 7F schematically shows a cross-section view of laminated glass using another embodiment of a bird-friendly interlayer in accordance with illustrative embodiments.

25 FIG. 7G schematically shows a cross-section view of laminated glass using another embodiment of a bird-friendly interlayer in accordance with illustrative embodiments.

FIG. 8 schematically shows an embodiment of a transparent luminescent solar concentrator in accordance with illustrative embodiments.

FIG. 9 shows an embodiment of a method to make a bird-friendly integrated glass unit in accordance with illustrative embodiments.

FIG. 10 shows another embodiment of a method to make a bird-friendly integrated glass unit in accordance with illustrative embodiments.

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DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In illustrative embodiments, glass in a window or a glass railing is configured to reduce the likelihood that a bird will fly into it. To that end, the glass preferably is a layered structure with an outside layer, an inside layer, and an interlayer between the inside and outside layers. Specifically, the interlayer may be adhered to the inner surface of the outside layer, and to the inner surface of the inside layer. To protect birds, the interlayer includes one or more ultraviolet absorbing coatings that produce spectral patterns under ultraviolet light (e.g., radiation) illumination. Among other things, the ultraviolet absorbing coating(s) may include a luminophore. Details of illustrative embodiments are discussed below.

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Bird-Friendly Glass

“Bird-friendly,” “Bird-safe,” and “Bird-strike” are all terms for the same goal to make glass specially designed to make the glass a visible obstacle to birds. That is, bird-safe glass should not be colorless, featureless, or fully transparent to birds. Ideally, the objective is to make glass visible to birds while still keeping it transparent enough for humans, such that as a human looks at the bird-friendly glass, it appears transparent and colorless, or nearly colorless, while a bird may see a colored, hazy, opaque. and/or patterned obstacle. Despite these requirements, birds still may fly into Bird-friendly glass. Accordingly, these terms are used to denote glass that should

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have significantly fewer bird strikes than glass without the features making the glass more visible birds.

Some embodiments of bird-friendly glass utilize ultraviolet (e.g., UV) absorbers, luminophores, or both, which absorb light in the UVA portion of the spectrum (300 nm to 450 nm) not visible to humans but is visible to birds. In fact, birds can see light in the UVA and near UV spectrum. This total wavelength of UV radiation is generally described as being in the range of 100–450 nm, and is further subdivided into bands with decreasingly shorter wavelengths (e.g., higher energies). These UV bands include UVA (300–450 nm), UVB (280–300 nm), and UVC (100–280 nm). The inventors recognized the bird strike problem and also that many birds perceive UVA wavelengths that are invisible to humans. Using these findings, the inventors sought to design panes of laminated glass (glass or other material used in windows, such as a polymer or composite). The design of various embodiments may be referred to here as “Integrated Glass Units,” or IGUs for short. IGUs, also called IGU stacks, preferably have UVA coatings that birds can see and are invisible to humans. That is, illustrative windows (e.g., laminated glass, an apparatus, or IGUs) provide visual information to birds that prevents them from colliding with the windows, while at the same time does not add features to the glass that are objectionable to humans (and ideally may not even be noticeable by humans).

Preferred embodiments provide visible spectral patterns that are seen and perceived as an obstacle to birds while being substantially invisible to humans. The patterns can appear “substantially” invisible to the human eye because it is engineered to blend seamlessly with the glass by manipulating light. However, one may look closely (e.g., under certain lighting conditions) and might notice faint differences, such as a subtle hue, sheen, or slight texture. These variations are often minimal and designed to be effectively or

nearly imperceptible in typical viewing conditions, making the coating nearly indistinguishable from the glass itself.

Photovoltaic Power from Bird-Friendly Glass

5 Additionally, in some embodiments, the bird-friendly product in a laminated glass or IGU stack may also be used to generate photovoltaic power. The ultraviolet absorbers may also be luminophores, which absorb light in the UVA portion of the spectrum while also emitting light to be waveguided to the edges of the window. This arrangement allows the
10 laminated glass or IGU stack to generate photovoltaic power while still simultaneously being bird-friendly. Accordingly, illustrative embodiments may serve dual purposes as a bird-friendly glass and as a luminescent solar concentrator (LSC) to generate photovoltaic power.

 Furthermore, as noted above, absorbers in the pattern may also absorb
15 some amount of visible light to augment its appearance as an obstacle to birds, while being minimal enough in coverage, feature size, and/or optical density in the visible portion of the spectrum to not be objectionable to humans. This incorporation of some visible absorbers may also include luminophores to allow simultaneous generation of photovoltaic power in the
20 laminated glass or IGU stack.

 Thus, in some embodiments, the interlayer material may include a first UV material that includes a layer of a luminophore material film absorbing a first UV wavelength and emitting (e.g., radiating) radiation of a first emitted wavelength. The same interlayer material may include a second luminophore
25 absorbing a second UV wavelength and emitting a second emitted wavelength. The second luminophore material may be discontinuous (i.e., non-continuous) with or on the first luminophore material with the second wavelength material arranged as a patterned, semi-patterned, or random discontinuous layer. The discontinuous second luminophore material may be

applied, deposited, bonded, adhered, or the like, to the first luminophore material in predetermined shapes or in patterns. Alternatively, the second luminophore material may be continuous with or on the first luminophore material

5 A variety of approaches, such as fritting, engraving, silk-screening, gravure printing, or the like, may be incorporated to deposit thin reflective polymer 'sequins', or other shapes to create a pattern that breaks up the reflectivity of the glass and alerts birds to its presence.. For spacing, alternative methods may follow the "2x4 rule" or 2"x2" rule, and this design
10 rule forms effective designs. Designs that include silk, engraving, coating, fritting, or markings are added across the pane (e.g. first or second layer), spaced two inches apart horizontally, and four inches apart vertically. Research has shown that birds typically will not attempt to fly through spaces less than two inches high or 4 inches wide.

15 Patterns and features on typical bird-safe glass are also preferred to be on top of the glass on its first surface, as research has shown this is preferred to layers underneath the partially reflecting outermost glass. Using an ultra-thin top pane of glass (e.g., outer layer) in some embodiments brings various patterns much closer to this first surface.

20 As noted, in some embodiments, patterns are created using material that is invisible to humans yet visible to birds, while also harnessing the UV light for photovoltaic power generation. These patterns can be changed to vary spectral absorption and visibility. They can contain multiple materials each with a different spectral visibility to cover more avian species. The
25 patterns also can be varied in frequency, optical density, pattern type (e.g., line, crosshatch, logo, dot, square, and the like). The patterns can be placed on either or both surfaces of the interlayer lamination film to provide a spatial dimension so that, to a bird, patterns appear like a 3-D (three dimensional) object instead of a planar and very thin object.

FIG. 1A shows a conceptual illustration of a bird-friendly IGU 2 according to illustrative embodiments. To that end, the IGU 2 is formed from multiple layers, including an interlayer 6 positioned between an outside layer 8 (e.g., an outboard lite) and an inside layer 12 (e.g., an inboard lite). The outside layer 8 and inside layer 12 may be formed from a glass material, a polymer material, a crystalline material, or the like. In some embodiments, the outside layer 8 and inside layer 12 may be formed from the same material, or from different materials. Also, the outside layer 8 and inside layer 12 may have different thicknesses or other dimensions. In some embodiments, the interlayer 6 also has a UV-absorbing coating patterned on at least one surface of the interlayer 6. The interlayer 6 may be positioned between the inside layer 12 and outside layer 8.

