

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

VARIABLE TRANSMISSIVITY VIRTUAL IMAGE PROJECTION SYSTEM**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims the benefit of United States Patent Application Serial No. 15/201,357 filed July 1, 2016, entitled "VARIABLE TRANSMISSIVITY VIRTUAL IMAGE PROJECTION SYSTEM," which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Embodiments herein generally relate to heads-up displays and in particular to systems for generating virtual images in a see-through heads-up display.

BACKGROUND

A heads-up display (HUD) can be implemented to provide a virtual image (e.g., images, text, or the like) superimposed onto a real world view. Common applications of HUDs include defense, transportation, industrial, entertainment, wearable devices, or the like.

In some HUD displays, the virtual image may be presented to a user by reflecting the virtual image off of a projection surface into a user's eye. The projection surface may be transparent to allow the user to view a real world scene simultaneously with the virtual image. Accordingly, ambient light from outside of the HUD is also incident on the user's eye. The brightness and/or the uniformity of the brightness of the ambient light may affect the ability of the user to see the virtual image.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a block diagram of an illustrative virtual image projection system according to a first embodiment.

FIG. 2 depicts a block diagram of an illustrative virtual image projection system according to a second embodiment.

FIG. 3 depicts a block diagram of an illustrative virtual image projection system according to a third embodiment.

FIG. 4A depicts a block diagram of illustrative projection surface according to a first embodiment.

FIG. 4B depicts a block diagram of illustrative projection surface according to a second embodiment.

FIG. 5 depicts a block diagram of an illustrative virtual image projection system according to a fourth embodiment.

FIG. 6 depicts an illustrative logic flow according to a first embodiment.

FIG. 7 depicts an illustrative logic flow according to a second embodiment.

FIG. 8 depicts an illustrative computer readable medium according to an embodiment.

FIG. 9 depicts an illustrative device according to an embodiment.

DETAILED DESCRIPTION

Various embodiments may be generally directed to virtual image presentation systems. Specifically, the present disclosure may be applicable to heads-up display (HUD) virtual image presentation systems having a transparent projection surface for projecting a virtual image superimposed onto a real-world scene visible through the projection surface.

For example, the present disclosure can be implemented as a HUD having a projection system and a projection surface. The projection surface may include an external side facing the external environment and an internal side facing a user. The projection surface may be transparent, substantially transparent, and/or semi-transparent (“transparent,” “light transmissive,” “see-through,” or the like) to allow ambient light incident on the external side to pass through to a user’s eye that is facing the internal side. In this manner, a user may see a real-world scene through the projection surface of the HUD. The projection system may scan light corresponding to pixels of a virtual image onto a projection zone on the internal side of the projection surface. The projection surface may include one or more layers (or lenses) configured to reflect at least a portion of the scanned light back to the user’s eye to generate the virtual image. Accordingly, a user may be able to see the virtual image superimposed onto the real-world view.

The projection surface may include a variable-transmissivity material configured to modify the ability of light to be transmitted through the projection surface (i.e., transmissivity). The variable-transmissivity material may modify the transmissivity of the projection surface responsive to an application of a stimulus. Non-limiting examples of a stimulus may include light, heat, sound waves, an electric current, a magnetic force, or the like. During operation, as the light is scanned across the projection zone, a stimulus source may apply the stimulus to a portion of the variable-transmissivity material to generate a modified-transmissivity zone on the projection surface. The modified-transmissivity zone may have a decreased transmissivity compared with the non-modified transmissivity of the projection surface outside of the modified-transmissivity zone (i.e., a non-modified zone). Accordingly, the brightness of the ambient light reaching the user’s eye through the projection surface may be selectively controlled by the HUD. The modified-transmissivity zone may be located based on various factors, including, without limitation, a location of the projection zone, user eye gaze location, a location of the virtual image, brightness of ambient light incident on the projection surface, and/or the like. As such, the HUD may adjust the transmissivity of the projection surface to compensate for ambient light conditions.

Superimposing a virtual image onto a real-world view is challenging, particularly in bright and/or non-uniform brightness environments. For example, a surface of a building in a real-world view that is directly illuminated by the sun will be brighter compared to an adjacent structure in the shadow of the building. Conventional solutions for providing virtual images under such conditions include increasing the brightness of the virtual image, for example, by increasing the intensity of the source light, or using photochromic lenses that change transmissivity when exposed to ultraviolet (UV) light. Increasing the intensity of the image source light requires increased power, is ineffective above certain brightness levels, and does not address non-uniform brightness environments. The use of photochromic lenses causes an entire viewing lens to be darkened, even though only a portion of the real-world view involves bright light and/or a superimposed image, ultimately leading to an uneven and/or distorted virtual image overlaid onto a real-world view. Accordingly, the described technology generally relates to virtual image presentation systems capable of dynamically modifying the transmissivity of discrete areas or zones of a projection surface thereof. In this manner, embodiments of the described technology may selectively compensate for bright ambient light and/or ambient light of non-uniform brightness while providing a distinct virtual image superimposed on a real-world view.

Reference is now made to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding thereof. It may be evident, however, that the novel embodiments can be practiced without these specific details. In other instances, known structures and devices are shown in block diagram form in order to facilitate a description thereof. The intention is to provide a thorough description such that all modifications, equivalents, and alternatives within the scope of the claims are sufficiently described.

Additionally, reference may be made to variables, such as, “a”, “b”, “c”, which are used to denote components where more than one component may be implemented. It is important to note, that there need not necessarily be multiple components and further, where multiple components are implemented, they need not be identical. Instead, use of variables to reference components in the figures is done for convenience and clarity of presentation.

FIG. 1 depicts a block diagram of an illustrative virtual image projection system according to a first embodiment. More specifically, FIG. 1 depicts a virtual image projection system **100** for projecting a virtual image superimposed over a real-world view according to some embodiments. In one embodiment, the virtual image projection system **100** may be implemented as a processor-based system that includes a device **102** having a processor circuit **110** (for

example, controller **530** depicted in FIG. 5) operably coupled to a memory unit **115**. Although one processor circuit **110** and one memory unit **115** are depicted in FIG. 1, embodiments may include a plurality of processor circuits **110** and/or memory units **115**. In some embodiments, the device **105** may not include a processor circuit **110** and/or memory unit **115**. In some
5 embodiments, the device **102** may receive control instructions from a remote computing device (not shown) having a processor circuit **110** and/or memory unit **115**.