FIG. 1A schematically illustrates the various layers involved in the formation of the example IGU 2 according to some embodiments. As shown, the outermost surface of the outside layer is identified as surface ID 1, while the inner surface of the outside layer 8 is identified as surface ID 2. The inner surface of the inside layer is identified as surface ID 3, while the innermost surface, with respect to the laminated glass 2, of the inside layer is identified as surface ID 4. The inner surfaces of the outside layer (ID2) and the inside layer (ID3) face the bird-friendly interlayer 6. That is, the bird-friendly interlayer 6 is positioned (e.g., sandwiched) between surface ID 2 and surface ID 3.

FIG. 1A conceptually illustrates an example of a comparison of what a bird 14 might see compared to what a human 16 might see when looking at the laminated IGU 2 of FIG. 1A. In the conceptual illustration of FIG. 1A, the interlayer 6 is shown as having a grid pattern 14 toward a top portion of the interlayer 6. This illustrates what a bird 14 might see when it looks at the laminated glass 2. That is, a bird sees the grid pattern 14 formed by a UV

absorbing material on the interlayer 6, because the visual range of a bird includes UVA (300–450 nm).

In contrast, as conceptually illustrated in the lower portion of the interlayer, a human 16 may not see the UV absorbing material because the human visual range does not include UVA. As schematically illustrated, even though the UVA grid pattern 18 is present on the entire interlayer 6, the bird 14 would see a grid pattern 18 formed of the UV coating, wherein the human 16 would not perceive the UV grid pattern 18.

The application and uses of the bird-friendly laminated glass 2 and IGUs 2 includes any setting where clear glass may be exposed to birds. This includes windows on a side or top of a building or structure, as well as barriers such as transparent railings, fences, or other borders to a space that may be provided for decorative or safety reasons.

FIG. 1B schematically illustrates an example of the laminated IGU 2 being assembled having with an interlayer 6 positioned (e.g., sandwiched) between an outside layer 8 and an inside layer 12. As indicated in FIG. 1B, the interlayer 6 in this embodiment includes two UV materials, a first UV material 20 and a second UV material 22. The two UV materials 20 and 22 may be applied to a clear, flexible substrate. According to some embodiments, the two UV materials 20 and 22 may absorb radiation having different wavelengths.

While not drawn to scale, in some embodiments, the first UV material 20 is illustrated as being thicker than second UV material 22. In some embodiments, one or more of the UV materials incorporated in the interlayer 6 may have a variable thickness to enable tailoring a specific amount of UV transparency. That is, the amount of UV radiation absorbed by a UV material may be increased or decreased according to its thickness according to the thickness of the material and the absorbance of the material at the wavelength of interest, as described by the Beer-Lambert Law (e.g., Beer's Law).

In some embodiments, the laminated glass 2 having an interlayer material 6 with the two UV materials positioned between the first layer 8 and the second layer 12 may include the first UV material 20 that is extruded onto and adhered to the clear, flexible substrate to form the interlayer material.

5 The second UV material 22 may be patterned into a coating on the first UV material 20. The second UV material 20 may be adhered to an inner surface (e.g., ID2) of the first layer 8 (outside layer), such that the surface of the interlayer that is opposite the surface having the first and second UV materials applied thereon is adhered to the inner surface (e.g., ID 3) of the
10 second layer 12 (e.g., inside layer). The second UV-absorbing 22 material patterned on a coating on top of the extruded first UV material 20 provides contrast for birds in the UVA.

In some embodiments, UV layers may be applied to a clear, flexible substrate comprising a polymer material to form an interlayer material using
15 a roll coating process. The roll coating process may be a precise method for applying a coating with a uniform thickness. Some benefits of roll coating include precise control of the amount of coating applied, faster speeds of coating than other coating methods, and enhanced UV material adhesion.

The bird-friendly interlayer may comprise a film of a UV absorbing
20 material deposited, grown, applied, printed, gravure printed, offset printed, spun, evaporated, sputtered, cast, or the like, on a clear, flexible substrate, such as a polymer film. The clear, flexible substrate may have a transparency greater than 95% over the visible, UVA, and UVB wavelength ranges, a transparency greater than 90% over the visible, UVA, and UVB wavelength
25 ranges, a transparency greater than 90% over the visible, UVA, and UVB wavelength ranges, or a transparency greater than 85% over the visible, UVA, and UVB wavelength ranges.

The laminated glass may be fabricated with rigid planar include glass materials, rigid plastic materials, rigid polymers. The laminated glass may

also include layers of bendable and flexible glass. Examples include, Corning Willow Glass which is a thin, lightweight, and flexible glass made using Corning's fusion draw process. Flexible glass substrates enable the creation of thin, lightweight windows. They are characterized by their optical and surface quality, dimensional and thermal stability, and hermeticity. Flexibility may be characterized by measuring its bending radius, thickness, optical properties (transparency, refractive index), mechanical strength under bending stress, surface quality, thermal stability, and dimensional stability; essentially assessing how much it can bend without breaking while maintaining its optical integrity and structural form, all within a very thin and lightweight profile.

The flexible substrate of the interlayer 6 may include a polymer film. In some embodiments, a thin film layer of a UV absorber may be applied to the polymer (e.g., plastic) film in a process such as web printing. Web printing refers to the process of printing directly onto a continuous roll of polymer film using a web printing press, which is a high-speed printing method that feeds large rolls of material through the machine for continuous printing, allowing for large-volume production of printed polymer products. The "web" (e.g., interlayer web) refers to a continuous roll of plastic film, which can be made from various polymers like polyethylene, polypropylene, polyester, or specialized blends depending on the application.

FIG. 1C illustrates a portion of a roller 28 used to produce the interlayer 6 with a web 26 roiling over a roller 28 as a part of a process that deposits a UV material in a grid pattern 18. In some embodiments, layers (e.g., coatings) of one or more UV materials may be applied directly on plastic sheets or be applied directly on a different UV material in a roll format using a high-volume web press. Examples of common application techniques, such as those used for web printing on polymer, include flexography, gravure printing, and offset lithography, each with its own advantages regarding

material transfer and print quality. The specific type of process incorporated for depositing the one or more UV material layers on the interlayer webs are optimized for the specific UV material.

In some embodiments, the polymer film (e.g., the interlayer web 26) might need a surface treatment to enhance UV material adhesion to the web. Different polymers require specific materials and/or additives to adhere properly and withstand the printing process. Furthermore, depending on the material and polymer used, special drying methods like UV curing might be necessary to quickly set the UV materials on the plastic film 26 (e.g., the interlayer).

In some embodiments, the film of a first UV absorbing material 20 or of a second UV absorbing material 22 may have a thickness of between about 100 nanometers (e.g., nm) and 5 millimeters (e.g., mm), between about 500 nm (0.5 micrometers, e.g., 0.5 μm) and 1 mm (1000 μm), between about 1000 nm (1 μm) and 0.1 mm (100 μm), or between about 5000 nm (5 μm) and 0.01mm (10 μm).