In some embodiments, the device **102** may have installed a control application for controlling various aspects of the device **102** according to some embodiments described herein. In some embodiments, the control application may include a plurality of applications and/or
10 modules, such as a transmissivity application or module configured to control the transmissivity of the projection surface **105** and/or a virtual image application or module configured to control the device **102** to generate a virtual image **155**. In some embodiments, the transmissivity application and/or the virtual image application may be stand-alone applications. The control application, transmissivity application or module, and/or virtual image application or module
15 may be configured to communicate with each other, including, without limitation, sharing data, providing instructions, or the like. The memory unit **115** may store an unexecuted version of the control application, transmissivity application or module and/or the virtual image application or module and/or one or more data units used for controlling various aspects of the device **102**.

The device **102** may be implemented in various forms including, without limitation, a
20 HUD, a head-worn display (HWD), glasses, binoculars, a monocular device (e.g., scope, or the like), goggles, a windshield, a window, a helmet, a visor, a wearable device, or the like. Embodiments are not limited in this context. Although the virtual image projection system **100** shown in FIG. 1 has a limited number of elements in a certain topology, it may be appreciated that the virtual image projection system **100** may include more or less elements in alternate
25 topologies as desired for a given implementation.

As shown in FIG. 1, the device **102** may include a projection surface **105** having an external side **107** and an internal side **109**. The external side **107** may be configured to face the external environment to receive ambient (or environmental) light **120**, for example, such as light from the sun or an artificial light source. The projection surface **105** may be transparent to allow
30 ambient light **122**, **124** to pass through the projection surface **105** and enter the eye **155** of a user, thereby allowing the user to see a real-world view of objects external to the device **102** through the projection surface **105**. Although one projection surface **105** is depicted in FIG. 1, embodiments may include a plurality of projection surfaces **105**.

The projection surface **105** may include various materials arranged in one or more layers, films, coatings, and/or lenses (see, for example, FIGS. 4A-4B). For example, the projection
35

surface **105** may include one or more lenses, optical or polymer layers, variable-transmissivity materials, light-directing layers, light filters, or the like. The optical layer may be configured to protect the eye of a user, protect the other layers of the projection surface **105**, and/or provide a substrate for other layers of the projection surface **105**. In some embodiments, the optical layer
5 may be formed from an at least partially transparent material, including, without limitation, polymers, pre-polymers, optical polymers, urethane, polycarbonate, polystyrene, allyl diglycol carbonate, glass, optical glass, and Trivex®.

The variable-transmissivity material may be configured to modify the transmissivity, or the ability of light to pass through an object, of the projection surface **105**. In some embodiments,
10 the variable-transmissivity material may be embedded within another layer of the projection surface **105**. For example, the variable-transmissivity material may be embedded in an optical layer of the projection surface **105**. The variable-transmissivity material may be included in the projection surface **105** in various forms, including, without limitation, dyes, crystals, films, lenses, coatings, or the like. In some embodiments, the variable-transmissivity material may
15 operate by undergoing a reversible transformation in transmissivity in response to a stimulus. For example, a variable-transmissivity material may include a chemical species that changes from a first form to a second form in response to the stimulus. This change in form of the chemical species may modify the absorption spectra of the variable-transmissivity material to photo-irradiation, thereby modifying the transmissivity of the material. Accordingly, the
20 transmissivity of the projection surface **105** may be modified by applying the stimulus to the variable-transmissivity material of the projection surface **105**. In some embodiments, the device **102** may change the transmissivity of the projection surface only within one or more modified-transmissivity zones **170**. As such, specific portions of the projection surface **105** may be colored, tinted, shaded, darkened, or otherwise modified to reduce or completely eliminate the
25 ability of light to pass through portions of the projection surface **105** within the modified-transmissivity zone **170**. In some embodiments, the projection surface **105** may include one or more non-modified zones **172** in which the transmissivity of the projection surface **105** has not been modified. Accordingly, the transmissivity of certain zones of the projection surface **105** may be modified while the transmissivity of the remainder of the projection surface is not
30 modified.

The variable-transmissivity material may operate according to various techniques. For example, the variable-transmissivity material may include a material configured to change transmissivity in response to a stimulus **165** applied to the variable-transmissivity material by a stimulus source **160**. Non-limiting examples of variable-transmissivity materials may include
35 photochromic materials that change color in response to light, thermochromic materials that

change color in response to temperature, electrochromic materials that change color in response to an electrical stimulus (e.g., voltage, current, or the like), and materials that change color in response to other stimuli, including, without limitation, sound waves (e.g., ultrasound waves), magnetic forces, or the like.

- 5 Non-limiting examples of photochromic materials include, without limitation, inorganic salts, silver, spiropyran, spirobenzopyran, benzopyran, naphthopyran, spiroxazine, fulgide, fulgimide, dithienylethene, azobenzene, azulene, stilbene, chromene, diarylethene, photoinitiators, derivatives thereof, alloys thereof, salts thereof, and combinations thereof. Non-limiting examples of thermochromic materials include, without limitation, leuco dyes,
- 10 spiro lactones, spiropyrans, fluorans, fulgides, thermochromic liquid crystals, cholesteryl nonanoate, and cyanobiphenyls. Non-limiting examples of electrochromic materials include, without limitation, transition metal oxides, tungsten oxide, nickel oxide, polyaniline, pollythiophene, polyoxotungstate, polyoxometallates, viologens, indium tin oxide, metal hydrides, metallohexacyanate, niobium pentoxide, molybdenum trioxide, Iridium oxide (or
- 15 Iridium Sesquioxide), metallophthalocyanine, metal hexacyanometallates, liquid crystal materials, derivatives thereof, alloys thereof, salts thereof, and combinations thereof. In some embodiments, the variable-transmissivity material may be formed of liquid crystal materials formed as a liquid crystal display (LCD), a polymer-dispersed LCD (PDLC), or the like. In some embodiments, the liquid crystal materials may be formed as a layer or lens of the
- 20 projection surface **105**. In some embodiments, the liquid crystal materials may be formed as a film configured to coat at least a portion of the projection surface **105**.

In some embodiments, a change in transmissivity may include a change in color of the variable-transmissivity material and, therefore, the projection surface **105**. In some

25 embodiments, a change in transmissivity may be reversed or removed responsive to removal of the stimulus. Accordingly, in some embodiments, a variable-transmissivity material may include a chemical species that changes from a first form to a second form responsive to a stimulus, and the chemical species changes back to the first form responsive to removal of the stimulus. The reversal (for example, the chemical species changing from the second form back to the first form) may occur instantaneously or substantially instantaneously with removal of the stimulus or

30 after a period of time following removal of the stimulus (e.g., a “reversion time period” or “persistence time period”). In some embodiments, the persistence time period of the variable-transmissivity period may be selected to be at least longer than one frame of a virtual image. Accordingly, a single application of a stimulus may persist for multiple frames of the virtual image, thereby decreasing the power and resources required to maintain a modified-

transmissivity zone **170**. In some embodiments, a change in transmissivity may decrease over time (e.g., “fade away”) following removal of the stimulus.

In some embodiments, a change in transmissivity may be modified by application of a one or more other stimuli. For example, a variable-transmissivity material may include a chemical
5 species that changes from a first form to a second form responsive to light having a first wavelength, and the chemical species may change from the second form back to the first form (or to a third form) responsive to light having a second wavelength that is different from the first wavelength. In another example, a variable-transmissivity material may be configured to change
10 from a first form to a second form responsive to a first electrical signal (e.g., a first voltage) and from the second form to the first form (or to a third form) responsive to a second electrical signal (e.g., a second voltage) that is different than the first electrical signal. Accordingly, in some embodiments, a change in transmissivity due to a first stimulus may be maintained until removal of the first stimulus and/or an application of a second stimulus.

In some embodiments, the transmissivity of the projection surface **105** may have two states
15 or levels. For example, the projection surface **105** may have an inactive (i.e., “normal,” “bleached,” “clear,” “transparent,” or “transmissive”) state that occurs in the absence of a stimulus. The projection surface **105** may have an active state that occurs responsive to application of the stimulus. A higher amount (i.e., luminous intensity) of ambient light **122** may be allowed to pass through the projection surface **105** when the projection surface **105** is in the
20 inactive state compared to the amount of ambient light **124** allowed to pass through the projection surface **105** when the projection surface **105** is in the active state. For example, the projection surface **105** may experience a transmissivity reduction of about 0.25%, about 0.5%, 1%, about 5%, about 10%, about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 90%, about 100% (no transmissivity), or any range between any two of
25 these values (including endpoints) when the projection surface **105** is in the active state compared with the transmissivity of the projection surface **105** in the inactive state. Accordingly, as shown in FIG. 1, a greater amount of ambient light **122** may pass through a non-modified zone **172** compared with the amount of ambient light **124** passing through a modified-transmissivity zone **170**.

30 In some embodiments, the transmissivity of the projection surface **105** may be set at variable levels based on the application of the stimulus (for example, a transmissivity value between a maximum transmissivity value and a minimum transmissivity value). For instance, the transmissivity of a projection surface **105** having an electrochromic material may be decreased by increasing a voltage applied to the electrochromic material (down to a minimum
35 transmissivity value) and vice versa. In another instance, the transmissivity of a projection

surface **105** having a photochromic material may be decreased by increasing the intensity of a light stimulus and/or increasing the exposure time of the photochromic material to the light stimulus. In another instance, the transmissivity of the projection surface **105** having a thermochromic material may be decreased by increasing the temperature of the thermochromic material and/or increasing the exposure time of the thermochromic material to a heat stimulus.

In some embodiments, the device **102** may be configured to generate a plurality of modified-transmissivity zones **170**. In some embodiments in which the projection surface **105** includes a plurality of modified-transmissivity zones **170**, at least a portion of the modified-transmissivity zones **170** may have different levels of transmissivity. In some embodiments in which the projection surface **105** includes a plurality of modified-transmissivity zones **170**, the modified-transmissivity zones **170** may have the same or substantially the same levels of transmissivity. In some embodiments, the plurality of modified-transmissivity zones **170** may be separate, non-overlapping areas on the projection surface **105**. In some embodiments, at least a portion of the plurality of modified-transmissivity zones **170** may be touching or overlapping. In some embodiments, a modified-transmissivity zone **170** may cover the entire or substantially the entire projection surface **105** such that the projection surface **105** does not include a non-modified zone **172**.

In some embodiments, the projection surface **105** may include a light-directing optical element (e.g., layer or lens) to direct light to one or more viewpoints, for instance, the eye **155** of a user (e.g., proximate to a user's eye, proximate to where a user's eye would or should be during operation, or the like). For example, the device **102** may include a light projector **135** configured to project light **140** corresponding to an image onto the projection surface **105**. The light **140** may be formed of a plurality of light waves or light beams. Although one light projector **135** is depicted in FIG. 1, embodiments may include a plurality of light projectors **135**. During operation, the light-directing lens may direct the light **140**, for example, by reflecting the light at one or more angles, to generate a virtual image **150** visible to the eye **155** superimposed or overlaid onto the projection surface **105** (and, therefore, superimposed or overlaid over the real-world view visible through the projection surface **105**). In some embodiments, the light-directing lens may redirect the light **140** scanned across the projection surface **105** to project the virtual image **155** at a viewpoint and also allow ambient light **122, 124** to pass through from the external environment to the viewpoint. As such, virtual images and real world images may be viewed simultaneously.

In some embodiments, the light-directing lens may include a holographic optical element and/or diffractive optics. In some embodiments, the light-directing portion may include a holographic combiner lens. In one example, the holographic combiner lens may include a

transparent substrate with a photosensitive material (e.g., a photopolymer, a diochromatic gelatin, or the like) coated thereon. In another example, the holographic combiner lens may include an opaque substrate with a photosensitive material (e.g., a photopolymer, a diochromatic gelatin, or the like) coated thereon. The photosensitive material may be etched, for example, using a holographic recording process to provide reflective portions or reflective features. With some examples, a protective layer and/or material may be coated onto the photopolymer, for example, after it has been holographically recorded. In some embodiments, the light-directing lens may include optical materials such as a volume hologram material and/or a diffraction grating.