A second UV absorbing material 22 may be deposited on the first UV material 20. In some embodiments, the first UV material 20 may comprise a thinner material deposited on the flexible substrate 26, and a second UV material 22 may be a thicker UV material deposited on the first UV material 20. In some embodiments, the first UV material 20 may comprise a thicker material deposited on a flexible substrate 26, and a second UV material 22 may be a thinner UV material deposited on the first UV material 20. In some embodiments, one or both of the UV materials (20 and/or 22) may be deposited using a roll process. In some embodiments, a first UV material 20 may be deposited on a first side of the plastic web 26, and a second UV material 22 may be deposited on an opposite side of the plastic web 26.

In some embodiments, one or both of the first UV material 20 or the second UV material 22 may be an extruded material. To that end, the

extruded UV material may be extruded onto 1) the flexible substrate 26 directly, 2) the first UV material 20 already present on the flexible substrate 26, or 3) into a space (e.g., a cavity) between a first layer 8 and a second layer 12 that have previously been connected, along one or more side edges of the paired first 8 and second layers 12.

In some embodiments, a first UV material 20 on an interlayer 6 may be adhered to an inner surface of either the first layer 8 (e.g., ID 2) or the second layer 12 (e.g., ID 3) of the laminated glass 2. The first 8 and second 12 layers of the laminated glass may be joined along one or more edges of the first 8 and second 12 layers forming a space (e.g., a cavity) between the two layers. A second UV material may be extruded into the cavity formed between the first 8 and second 12 layers.

The perception of different wavelengths in the UV region by birds may be analogous to how humans perceive different colors in the visible region. For example, FIG. 2 shows human color sensitivity to illustrate how a 80 nm change in absorption typically may be perceived. In this figure, the spectra are the normalized spectral sensitivities of the three types of color receptors in the human eye plotted versus wavelength (along the x-axis). The wavelength difference between the short wavelength spectrum 30 and the medium wavelength spectrum 32 is about 80 nm. For humans, the 80 nm difference accounts for the visual perception of blue and green, a difference which is noticeable for humans. The wavelength difference between the short wavelength spectrum 30 and the long wavelength spectrum 34 is about 120 nm.

2-Dye Color Systems

FIG. 3A and FIG. 3B illustrate how two luminophores can be coated (e.g., applied) in separate layers to augment visibility to birds by using a different pattern for each feature. In some embodiments, the luminophores

may comprise a dye. That is, the luminophore may serve a dual purpose in the apparatus of augmenting the visibility of birds as a UV material, and providing a luminescent solar concentrator material. FIG. 3A shows the absorption spectra of two different dyes, illustrating how far apart in wavelength they are to show how they would have very different apparent colors to birds. Dye 3 has a peak absorbance 36 around 360 nm, while Dye 21 has a peak absorbance 38 around 450 nm with a difference of about 90 nm. Patterns formed incorporating Dye 3 and Dye 21 would appear to birds as having different colors.

FIG. 3B shows an absorption spectrum 40 from a combination of Dye 3 + Dye 21, from FIG. 3A, to show how mixing of the two dyes can appear as a different color entirely to the bird. Combining of the UV material dyes is similar to mixing blue and yellow to form green for human vision.

FIG. 4A and FIG. 4B show two different pairings of absorption spectra of two UV-absorbing materials with high visible transparency (no absorption longer than 420 nm). These plots show two different absorption spectra visible to birds as two different apparent "colors" to achieve contrast for the bird-friendly spectral patterns on/in the interlayer.

FIG. 4A shows absorbance spectra for two different UV absorbent dyes, Dye 1 and Dye 2. Dye 1 has a peak absorbance 42 around 355 nm and Dye 2 has a peak absorbance 44 around 390 nm. These two dyes have peak absorbances that differ by about 40 nm, a difference that should be sufficient to appear as two different "colors" to birds.

FIG. 4B shows absorbance spectra for two different UV absorbent dyes, Dye 3 and Dye 36. Dye 3 has a peak absorbance 46 around 365 nm and Dye 36 has a broad absorption band 46 between about 360 nm and 390 nm. The optical differences absorption differences between these two dyes would be sufficient to appear as two different "colors" to birds.

FIG. 4C schematically illustrates the effect of overlapping two filters comprising different materials having different absorption peak profiles and optical densities. In this illustration, a first filter 50 has a darker shade and higher optical density (e.g., less transparency) than a second filter 52. The two filters have different spectral absorption peaks and profiles giving rise to the different shades and optical densities. The stacking of the two filters leads to an overlap region 54 having a third shade and optical density. This illustrates the principle that by overlapping two different UV materials having different absorption peak profiles and optical densities UV can lead to effectively a third UV color as it may appear to the avian eye.

Additional examples of illustrating color differences effective for producing bird-friendly windows are provided for two-dye systems in FIG. 5A, and for 3-dye systems in FIG. 5B. FIG. 5A illustrates a two-dye system with a significantly different peak absorption. The Dye 3 absorption spectrum 56 and the Dye 18 absorption spectrum 58 have a greater than 80 nm difference, and this gap corresponds to a difference in human perception of color as different as blue and yellow. Even a difference in wavelength greater than 50 nm will be seen by a bird as a very different color.

3-Dye Color Systems

FIG. 5B shows a three-dye system which could be utilized to provide 3-D shading and color on an essentially 2-D (e.g., two dimensional) surface, such as that of an interlayer between two layers. The Dye 3 absorption spectrum 60 has a peak absorbance about 360 nm, the Dye 10 absorption spectrum 62 has a peak absorbance about 410 nm, and Dye 21 absorption spectrum 64 has a peak absorbance about 440 nm. These absorbance profiles

provide sufficient differences to make designs on an interlayer which appear to be 3-D to a bird.

The use of two or more colors (e.g., wavelengths) can provide more contrast to patterns provided on the UV materials of the interlayer. The utility of using two or more colors in the designs of the patterns used on the UV materials of the interlayer are illustrated in FIG. 6A and FIG. 6B.

FIG. 6A shows a line drawing of a cube 66 using a single material (e.g., single color) line on a solid background. In some embodiments, the single color (e.g., UV wavelength peak) line may be fabricated with a UV material that can be observed by a bird. The depth of the thickness of the single line may be tailored to provide a level of contrast with the background material. In some embodiments, a background material of a first UV material may be deposited on the interlayer film so that a second UV material may be deposited as the single line, such that a contrasting design provided by first and second UV materials is present in the IGU.

FIG. 6B shows a shaded drawing of a cube 68 using a single color line of a first UV material and adding two different additional color shades, 70 and 72, (e.g., different UV materials) to provide the appearance of depth to the cube. The differences between the cubes 66 and 68 shown in FIG. 6A and FIG. 6B, respectively, due to adding shading with two additional colors (70 and 72) to cube 68, illustrate how adding more than one color (e.g., UV material profile) to a design can more readily portray 3-D shapes on this flat surface and be used to create the illusion of depth. The illusion of depth can be used to increase the perception of the appearance of physical objects birds are familiar with and have learned to avoid to further deter birds from flying into IGUs 2 containing the disclosed bird-friendly interlayers formed with two or more UV-absorbing materials to provide apparent color contrast and spectral patterns to bird vision.