In some embodiments, the device **102** may include one or more brightness (or ambient light) sensors **190** to measure the amount, intensity, brightness, or the like of the ambient light **120** external to the device **100** and/or the brightness of the ambient light **122**, **124** that has passed through the projection surface **105**. The one or more brightness sensors **190** may generate brightness information associated with the external ambient light **120** and/or the internal ambient light **122**, **124**. The brightness information may indicate and/or be a measurement of the brightness of the external ambient light **120** and/or the internal ambient light **122**, **124**. In some embodiments, the brightness information may be used by the device **102** to determine a brightness differential information of the ambient light **120** and/or the ambient light **122**, **124** as a measure of non-uniform brightness conditions on discrete areas of the projection surface. For example, the projection surface **105** may be divided into a plurality of areas and brightness information may be provided for at least a portion of the plurality of areas. The device **102** may compare the brightness of the external ambient light **120** and/or the internal ambient light **122**, **124** associated with each of the plurality of areas to determine the brightness differential information. The brightness information and/or brightness differential information may be transmitted to the processor circuit **110** and/or stored in the memory **115**, for example, for use by the control application.

In some embodiments, a change in the transmissivity of the projection surface **105** may be initiated and/or performed based on the brightness information and/or the brightness differential information. For instance, the device **102** may cause a change in transmissivity of the projection surface **105** responsive to the brightness of the ambient light **120** and/or the ambient light **122**, **124** being above a threshold level based on the brightness information. In another instance, a level of transmissivity of the projection surface **105** may be based on the brightness information (i.e., the brighter the ambient light **120** and/or the ambient light **122**, **124** the lower the transmissivity level of a modified-transmissivity zone **170** and vice versa). In a further instance, the device **102** may cause a change in transmissivity of the projection surface **105** responsive to

the brightness differential of one or more areas of the projection surface **105** being above a threshold level based on the brightness differential information.

The device **102** may include an eye gaze tracker **175** to monitor the point of gaze of the eye **155**. The eye gaze tracker **175** may provide real-time and/or substantially real-time information
5 indicating the point of gaze of a user interfacing with the device **102**. The eye gaze tracker **175** may generate eye gaze information that may be transmitted to the processor circuit **110** and/or stored in the memory **115**, for example, for use by the control application. A head position tracker **180** may be used to monitor the position of the head of a user interfacing with the device **102**. The head position tracker **180** may generate head position information that may be
10 transmitted to the processor circuit **110** and/or stored in the memory **115**, for example, for use by the control application. The device **102** may use the eye gaze information and/or the head position information to determine an eye gaze location **185** of the eye **155** on the projection surface **105**. The eye gaze location **185** may indicate an area of the projection surface **105** that is being looked at by the user (i.e., user focal point on the projection surface **105**). In some
15 embodiments, the device **102** may specifically determine the brightness of light at the eye gaze location **185** for use in generating a modified-transmissivity zone according to some embodiments.

During operation, the device **102** may be configured to provide one or more virtual images **150** at one or more viewpoints superimposed on a real-world view observed by the eye **155**
20 through the projection surface **105**. The processor **115** may execute a control application (and/or virtual image application or module) operable to instruct a light projector **135** to project light **140** corresponding to an image on the projection surface **105**. The light projector **135** may include various light projection elements. In some examples, the light projector **135** may include a scanning mirror or panel microdisplay projector to project the light **140** onto the projection
25 surface **105**. In general, the light projector **135** may include a power source, a light source, and a projection system. In some examples, the power source may be a battery. In some embodiments, the light source may be a laser light source, a light emitting diode (LED) light source, or in general, any light source configured to emit light. In some embodiments, the light projector **135** may include a micropanel projector. In some embodiments, the light projector **135**
30 may include a microelectromechanical system (MEMS) based scanning mirror projection system. In some embodiments, the light projector **135** may include a digital light processing (DLP) based projection system. In some embodiments, the light projector **135** may include one or more of a signal processing component, a signal interface component, and a graphics processing component to project light onto the projection surface **105** to project a virtual image
35 at a viewpoint.

During operation of the device **102**, the light projector **135** may direct the light **140** toward a projection zone **145** on the projection surface **105**. The light-directing lens of the projection surface **105** may cause at least a portion of the light **140** to be redirected to generate the virtual image **150** at a viewpoint. The eye **155** may view the virtual image **150** superimposed onto a real-world view. In some embodiments, the projection zone **145** may be determined based on the eye gaze information, the head position information, and/or the eye gaze location **185**.

During operation of the device **102**, the control application (and/or transmissivity application or module) may direct a stimulus source **160** to apply a stimulus **165** to at least a portion of the variable-transmissivity material of the projection surface **105** to generate a modified-transmissivity zone **170** having various properties on the projection surface **105**. The properties of the modified-transmissivity zone **170** may include, without limitation, location, size (e.g., zone area), duration, transmissivity reduction amount, color, or the like. In some embodiments, the control application may dynamically modify properties of a modified-transmissivity zone **170**, for example, based on various information as described herein.

The stimulus **165** used to generate a modified-transmissivity zone **170** may include various forms, including, without limitation, light, sound, heat, electrical signals, magnetic forces, or the like. In general, the stimulus **165** may be selected based on a reaction required to change the transmissivity of the variable-transmissivity material of the projection surface **105**. In an embodiment in which the variable-transmissivity material includes a photochromic material, a light stimulus source **165** may provide a light stimulus **165** having a wavelength that causes a change in the transmissivity of the photochromic material. For instance, the stimulus **165** may include ultraviolet (UV) light and the transmissivity of the variable-transmissivity material may change in response to UV light. Non-limiting examples of a light stimulus **165** may include UV light (e.g., light having a wavelength of about 10 nanometers (nm) to about 400 nm), visible light (e.g., light having a wavelength of about 400 nm to about 700 nm), and infrared (IR) light (e.g., light having a wavelength of about 700 nm to about 1 millimeter (mm)). In some embodiments, a stimulus source **160** for a light stimulus **165** may include, without limitation, a laser light source, an LED light source, or in general, any light source configured to emit light.

In an embodiment in which the variable-transmissivity material includes an electrochromic material, an electrical stimulus source **165** may provide an electric signal stimulus **165** that causes a change in the transmissivity of the electrochromic material. For instance, the stimulus **165** may include a voltage and the transmissivity of the variable-transmissivity material may change in response to an applied voltage. In another instance, the variable-transmissivity material may include an LCD film arranged on at least a portion of the projection surface **105** and the stimulus **165** may include an electric current applied to the LCD film via an electrical

stimulus source **160**. In an embodiment in which the variable-transmissivity material includes an LCD material, the LCD material may be formed of a plurality of cells. The device **102** may selectively apply the stimulus **165** to the individual cells to form the modified-transmissivity zone **170**.

5 In embodiments in which the variable-transmissivity material includes a thermochromic material, a thermal stimulus source **160** may be configured to apply a thermal stimulus **165** to the variable-transmissivity material. A non-limiting example of a thermal stimulus source **160** may include a laser configured to apply a heat stimulus **165** to the variable-transmissivity material.

Although FIG. 1 depicts the light projector **135** and the stimulus source **160** as being
10 separate elements, embodiments are not so limited. For example, the light projector **135** may include the stimulus source **160** (see, for example, FIG. 3). For instance, the stimulus source **160** may be a UV light source arranged within a light projector **135** configured to project red, green, and blue (“RGB”) light **140**. In some embodiments, the light projector **135** may be a stimulus source **160**. For instance, the stimulus **165** may be visible light, such as red light (e.g., light
15 having a wavelength of about 620 nm to about 750 nm), and the light projector **135** may project RGB light **140**. Accordingly, the light projector **135** may also operate as the stimulus source **160** because red light in the RGB light **140** used to form the virtual image **150** also operates as the stimulus **165**.

In some embodiments, the device **102** may direct the stimulus source **160** to generate the
20 modified-transmissivity zone **170** during the display of a virtual image **155**. In some embodiments, the device **102** may direct the stimulus source **160** to generate the modified-transmissivity zone **170** during the display of a virtual image **155** based on one or more factors. Illustrative and non-limiting examples of factors may include the brightness of the external ambient light **120** and/or internal ambient light **122**, the brightness differential (e.g., non-uniform
25 brightness) of the external ambient light **120** and/or internal ambient light **122**, user-specified settings, and aspects of the virtual image **155**, such as the brightness and/or the colors of the virtual image **155**. For example, the device **102** may generate a modified-transmissivity zone **170** responsive to the brightness of the external ambient light **120** and/or internal ambient light **122** being above a threshold amount. In another example, the device **102** may generate a
30 modified-transmissivity zone **170** to compensate for a non-uniform brightness environment by reducing the transmissivity of areas of the projection surface **105** exposed to higher intensity ambient light **120**. For instance, the control application may determine a brightness differential of areas of the projection surface **105** based on the brightness information and may generate one or more modified-transmissivity zones **170** in areas where the brightness differential is above a
35 threshold value. For example, light having a first luminous intensity may be incident on a first

area of the projection surface **105** (e.g., direct sunlight) and light having a second luminous intensity that is less than the first luminous intensity (e.g., indirect sunlight or light from a shaded object) may be incident on a second area of the projection surface. The device **102** may be configured to generate a modified-transmissivity zone **170** on the first area in order to reduce the transmissivity of (e.g., “dim” or “darken”) the first area. Accordingly, the device **102** may operate to provide uniform or substantially uniform brightness to a user.

In a further example, the device **102** may generate a modified-transmissivity zone **170** responsive to the brightness of the virtual image **155** being below a threshold value.

Accordingly, the device **102** may reduce the power required to generate a brighter image via increasing the intensity of the light **140**. In a still further example, the device **102** may generate a modified-transmissivity zone **170** responsive to the virtual image including certain colors, for example, yellow, that may be difficult to see superimposed over the ambient light **122**. In yet a still further example, the device **102** may generate a modified-transmissivity zone **170** to highlight and/or provide contrast with aspects and/or colors of a virtual image **155** and/or a real-world view. For instance, the device **102** may generate a red or yellow non-transmissivity zone **170** to highlight a virtual image **155** and/or portions of the virtual image **155**. In another instance, the device **102** may generate a modified-transmissivity zone **170** to highlight, cover, or otherwise delineate an object in the real-world view (e.g., form a darkened or yellow box around an object in the real-world view).

In some embodiments, the device **102** may generate and/or not generate a modified-transmissivity zone **170** responsive to user input (e.g., an IR sensor for hand gestures, audio input device, buttons, user-specified preferences, or the like). In some embodiments, the device **102** may generate a modified-transmissivity zone **170** responsive to one or more control signals from the virtual image application (or virtual image module of the control application). For example, the instructions for generating a virtual image **150** on the device **102** may include instructions for the device to generate a modified-transmissivity zone **170** according to some embodiments described herein.

In some embodiments, the modified-transmissivity zone **170** and/or the non-modified zone **172** may be associated with zone information. The zone information may provide instructions, data, or the like for generating a modified-transmissivity zone **170** or maintaining a non-modified zone **172**. The zone information may specify properties of a modified-transmissivity zone **170**. For example, the zone information may include, without limitation, location, size, duration, transmissivity level, color, stimulus, stimulus source, virtual image overlap (e.g., amount modified-transmissivity zone should extend beyond virtual image), projection surface for transmissivity zone (e.g., for multi-projection surface device), zone active/inactive information

(e.g., a trigger indicating whether a specified modified-transmissivity zone should be generated), and/or the like. The control application (or transmissivity application or module) may use the zone information to control the generation of the modified-transmissivity zone **170**. For instance, the zone information may specify that a modified-transmissivity zone **170** should be
5 generated at location X, Y on the projection surface **105** having a size Z, for a duration of 30 seconds (or while a virtual image is being generated), and the modified-transmissivity zone **170** should reduce the transmissivity of the projection surface **105** by 20% (or provide a target luminous intensity of the ambient light **124**). In another instance, the zone information may provide data and/or instructions that a modified-transmissivity zone **170** should not be generated
10 in a certain area of the projection surface **105**, for example, to maintain a non-modified zone **172**.

In some embodiments, the device **102** may generate at least a portion of the zone information. In some embodiments, at least a portion of the zone information may be based on user-specified preferences. In some embodiments, the virtual image application may provide zone information to the control application for generating the modified-transmissivity zone **170**.
15 The zone information may be generated based on various information including, without limitation, projection zone information (e.g., location, size, duration, and/or the like of the projection zone), virtual image information (e.g., location, size, duration, colors, brightness, and/or the like of the virtual image), brightness information, brightness differential information, eye gaze information, head position information, eye gaze location **185**, and/or the like. In some
20 embodiments, at least a portion of the zone information may be used to ensure that a modified-transmissivity zone **170** is located, sized, and/or tinted appropriately for a virtual image **150**. For example, the zone information may indicate where the modified-transmissivity zone **170** should be located such that the virtual image **150** is superimposed on the real-world view over the modified-transmissivity zone **170** (i.e., to reduce the brightness of the ambient light **124** incident
25 on the eye **155** in the area where the virtual image **150** is generated). In another example, the transmissivity reduction of a modified-transmissivity zone **170** may be determined and/or dynamically modified based on the brightness of the external ambient light **120** and/or internal ambient light **122**, **124** based on the brightness information.