Technical Approach to Fabricating Bird-Friendly Laminated Glass and Integrated Glass Units (IGUs)

In some embodiments, one or more UV absorbers may be coated on a lamination interlayer (e.g., interlayer) of polyvinyl butyral (PVB),
5 thermoplastic polyurethane (TPU), ethylene vinyl acetate (EVA), including polymers like polyethylene, polypropylene, polyester, or other specialized blends depending on the UV material or other common lamination films.

In some embodiments, a first UV material may be deposited as an intact, single layer covering essentially all of one or both surfaces of the
10 lamination interlayer material (e.g., web).

In some embodiments, a UV material may be patterned on the interlayer using a gravure printing process. Gravure printing involves transferring an ink, dye, slurry, or some other form of a transferrable material, from a Gravure cylinder to a substrate. Gravure cylinders are typically made
15 of steel and plated with copper, but other materials, like ceramics, can also be used. The desired pattern is engraved into the cylinder, and during printing, the recessed cells in the surface of the cylinder are filled with the material to be applied, and then the cylinder is rolled over the substrate, thus applying the material in the desired pattern. In some embodiments

20 FIG. 7A schematically shows a cross-section view of laminated glass 2 (e.g., IGU) using a bird-friendly interlayer 6 according to some embodiments. The IGU 2 includes an outside layer 8, an inside layer 12, and an interlayer 6 positioned between the outside layer 8 and inside layer 12. The interlayer 6 comprises a lamination film 26, such as PVB, TPU, EVA or another common
25 lamination film. The lamination film 26 forms an interlayer substrate upon which a pattern of UV features 76 is deposited. The patterned lamination film 26 is then sandwiched between the outside layer 8 and inside layer 12 to form a unit of laminated glass (e.g., as a standalone window or component of an IGU).

FIG. 7B schematically shows a view of another embodiment of the bird-friendly interlayer 6. In this case, the bird-friendly interlayer 6 includes a base layer coating (e.g., layer) of a first UV material 20 deposited on a lamination film 26. A pattern of features composed of a second UV material 22 is deposited on the base layer coating 20. In some embodiments, the first UV material 20 and the second UV material 22 are different UV materials with different absorption peak profiles and optical densities. In some embodiments, one or both of the first UV 20 or second UV materials 22 may be UVA materials. In some embodiments, one or both of the first UV 20 or second UV 22 materials may be UVB materials. In some embodiments, one or both of the first UV 20 or second UV 22 materials may be a combination of UVA and UVB materials.

The first UV material 20 base layer and the second UV material 22 pattern of features deposited on the lamination film 26 bird-friendly interlayer 6 may represent features with a different UVA or UVB absorption wavelength spectra to provide differentiation in apparent color to birds of varying species with different spectral sensitivities. Since the base layer coating 20 and the pattern of features 22 each absorb in the UVA and/or UVB wavelength range, the layer 20 and features 22 will be apparent to birds but not detrimental to human visibility. Additional patterns of UV-absorbing features may include bird silhouettes, logos, stripes, crosshatches, dots, or other patterns.

In some embodiments, the base layer coating 20 may be fabricated from a luminescent material (e.g., a luminophore) that absorbs UV wavelengths and emits visible light, such that the base coating 20 also functions as luminescent solar concentrator (e.g., LSC) material. In such embodiments, the base coating serves a dual purpose as a bird-friendly layer and an LSC, as well. Luminescent solar concentrators and luminophore materials are discussed in greater detail below.

FIG. 7C schematically shows a top view of various different patterns of UV materials deposited on a lamination film 26 that may be fabricated as examples according to some embodiments. In an embodiment 86 of a pattern of UV materials applied to a lamination film 26, a pattern of circles of a first UV material 20 are shown on a surface 87. The surface 87 may comprise a layer of a second UV material 22, or the surface may be the surface of the lamination film 26. In some embodiments, when the surface 87 comprises a second UV material 22, the first and second UV materials may be different materials with different absorption peak profiles and optical densities.

In another embodiment 90 of a pattern of UV materials applied to a lamination film 26, a pattern of lines of a first UV material 20 are shown on a surface 87. The surface 87 may comprise a layer of a second UV material 22. In some embodiments, when the surface 87 comprises a second UV material 22, the first UV material 20 and second UV material 22 may be different materials with different absorption peak profiles and optical densities.

In yet another embodiment 94 of a pattern of UV materials applied to a lamination film 26, a pattern of lines of a first UV material 20 are shown on a surface 87. The surface 87 may comprise a layer of a second UV material 22. In some embodiments, when the surface 87 comprises a second UV material 22, the first UV material 20 and the second UV material 22 may be different materials with different absorption peak profiles and optical densities.

FIG. 7D schematically shows a cross-section view of another embodiment of a laminated glass 2 using a bird-friendly interlayer 6 according to some embodiments. This embodiment of laminated glass 2 includes the outside layer 8, the inside layer 12, and the interlayer 6 positioned between the outside layer 8 and inside layer 12. The interlayer 6 comprises a lamination film 26, such as PVB, TPU, EVA or another common lamination film 26 that is coated on both sides with different UVA-absorbing dyes and patterns. A first UV absorbing dye 102 may be applied to a first side

of the lamination film 26, while a second UV absorbing dye 104 may be applied to a second side of the lamination film 26. That is, UV absorbing (e.g., UVA-absorbing) dyes may be applied to each side of the PVB, TPU, EVA or other common lamination film substrate. In some embodiments, the

5 laminated glass 2 having the interlayer 6 coated on both sides may serve as a standalone window or a component of an IGU. Furthermore, in some embodiments a third UV absorbing dye may be applied over either of the first UV absorbing dye 102, or the second UV absorbing dye 104. The third UV absorbing dye may be the same as one or both of dye 102 or dye 104, dye, or

10 the third UV absorbing dye may be different than both of dye 102 and dye 104. Additionally, the third UV absorbing dye may be applied as a contiguous layer or in a pattern of features.

FIG. 7E schematically shows a top view of two different examples of interlayers 6. The embodiment shown in example 106 is a bird-friendly

15 interlayer 6 approach that is an example of adding a second UV absorber 22 (e.g., UV dye and/or material) to create contrast to the bird-friendly layer. Example 106 shows several different possible patterns of a second UV material 22 that can be added to (e.g., applied to) a first UV absorbing layer 20 that has been applied to a lamination film. In this example, the pattern

20 provided by the additional (e.g., second) UV absorber 22 is adding additional optical density features to form the patterns that provide contrast. These patterns can be bird silhouettes, logos, stripes, grids, crosshatches, squares, dots, or other shapes.