In some embodiments, the projection surface **105** may include a plurality of variable-transmissivity materials. In some embodiments, the plurality of variable-transmissivity materials
30 may be arranged in a plurality of layers, films, lenses, or the like. In some embodiments, the plurality of variable-transmissivity materials may be arranged in one layer, film, lens, or the like of the projection surface **105**. In some embodiments, at least a portion of the plurality of variable-transmissivity materials may have different transmissivity modification characteristics.
35 For example, certain of the plurality of variable-transmissivity materials may be configured to

modify the transmissivity of the projection surface **105** by changing to different colors in response to a stimulus **165**. For instance, a first variable-transmissivity material layer may be configured to change to yellow in response to a first stimulus **165** and a second variable-transmissivity material layer may be configured to change to magenta in response to a second stimulus **165**. In another example, certain of the plurality of variable-transmissivity materials may be have a different duration of maintaining a modified state after removal of a stimulus a stimulus **165**. In a further example, certain of the plurality of variable-transmissivity materials may experience a modification of transmissivity in response to different stimuli **165**. For instance, a first variable-transmissivity material may undergo a transmissivity modification in response to an electric signal stimulus **165** (e.g., an LCD layer), and a second variable-transmissivity material may undergo a transmissivity modification in response to a light stimulus **165** (e.g., a photochromic material layer). In this manner, the device **102** may be configured to modify the transmissivity of select portions of the projection surface **105** using a plurality of transmissivity characteristics.

In some embodiments, the projection system **100** may include additional elements not shown in FIG. 1. Non-limiting examples of additional elements may include a power source, wireless communication elements (e.g., transceivers), user input elements (e.g., buttons, switches, audio command input elements, touchscreen elements, gesture input elements, or the like), video and/or still image cameras, video and/or still image displays, sensors (e.g., heat sensors, touch sensors, or the like), or the like.

FIG. 2 depicts a block diagram of an illustrative virtual image projection system according to a second embodiment. More specifically, FIG. 2 illustrates an internal view of an example optical system **200** for projecting a virtual image at a viewpoint according to some embodiments. As shown in FIG. 2, a device **102** or at least a portion of a device **102** may be implemented as an optical system **200** in the form of a HWD (i.e., glasses). FIG. 2 depicts the virtual image **150** and the modified-transmissivity zone **170** as would be observed by the eye **155** of a user of the optical system **200**.

The projection surface **105** may be formed as an optical lens arranged in the frame **205** of the glasses. The light projector **135** may generate a virtual image **150** superimposed over at least a portion of a real-world view **210** visible through the projection surface **105**. The stimulus source **160** may generate a modified-transmissivity zone **170** on the projection surface **105** according to some embodiments described herein. Although the light projector **135** and the stimulus source **160** are depicted in FIG. 2 as being arranged on a temple or hinge region of the frame **205**, embodiments are not so limited. For instance, the light projector **135** and the

stimulus source **160** may be arranged on any portion of the frame **205** capable of operating according to some embodiments described herein.

In some embodiments, the device optical system **200** may be configured to receive information of a location of and/or determine a location of the virtual image **150** overlaid on the projection surface **105** as viewed by the eye **155** of a user. For example, the control application may receive and/or determine virtual image location information that indicates an area of the projection surface **105** that is overlapped by the virtual image **150** from the perspective of the eye **155** of a user. The virtual image location information may be based on various information including, without limitation, eye gaze information, head position information, eye gaze location **185**, a location of the projection zone **145**, or a combination thereof.

In some embodiments, the modified-transmissivity zone **170** may be positioned on the projection surface **105** to correspond with the location of the virtual image **150** as viewed by the eye **155**. In some embodiments, the virtual image **150** may be positioned to correspond with the location of the modified-transmissivity zone **170**. For example, the modified-transmissivity zone **170** may be positioned on the projection surface **105** such that at least a portion of the virtual image **150** is overlaid on the modified-transmissivity zone **170** as visible to the eye **155**. Accordingly, from the perspective of the eye **155** of the user, the modified-transmissivity zone **170** is arranged on the projection surface **105** such that the modified transmissivity zone **170** is behind the virtual image **150**. In this manner, the light **140** incident on the eye **155** to generate the virtual image **150** is overlaid on the reduced-transmissivity internal ambient light (i.e., ambient light **124**) that is incident on the eye **155** after passing through the reduced-transmissivity zone **170** to provide at least a portion of the image of the real-world view **210** (i.e., a reduced-transmissivity portion of the real-world view **210**). As described according to some embodiments, the reduced-transmissivity internal ambient light (i.e., ambient light **124**) has a reduced transmissivity as a result of passing through the reduced-transmissivity zone **170** as compared with the internal ambient light (i.e., ambient light **122**) that passes through the non-modified zone **172**.

In some embodiments, the modified-transmissivity zone **170** may be positioned on the projection surface **105** such that all or substantially all of the virtual image **150** is overlaid on the modified-transmissivity zone **170** (or the real-world view **210** formed from ambient light (i.e., ambient light **124**) passing through the modified-transmissivity zone **170**). In some embodiments, the modified-transmissivity zone **170** may be sized such that the modified-transmissivity zone **170** is larger than the virtual image **150** as visible to the eye **155**. For example, as shown in FIG. 2, all of the virtual image **150** is overlaid on the modified-transmissivity zone **170** and at least a portion of the modified-transmissivity zone **170** extends

beyond the virtual image **150**. In some embodiments, the size of the modified-transmissivity zone **170** may be a specified amount larger than the virtual image **150**. For example, the modified-transmissivity zone **170** may be a specified percentage larger than the virtual image **150**. Non-limiting examples of a specified percentage may include 0.5%, 1%, 5%, 10%, 20%, 50%, 100%, and any value or range between any two of these values (including endpoints). In another example, For example, the modified-transmissivity zone **170** may be a specified distance larger than the virtual image **150** in one or more directions (e.g., the horizontal direction, the vertical direction, etc.). Non-limiting examples of a specified distance may include 0.1 mm, 0.25 mm, 0.5 mm, 1.0 mm, 2.0 mm, 5.0 mm, and any value or range between any two of these values (including endpoints).

FIG. 3 depicts a block diagram of an illustrative virtual image projection system according to a third embodiment. More specifically, FIG. 3 illustrates an example optical system **300** for projecting a virtual image at a viewpoint according to some embodiments. As shown in FIG. 3, an optical system **300** may include a light source **135** having an RGB light element **315** for providing light for generating a virtual image. The light source **135** may also include a stimulus source **160** in the form of a UV light source. The UV light provided by the stimulus source may modify the transmissivity of a variable-transmissivity material of the projection surface **105**. The optical system **300** may include an optical element **305** configured to receive the RGB light and/or the UV light from the light projector **135**. The optical element **305** may be configured to shape, collimate, and/or otherwise combine the RGB light and/or the UV light into a combined light beam **320** for transmission to a projection optics element **310**. The optical element **305** may contain various components for combining the RGB light and/or the UV light from the light projector **135** including, without limitation, mirrors, lenses, collimators, lasers, a combination thereof, or the like.

The projection optics element **310** may receive the combined light beam **320** from the optical element **305** and scan the combined light beam **320** as projected light **325** on a projection zone **145** of the projection surface **105** to generate a virtual image (not shown). The projection optics element **310** may contain various components for scanning the projected light **325** onto the projection surface **105**, including, without limitation, mirrors, lenses, a MEMS-based projection system (e.g., a two-dimensional (2D) MEMS scanning mirror projection system), a matrix-based projection system (e.g., DLP), a combination thereof, and/or the like.

At least a portion of the RGB light in the projected light **325** scanned by the projection optics element **310** may reflect off of the projection surface **105** (or a holographic lens of the projection surface **105**) to generate a virtual image. At least a portion of the UV light in the projected light **325** scanned by the projection optics element **310** may be incident on a variable-

transmissivity material of the projection surface **105** to generate a modified-transmissivity zone **170**.

FIG. 4A depicts a block diagram of illustrative projection surface according to a first embodiment and FIG. 4B depicts a block diagram of illustrative projection surface according to a second embodiment. As shown in FIGS. 4A-4B, in some embodiments, the projection surface **105** may include a plurality of layers. In some embodiments, the plurality of layers may include lenses, films, coatings, or the like. As shown in FIG. 4A, a projection surface **105** may include a variable-transmissivity layer **404**, a light-directing layer **406**, and an optical lens layer **402**. In some embodiments, the variable-transmissivity layer **404** may be formed as an optical lens coated with and/or embedded with a variable-transmissivity material. In some embodiments, the variable-transmissivity layer **404** may be applied to the external side **107** of the projection surface **105** in order to only reduce the transmissivity of the external ambient light **120** entering the eye **155**, while not reducing the brightness of the projected light **140** used to generate the virtual image **150**.

As shown in FIG. 4B, a projection surface **105** may include a first optical lens layer **402a**, a filter layer **408**, a variable-transmissivity layer **404**, a light-directing layer **406**, and a second optical lens layer **402b**. In some embodiments in which the stimulus for the variable-transmissivity layer **404** includes light in the spectrum of ambient light **120** (e.g., UV light), the filter layer **408** may filter out the stimulus light in order to prevent ambient light **120** from modifying the transmissivity of the variable-transmissivity layer **404**. In some embodiments, the filter layer **408** may operate to filter UV light from the ambient light **120**. In some embodiments, the filter layer **408** may operate to filter certain wavelengths of the ambient light **120** to change the color(s) of the internal ambient light **122**.

Although FIGS. 4A-4B depict layers of the projection surface **105** in a particular topology, embodiments are not so limited, as the projection surface **105** may contain more or less layers and/or layers arranged in other topologies. In a first example, the projection surface **105** may include, in an order from the external side **107** to the internal side **109**, a variable-transmissivity layer **404**, a light-directing layer **406**, and an optical lens layer **102**. In a second example, the projection surface **105** may include, in an order from the external side **107** to the internal side **109**, a variable-transmissivity layer **404** and a light-directing layer **406**. In a third example, the projection surface **105** may include, in an order from the external side **107** to the internal side **109**, an optical lens layer **102**, a first variable-transmissivity layer **404**, a second variable-transmissivity layer **404** having a variable-transmissivity material different than the first variable-transmissivity layer **404**, a light-directing layer **406**, and an optical lens layer **102**. Embodiments are not limited in this context.

In addition, although FIGS. 4A-4B depict layers of the projection surface **105** as separate layers, embodiments are not so limited as the layers may include a first layer incorporated into a second layer. For example, the light directing layer **406** may be incorporated into an optical layer **402** (e.g., light directing optics incorporated into a polycarbonate layer). In another
5 example, the variable-transmissivity layer **404** may be incorporated into a light directing layer **406** (e.g., a variable-transmissivity material may be incorporated into the material of the light directing layer **406**). Embodiments are not limited in this context.

FIG. 5 depicts a block diagram of an illustrative virtual image projection system according to a fourth embodiment. More specifically, FIG. 5 depicts a block diagram of a virtual image
10 projection system **500**. In some examples, the virtual image projection system **500** may be implemented as the virtual image projection system **100**, **200**, and/or **300** described herein. In general, the virtual image projection system **500** may be provided to scan light over a projection surface (e.g., projection surface **105**) to generate a virtual image according to some embodiments described herein.

15 In particular, the system **500** may include a scanning optical system **505**. The scanning optical system **505** may include a light source **515** (e.g., a laser, an LED, or the like). Additionally, the scanning optical system **505** may include a mirror **510**. The mirror **510** may be and/or include a MEMS-based mirror configured to scan light emitted from the light source **515** across a projection surface.

20 The scanning optical system **500** may include a transmissivity modification system **520** configured to modify the transmissivity of a projection surface used to generate a virtual image. The transmissivity modification system **520** may include at least one stimulus source **525a-n** configured to apply a stimulus to a variable-transmissivity material of the projection surface.