A different embodiment shown in example 110 is a bird-friendly

25 interlayer approach that is an example of having a pattern formed in a first UV material 20 by having an absence, or greatly reduced, UV absorber material in the shape of the patterns 112. In this embodiment, contrast is provided by the absence of a UV dye and/or UV material in the base layer of the first UV material 20 providing a lower optical density pattern in the first

UV absorbing layer 20. In some embodiments, the deposition of first UV material 20 base layers with patterns formed by an absence of the UV material can include bird silhouettes, logos, stripes, grids, crosshatches, squares, dots, or other shapes.

5 In some embodiments, one or more ultraviolet (e.g., UV) absorbers may be coated on PVB, TPU, EVA or other common lamination film 26 with a patterned gravure cylinder to create skips that have no coating (e.g., blank) so the window would appear to have a pattern to a bird with UVA or near-UV (e.g., violet) spectral sensitivity. Patterns could include bird silhouettes, dots
10 or other patterns. In some embodiments, a second coating station could apply a UV absorber luminophore with a different spectral absorbance. The different spectral absorbance could be achieved by either by being a different UV absorber, or with the same UV absorber present in a differing concentration. In some embodiments, the second UV absorber 22 is deposited
15 in the areas with no coating in the first layer. That is, the deposition of the second UV absorber 22 is aligned with the blank areas in the first coating applied of the first UV material 20.

 In some embodiments, a first ultraviolet absorber 20 may be coated on a first side of PVB, TPU, EVA or other common lamination film substrate 26
20 and a second ultraviolet absorber 22 may be coated in patterns on the second side of the lamination film substrate 26.

 In some embodiments, the patterned coatings on a laminated film 26, as described above for embodiments described for FIGS. 1A through 7E, may be incorporated into laminated glass or IGUs 2 that use a top glass substrate
25 of sub-millimeter thickness (such as Corning "Gorilla Glass" or "Willow Glass") to bring the patterned features as close as possible to being "first-surface" (e.g., surface ID 1 in FIG 1A) patterns as is often preferred for bird-friendly glass. That is, by using a top glass substrate of sub-millimeter thickness, it is possible to have the coated PVB, TPU, EVA or other common

lamination films interlayer 6 to within less than 100 microns of the outer surface ID1 of the outside layer 8 . Using the top glass 8 substrate of sub-millimeter thickness also considerably lessens the overall thickness of the laminated glass or IGU 2, making this laminated glass or IGU 2 much more
5 similar to a single pane of glass and a not a more bulky, traditional laminated glass stack.

In some embodiments, coatings of an ultraviolet absorber or multiple ultraviolet absorbers, as described above for embodiments described for FIGS. 1A through 7E, may be applied that are also emissive luminophores to form a
10 luminescent solar concentrator (LSC) on PVB, TPU, EVA or other common lamination films 26. The emissive luminophores may be applied with a patterned gravure cylinder to create skips (e.g., blank areas) that have no coating on the lamination film so the window should appear to have a pattern to a bird with UVA or near UV (violet) spectral sensitivity. Patterns may
15 include bird silhouettes, logos, stripes, crosshatches, dots or other patterns.

In some embodiments, coatings of one or more ultraviolet absorbers that are also emissive luminophores, as described above for embodiments described for FIGS. 1A through 7E, may be applied in layers or simultaneously to form a luminescent solar concentrator (LSC) on PVB, TPU,
20 EVA or other common lamination films with patterned gravure cylinder to create skips that have no coating so the window would appear to have a pattern to a bird with UVA or near-UV (violet) spectral sensitivity. Patterns could include bird silhouettes, dots or other patterns. A second coating station could apply a luminophore with a different spectral emission aligned
25 with the skip areas in the first coating applied. Alternatively, the second station could apply one or more layers all across the film forming a nth functional coating. That is, functional UV material coatings may be built up as a 1st coating, a 2nd coating, up to an nth coating as required by the specifications and/or requirements of a user.

In some embodiments, patterned coatings containing LSC materials on PVB, TPU, EVA or other common lamination films may be used in any of embodiments described for FIGS. 1A through 7E, but with the use of a top glass layer 8 of sub-millimeter (50-200 micron) thickness (such as Corning
5 “Gorilla Glass” or “Willow Glass”) to bring the patterned features as close as possible to being “first-surface” patterns, as is often preferred for bird-friendly glass. In addition to bringing the patterns within less than 100 microns of the first surface, this embodiment also brings improved off axis visibility in addition to providing the ability to harvest solar energy to
10 generate electricity. Using a thin flexible glass also considerably lessens the overall thickness of the laminated glass or IGU making the lamination thickness or height more equivalent to a single pane of glass and thus able to be utilized in other architectural glass applications.

In some embodiments, a visible absorber or visibly absorbing
15 luminophore may be used in any of embodiments described for FIGS. 1A through 7E above to augment its appearance as an obstacle to birds and/or improve its efficiency in generating photovoltaic energy, but with the visible absorber being minimal enough in coverage, feature size, and/or optical density in the visible portion of the spectrum to not be objectionable to
20 humans.

In some embodiments, an external lamination consisting of patterned lamination film such as PVB, TPU, EVA or other common lamination film 26 may be laminated to a thin glass substrate such as Corning Willow, Gorilla or other thin glass substrate for in situ installation on the exterior of existing
25 architectural windows using a vacuum clamping device, a method of heating the laminated glass interlayer film or a combination of both heat and vacuum.

Double- and Triple-Pane Bird-Friendly Laminated Glass and Integrated Glass Units (IGUs)

FIG. 7F schematically shows a cross-section view of an embodiment of a laminated glass using a bird-friendly interlayer 6 in a double-pane IGU 2 with an air gap 13 according to some embodiments. This embodiment of the laminated glass 2 includes an interlayer 6 formed of a first UV material 20 that has been applied to lamination film 26. The outer surface of the first UV material 20 on the laminated film 26 is adhered to an inner surface ID 2 of an outside layer 8. A back surface 27 (surface opposite the surface attached to the first UV material 20) of the lamination film 26 exposed to the air gap 13. The air gap 13 is positioned between the back surface 27 of the lamination film 26 and the inner surface ID 3 of the inside layer 12.

In some embodiments, the “air gap” 13 volume is defined by the back surface 27 of the lamination film 26, the inner surface ID 3 of the inside layer 12, and an air tight envelope that maintains the pressure condition of the air gap 13 and impedes thermal flow through the IGU 2. The pressure condition of the air gap may include a vacuum gap, a gap filled with air, or some other gas, such as nitrogen, helium, argon, or the like.

FIG. 7G schematically shows a cross-section view of an embodiment of a laminated glass using a bird-friendly interlayer 6 in a triple-pane IGU 2 with an air gap 13 according to some embodiments. This embodiment of the laminated glass includes an interlayer 6 formed of a first UV material 20 that has been applied to lamination film 26. The outer surface of the first UV material 20 on the laminated film 26 is adhered to an inner surface ID 2 of the outside layer 8. The back surface 27 of the lamination film 26 is adhered to the inner surface ID 3 of the inside layer 12. Up to this point in the embodiment of a triple-pane IGU 2, is similar to the laminated glass stack described in FIG. 7A. However, in this embodiment of a triple-pane bird-friendly IGU 2, a third layer 15 is positioned inside of the inside layer 12 (e.g., the side of the IGU 2 opposite from the front surface ID 1) with an “air gap”

13 between the innermost surface layer ID 4 of the inside layer 12 and an inner surface ID 5 of third layer 15.

In some embodiments, the air gap 13 volume is defined by the innermost surface layer ID 4 of the inside layer 12, the inner surface ID 5 of third layer 15, and an air tight envelope that maintains the pressure condition of the air gap 13 and impedes thermal flow through the IGU 2. The pressure condition of the air gap may include a vacuum gap, a gap filled with air, or some other gas, such as nitrogen, helium, argon, or the like.

10 **Transparent Luminescent Solar Concentrators (LSCs)**

FIG. 8 schematically shows an embodiment of a transparent luminescent solar concentrator (e.g., LSC) 700. This embodiment of a transparent LSC 700 includes a film, plexiglass, or glass substrate 720 that can act as a waveguide for absorbed radiation. The radiation may be concentrated as re-emitted light in plane, and/or harvested at a periphery (e.g., side surface, or edge) of the film, plexiglass, or glass substrate, for electricity.

A photovoltaic device 730 is positioned at a side edge of the of the LSC substrate 720 to collect radiation that is emitted from the substrate waveguide 720. The photovoltaic device 730 may be comprised of any type device that converts radiation into electrical power. Examples include, but are not limited to, thin film, single crystal, polycrystalline, amorphous photovoltaic devices, and the like. The solar materials may include, but are not limited to, silicon, CdTe (cadmium telluride), GaAs (gallium arsenide), CGIS (copper gallium indium sulfide), transparent OPV's, and the like.

In illustrative embodiments, one or more embedded luminophores that absorb and emit light during device operation may be embedded in the substrate. The embedded luminophore(s) may be, but is not limited to, one or a combination of two of more of the following: coumarins, naphthalimides,

coronenes, anthracenes, rubrenes, thiophenes, fluorenes, diazafluorenes, fluorenones, dicyanomethylenes, rhodamines, perylenebisimides, and bipyridines, as the UV absorbing luminophore(s) 740 (absorbing near UV light with a peak absorption between 300 and 450 nm), which may emit
5 photons 745 at a different wavelength than was absorbed (emitting in the visible with peak wavelengths from 400 to 780 nm). The photons 745 emitted from the UV absorbing luminophore 740 may be internally reflected 760 off of the surfaces the LSC substrate 720 and directed to the photovoltaic device 730 for conversion to electrical power.

10 In illustrative embodiments, embedded luminophores may be visible light absorbing luminophores 770 that absorb a narrow wavelength band of visible light. The embedded luminophore(s) may be, but is not limited to, one or a combination of two or more of the following: coumarins, naphthalimides, coronenes, anthracenes, rubrenes, thiophenes, fluorenes, diazafluorenes,
15 fluorenones, dicyanomethylenes, rhodamines, perylenebisimides, and bipyridines. For example, an embedded luminophore may be a VIS absorbing luminophore 770 (absorbing visible light with a peak absorption between 400 and 780 nm), which may emit photons 775 at a different wavelength than was absorbed (emitting in the visible and near infrared with peak wavelengths
20 from 400 to 1000 nm). The photons 775 emitted from the VIS absorbing luminophore 770 may be internally reflected off of the surfaces the LSC substrate 720 and directed to the photovoltaic device 730 for conversion to electrical power. The luminophores that are incorporated into LSC devices may also be used as a patterned base layer, as well as a patterned second
25 layer.

FIG. 9 shows an embodiment of a method to make a bird-friendly integrated glass unit (IGU). In Step 910, a first ultraviolet (UV) material is applied to a first side of a clear flexible substrate to form a first side of an interlayer. The UV material is a UV radiation absorber. The UV may be

applied as a thin film. In some embodiments, the first ultraviolet (UV) material may be a luminophore.

In Step 920, the first side of the interlayer is adhered to an inner surface of a first outside layer. The first outside layer has an outer surface opposite
5 the inner surface.

In Step 930, a second side of the interlayer is adhered to an inner surface of an inside layer. The second surface of the inside layer is opposite the first surface. The interlayer is sandwiched between the outside layer and inside layer to form an integrated glass unit.

10 In optional Step 940, a second UV material is applied to the first UV layer. In some embodiments, the second UV material may be a pattern of shapes comprising at least one of bird silhouettes, logos, stripes, grids, crosshatches, squares, dots, or other shapes. At least one of the first UV material or the second UV material may be applied as a thin film. The at
15 least one of the first UV material or the second UV material applied as thin films are applied by a gravure printing process.

In optional Step 950, an inner pane of glass is secured to the outer surface of the inside layer of the integrated glass unit in an air-tight manner.

FIG. 10 shows another embodiment of a method to make a bird-
20 friendly IGU. In Step 1010, a first ultraviolet (UV) material is applied to a first side of a clear flexible substrate to form a first side of an interlayer. The first UV material is a UV radiation absorber. The UV radiation absorber may absorb UVA or UVB radiation.

The first ultraviolet (UV) material may be applied as a thin film. The
25 film of the UV absorbing material may be deposited, grown, applied, printed, gravure printed, offset printed, spun, evaporated, sputtered, or cast. The clear, flexible substrate may be a polymer film. The clear flexible substrate may be a film of polyvinyl butyral (PVB), thermoplastic polyurethane (TPU),

or ethylene vinyl acetate (EVA). The clear flexible substrate may be a film of polyethylene, polypropylene, or polyester.

At step 1020, a second ultraviolet (UV) material may be applied to a second side of the clear flexible substrate to form a second side of the
5 interlayer. The second UV material is a UV radiation absorber. The UV radiation absorber may absorb UVA or UVB radiation.

The interlayer has the first ultraviolet (UV) material on the first side and the second ultraviolet (UV) material on the second side of the interlayer.

At optional Step 1030, a third ultraviolet (UV) material may be applied
10 to the first ultraviolet (UV) material or the second ultraviolet (UV) material.

At optional Step 1040, the first side of the interlayer is adhered to an inner surface of an outside layer. The outside layer has an outer surface opposite the inner surface; and

At optional Step 1050, the second side of the interlayer is adhered to an
15 inner surface of an inside layer. The inside layer has an outer surface opposite the inner surface. The interlayer is sandwiched between the outside layer and inside layer in an air-tight manner to form an integrated glass unit.

The embodiments of the invention described above are intended to be merely exemplary; numerous variations and modifications will be apparent to
20 those skilled in the art. Such variations and modifications are intended to be within the scope of the present invention as defined by any of the appended claims.

EXAMPLES

25 Threat factors of several IGUs were measured by The American Bird Conservancy (e.g., ABC) at the Foreman's Branch Bird Observatory. The American Bird Conservancy aims to accelerate the development and adoption of bird-friendly building design. The Foreman's Branch Bird Observatory has developed methods to assess Threat Factors reflecting the relative response to

different patterns by songbirds flown in the tunnel. Sample IGUs 2 were tested to determine a “Threat Factor” according to the description of the testing features below:

- 5 1. The threat factor of a material is based on flying at least 80 individual birds down the tunnel and recording whether they fly towards the control or to the patterned test pane. For example, suppose 80 birds flew down the tunnel, with 20 flying towards the test pattern and 60 toward the control. 25% (20/80) of the birds flew towards the test pattern and it would
10 therefore have $TF=25$.
2. Threat Factors do not equal the percent reduction in collisions expected when a glass is installed on a building. In fact, the same glass may perform differently on each side of a building, depending on angle to the sun, habitat reflected, etc. Threat Factors are an index, reflecting the relative
15 response to different patterns by songbirds flown in the tunnel. However, where monitoring data on tunnel tested products are available, they confirm that the lower the threat factor, the fewer collisions. ABC defines “bird-friendly” materials conservatively, as materials having a threat factor ≤ 30 , which we believe corresponds to a reduction of collisions of at least 50%
20 under real world conditions.
3. A score of 50 means equal numbers of birds flew toward the control and test panes and thus means ‘no deterrent effect’ for a test material.
4. At least 80 trials were run for each sample.
5. All samples tested with background reducing backlighting.
- 25 6. All samples imaged in visible light.

Example 1

Experimental Details:

Sample Name: ATBF-AA01-A06 was tested.

Description of sample: Laminated Glass (3.2 mm low iron glass lite 1 +
5 0.76 mm patterned & coated interlayer + 3.2 mm low iron glass lite 2)

Bird Friendly Pattern: Surface 2 UV pattern (interlayer)- 2" square
with 1/2" x 1/2" spacing.

Base = DPC24-40SD (ARLP-3). **Patterned** = DPC24-40G

Useable Flights: 82

10 **Threat Factor:** 27

Discussion of Experimental Results for Example 1:

Sample ATBF-AA01-A06 was determined to have a threat factor of 27.

This threat factor, being less than 30, is believed by ABC to correspond to a
15 reduction of collisions of at least 50% under real world conditions.

Example 2

Experimental Details:

Sample Name: ATBF-AA01-A05

20 **Description:** Laminated Glass (3.2mm low iron glass lite 1 + 0.76mm
patterned & coated interlayer + 3.2mm low iron glass lite 2)

Bird Friendly Pattern: Surface 2 UV pattern (interlayer)- 2" square
with 1/2" x 1/2" spacing.

Base = no coating. **Pattern** = Hi T928+ARLP

25 **Useable Flights:** 85

Threat Factor: 29

Discussion of Experimental Results for Sample 2:

Sample ATBF-AA01-A06 was determined to have a threat factor of 27. This threat factor, being less than 30, is believed by ABC to correspond to a reduction of collisions of at least 50% under real world conditions.

5 Conclusions from testing of Examples 1 and 2

Samples 1 and 2 received a “threat factor” grade of 27 for our “best” coating and a 29 for a second coating, respectively. Both samples “pass” according to the ABC metrics, where a threat factor <30 is considered “bird-friendly”.

10 Using these findings, ABC has indicated the inventors have successfully demonstrated (via their third-party testing) the first bird-friendly interlayer with a UV-only absorbing coating. The disclosed laminated glass design does not have to be an outer surface ID 1 coating (outermost, closest to the sun, exterior to the elements) on the outside layer 8.

15 Previously it was thought to be impossible to have an effective bird-friendly IGU 2 with the bird-friendly coating behind the outside glass 8 layer. This testing has demonstrated that the bird-friendly coating be on an inner surface ID 2 of the outside layer 8, or on the inner surface ID 3 of the inside layer 12, sandwiched between outside 8 and inside 12, forming a laminated
20 glass 2 that includes surfaces ID 1 through ID 4.

Thus, it is shown that a laminated glass 2 can be incorporated into a double-pane or triple-pane IGU, with the bird-friendly UV laminated layer 36 as the outer glass laminate, followed by an air gap, and an lite which will be in most cases a piece of low-e coated glass.

25 It is surprising and unexpected that various embodiments described herein can provide a bird-friendly window utilizing flexible substrates (e.g., polymer films), without lessening the human experience. It is further surprising and unexpected that a bird-friendly window could be provided that also can be configured to optionally generate electricity via photovoltaic

methods, such as luminescent solar concentrators (LSCs) to generate photovoltaic power.

What is claimed is:

1. A bird-friendly interlayer comprising:
a clear flexible substrate having a first surface and a second surface;
5 and
an ultraviolet absorbing material on the first surface of the substrate,
the ultraviolet absorbing material configured to produce one or more spectral
patterns under ultraviolet illumination, the clear, flexible substrate configured
to abut a first substantially flat glass pane on the first surface and a second
10 substantially flat glass pane on the second surface.
2. The interlayer of claim 1, wherein ultraviolet absorbing material
comprises a luminophore.
- 15 3. The interlayer of claim 1, wherein the ultraviolet absorbing material
comprises:
a first material of a contiguous ultraviolet absorbing coating having a
first absorbance spectrum covering a first surface of the substrate; and
a second material having a second absorbance spectrum applied to the
20 first material, the second material having a pattern of ultraviolet absorbing
features,
wherein the pattern of ultraviolet absorbing features and the
contiguous ultraviolet absorbing material provide the one or more spectral
patterns of ultraviolet wavelength contrast.
- 25 4. The interlayer of claim 1, wherein:
the substrate is impregnated with an ultraviolet absorbing dye having
a first absorbance spectrum throughout its bulk uniformly and contiguously;
and

the ultraviolet absorbing material comprises:

a first material of a contiguous ultraviolet absorbing coating
having a first absorbance spectrum covering a first surface of substrate; and

a pattern of ultraviolet absorbing features having a second
5 absorbance spectrum deposited on the ultraviolet absorbing material,

wherein the pattern of ultraviolet absorbing features and the
contiguous ultraviolet absorbing coating provide the one or more spectral
patterns of ultraviolet wavelength contrast.

10 5. The interlayer of claim 4, wherein the one or more ultraviolet
absorbing coatings comprise a luminophore.

6. The interlayer of claim 4, wherein the ultraviolet absorbing dye and the
ultraviolet absorbing coating comprise luminophores.

15

7. The interlayer of claim 3, wherein the pattern of ultraviolet absorbing
features and the contiguous ultraviolet absorbing coating are deposited by a
gravure cylinder.

20 8. The interlayer of claim 1, wherein the clear flexible substrate has:
a first ultraviolet absorbing coating having a first ultraviolet
absorption spectrum on the first surface; and
a second ultraviolet absorbing coating with a second ultraviolet
absorption spectrum on a second surface, the second surface being opposite
25 the first surface, wherein one or both of the first ultraviolet absorbing coatings
or the second ultraviolet absorbing film have a pattern.

9. A bird friendly apparatus comprising:
an outside layer having first outer surface and a first inner surface;

an inside layer having a second inner surface and a second outer surface;

a clear flexible substrate having a first surface and a second surface, the first surface coupled to the first inner surface of the outside layer, the second surface coupled to the second inner surface of the inside layer, the clear flexible substrate comprising one or more ultraviolet absorbing coatings that produce spectral patterns under ultraviolet illumination.

10. The bird friendly apparatus of claim 9, wherein the one or more ultraviolet absorbing coatings comprise a luminophore.

11. The bird friendly apparatus of claim 9, wherein the one or more ultraviolet absorbing coatings comprise:

a first material of a contiguous ultraviolet absorbing coating having a first absorbance spectrum covering a first surface of the substrate; and a second material having a second absorbance spectrum applied to the first material, the second material having a pattern of ultraviolet absorbing features,

wherein the pattern of ultraviolet absorbing features and the contiguous ultraviolet absorbing material provide the one or more spectral patterns of ultraviolet wavelength contrast.

12. The bird friendly apparatus of claim 9, wherein: the substrate is impregnated with an ultraviolet absorbing dye having a first absorbance spectrum throughout its bulk uniformly and contiguously; and the ultraviolet absorbing material comprises:

a first material of a contiguous ultraviolet absorbing coating having a first absorbance spectrum covering a first surface of substrate; and

a pattern of ultraviolet absorbing features having a second absorbance spectrum deposited on the ultraviolet absorbing material,

wherein the pattern of ultraviolet absorbing features and the contiguous ultraviolet absorbing coating provide the one or more spectral patterns of ultraviolet wavelength contrast.

13. The bird friendly apparatus of claim 9, wherein the one or more ultraviolet absorbing coatings comprise a luminophore.

10 14. The bird friendly apparatus of claim 9, wherein the ultraviolet absorbing dye and the ultraviolet absorbing coating comprise luminophores.

15. The bird friendly apparatus of claim 9, wherein the clear flexible substrate comprises:

15 a first ultraviolet absorbing coating having a first ultraviolet absorption spectrum on the first surface; and

a second ultraviolet absorbing coating with a second ultraviolet absorption spectrum on a second surface, the second surface being opposite the first surface, wherein one or both of the first ultraviolet absorbing coatings or the second ultraviolet absorbing film have a pattern.

16. The bird friendly apparatus of claim 11, wherein:

the ultraviolet absorbing coatings comprise a luminophore which emits light that is waveguided to the edges of the apparatus; and

25 the edges of the apparatus are fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator.

17. The bird friendly apparatus of claim 14, wherein:

the ultraviolet absorbing dye and coating comprise luminophores which emit light that is waveguided to the edges of the apparatus; and the edges of the apparatus are fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator.

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18. The bird friendly apparatus of claim 9, wherein:

the outside layer is a submillimeter thick piece of glass ranging in thickness from 30 microns to 20 millimeters; and

the spectral patterns under ultraviolet illumination are on the first surface of the clear flexible substrate to be as close as possible to the outer surface of the apparatus.

19. A bird-friendly integrated glass unit comprising:

an outer pane of laminated glass comprising:

an outside layer having first outer surface and a first inner surface;

an inside layer having a second inner surface and a second outer surface; and

a clear flexible substrate having a first surface and a second surface, the first surface coupled to the first inner surface of the outside layer, the second surface coupled to the second inner surface of the inside layer, the clear flexible substrate comprising one or more ultraviolet absorbing coatings that produce spectral patterns under ultraviolet illumination; and

a gap filled with vacuum, air, or inert gas; and

an inner pane of glass, wherein the outer pane of glass and the inner plane of glass are secured together in an air-tight manner.

20. A bird-friendly integrated glass unit comprising:

an outer pane of laminated glass comprising:

an outside layer having first outer surface and a first inner surface;

an inside layer having a second inner surface and a second outer surface; and

5 a clear flexible substrate having a first surface and a second surface, the first surface coupled to the first inner surface of the outside layer, the second surface coupled to the second inner surface of the inside layer, the clear flexible substrate comprising a film of an ultraviolet absorbing dye and a film comprising luminophores which emit light that is waveguided to edges
10 of the laminated glass; the films of the ultraviolet absorbing dye and the coating configured to provide bird-friendly patterns, the edges of the laminated glass are fitted with photovoltaic cells to generate electrical power utilizing this as a luminescent solar concentrator;

an inner pane of glass;

15 a gap between the outer pane of laminated glass and the inner pane of glass; and

electrical contacts to harvest the electrical power generated from the laminated glass that incorporates bird-friendly patterns and functions as a luminescent solar concentrator,

20 wherein:

the gap is evacuated or filled with air, or inert gas; and

the outer pane of laminated glass and the inner pane of gas are secured to each other in an air-tight manner.

25 21. The bird-friendly integrated glass unit of claim 20, wherein:

the outside layer is a submillimeter thick piece of glass ranging in thickness from 30 microns to 10 millimeters; and

the inner pane of glass is secured to the outer pane of laminated glass in an air-tight manner.

22. A method to make a bird-friendly integrated glass unit comprising:
applying a first ultraviolet (UV) material to a first side of a clear
flexible substrate to form a first side of an interlayer, the UV material being a
5 UV radiation absorber;
adhering the first side of the interlayer to an inner surface of a first
outside layer, the first outside layer having an outer surface opposite the
inner surface; and
adhering a second side of the interlayer to an inner surface of an inside
10 layer, the second surface of the inside layer being opposite the first surface,
wherein the interlayer is sandwiched between the outside layer and
inside layer to form an integrated glass unit.
23. The method of claim 22, wherein the first ultraviolet (UV) material is a
15 luminophore.
24. The method of claim 22 further comprising:
applying a second UV material to the first UV layer.
- 20 25. The method of claim 24, wherein the second UV material comprises a
pattern of shapes comprising at least one of bird silhouettes, logos, stripes,
grids, crosshatches, squares, dots, or other shapes.
26. The method of claim 25, wherein at least one of the first UV material or
25 the second UV material are applied as a film.
27. The method of claim 26, wherein the at least one of the first UV
material or the second UV material applied as thin films are applied by a
gravure printing process.

28. The method of claim 22, wherein the outside layer and the inside layer comprise a glass material.

5 29. The method of claim 28 further comprising:
securing an inner pane of glass to the outer surface of the inside layer of the integrated glass unit in an air-tight manner.

30. A method to make a bird-friendly apparatus comprising:
10 applying a first ultraviolet (UV) material to a first side of a clear flexible substrate to form a first side of an interlayer, the first UV material being a UV radiation absorber; and
applying a second ultraviolet (UV) material to a second side of the clear flexible substrate to form a second side of the interlayer, the second UV
15 material being a UV radiation absorber,
wherein the interlayer has the first ultraviolet (UV) material on the first side and the second ultraviolet (UV) material on the second side of the interlayer.

20 31. The method of claim 30 further comprising:
applying a third ultraviolet (UV) material to the first ultraviolet (UV) material or the second ultraviolet (UV) material.

32. The method of claim 30 further comprising:
25 adhering the first side of the interlayer to an inner surface of an outside layer, the outside layer having an outer surface opposite the inner surface;
and

adhering the second side of the interlayer to an inner surface of an inside layer, the inside layer having an outer surface opposite the inner surface,

wherein the interlayer is sandwiched between the outside layer and the
5 inside layer in an air-tight manner to form an integrated glass unit.

33. The method of claim 30, wherein the clear flexible substrate comprises a film of polyvinyl butyral (PVB), thermoplastic polyurethane (TPU), or ethylene vinyl acetate (EVA).

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34. The method of claim 30, wherein the clear flexible substrate comprises a film of polyethylene, polypropylene, or polyester.