The scanning optical system **500** may also include a controller **530**. In general, the
25 controller **530** may comprise hardware and/or software (e.g., a control application, a virtual image application or module, and/or a transmissivity application or module) and may be configured to execute instructions to cause the controller **530** to send information and/or one or more control signals to light source **510** and/or the mirror **515** to cause the light source **510** to emit light and the mirror **515** to rotate about a number of axes to scan the light over and/or across
30 the projection surface. The controller may be configured to execute instructions to cause the controller **530** to send information and/or one or more control signals to the transmissivity modification system **520** to instruct a stimulus source **525a-n** to apply a stimulus to a variable-transmissivity material of the projection surface.

The controller **530** may include an eye tracking component **535a**. The eye tracking
35 component **535a** may include a camera, a combination of an LED, a vertical-cavity surface-

emitting laser (VCSEL), a micro-LED, a resonant-cavity light emitting diode (RC-LED), a laser-based illumination source and a photo-sensor, such as a photodiode or an array of photodiodes, and/or the like. The eye tracking component **535a** may be configured to track and/or determine a position or viewpoint of a user's eyes and/or head. In some embodiments, the eye tracking component **535a** may be used to generate eye gaze information, head position information, and/or an eye gaze location (e.g., eye gaze location **185**).

The controller **530** may include a light measurement component **535b**. The light measurement component **535b** may include one or more sensors configured to measure the brightness, intensity (e.g., luminous intensity), density, or other measurable characteristics of light. Non-limiting examples of sensors may include, without limitation, photoelectric sensors, cameras, light dependent resistors (LDR) (e.g., photodiodes and photoresistors), or the like. In some embodiments, the light measurement component **535b** may operate to generate brightness information indicating a brightness (e.g., luminous intensity) of external ambient light and/or internal ambient light. In some embodiments, the light measurement component **535b** may be configured to measure, indicate, or otherwise derive brightness differential information for external ambient light incident on a projection surface and/or internal ambient light directed toward a user (and potentially incident on the eye of the user). In some embodiments, the brightness differential information may indicate locations and/or amounts of non-uniform brightness of external ambient light and/or internal ambient light. For example, the brightness differential information may be used to indicate the brightness and/or differences in brightness of external ambient light incident on different areas of the projection surface and/or internal ambient light passing through the different areas of the projection surface. Accordingly, the scanning optical system **500** may use the brightness differential information to determine bright/dark areas of the projection surface and/or brightness variances on areas of the projection surface for generating modified-transmissivity zones.

The controller **530** may include an image processor component **535c**. The image processor component **535c** may be configured to use the scanning optical system **505** to generate virtual images. The image processor component **535c** may include hardware and/or software configured to generate virtual images according to a virtual image application or module of a scanning optical system **500** control application. The image processor component **535c** may be configured to receive, determine, or otherwise originate a source image to be displayed to a user of the scanning optical system **500**. The image processor component **535c**, for example, through controller **530**, may control the transmission of light from a light source (e.g., light source **135**) onto a projection surface (e.g., projection surface **105**) to generate a virtual image of the source image visible to the user. The image processor component **535c** may determine the type of light

(e.g., the combination of red, blue, green, etc. light beams), the target location of the light (e.g., projection zone **145** and/or target locations of the scanned light beam(s) within the projection zone **145**), angles of light projection, light scan duration, light intensity, and/or the like to generate the virtual image. The image processor component **535c** may access information from one or more other components of the scanning optical system **500**, such as the eye tracking component **535a**, the light measurement component **535b**, and/or the transmissivity component **535d**. In some embodiments, the image processor component **535c** may generate and/or receive image information associated with the virtual image (e.g., virtual image **155**) including, without limitation, colors, size, location, brightness, object information, active/inactive status (e.g., a signal indicating a virtual image is being displayed, a signal that a virtual image is no longer being displayed, or the like), duration, or the like. In some embodiments, the scanning optical system **505** may receive and/or generate at least a portion of the image information. For instance, the scanning optical system **505** may provide image information relating to the creation of the virtual image to the controller **530**, image processor component **535c**, and/or transmissivity component **535d**.

The controller **530** may include a transmissivity component **535d** configured to generate one or more modified-transmissivity zones (e.g., modified-transmissivity zone **170**) according to various embodiments. The transmissivity component **535d** may operate to use the transmissivity modification system **520** to modify the transmissivity of a projection surface of the scanning optical system **500**. The transmissivity component **535d** may include hardware and/or software configured to modify the transmissivity of the projection surface according to a transmissivity application or module of a scanning optical system **500** control application.

The transmissivity component **535d** may operate to instruct the transmissivity modification system **520** to apply a stimulus to the projection surface according to zone information. For example, the transmissivity component **535d** may control a stimulus source to apply a stimulus to generate a modified-transmissivity zone on the projection surface at a location and having a size, duration, and/or color based on the zone information. In some embodiments, the transmissivity component **535d** may receive information from various components, such as the eye tracking component **535a**, the light measurement component **535b**, and/or the image processor component **535c**. The transmissivity component **535d** may operate to generate a modified-transmissivity zone based on one or more factors, including, without limitation, ambient light brightness, eye gaze location, virtual image information, projection zone location, or the like. For example, the transmissivity component **535d** may initiate the generation of a modified-transmissivity zone responsive to receiving virtual image information indicating a virtual image is being generated, and the transmissivity component **535d** may stop the

application of a stimulus to generate a modified-transmissivity zone responsive to receiving virtual image information indicating that the virtual image is no longer being generated. In another example, the transmissivity component **535d** may modify one or more attributes of a modified-transmissivity zone responsive to virtual image information. For instance, the

5 transmissivity component **535d** may change the location, size, color, transmissivity reduction, or the like responsive to image information indicating a change in a corresponding property of a virtual image being presented to a user. In some embodiments, the transmissivity component **535d** may dynamically and/or automatically modify properties of a modified-transmissivity zone based on information received from such as the eye tracking component **535a**, the light

10 measurement component **535b**, and/or the image processor component **535c**. For example, the location of a modified-transmissivity zone may be changed based on a change in the eye gaze location. In another example, the transmissivity reduction amount may be increased/decreased due to an increase/decrease in the brightness of ambient light. In a further example, properties of a modified-transmissivity zone may be modified responsive to changes in the virtual image. In a

15 still further example, a plurality of modified-transmissivity zones may be generated responsive to image information indicating a plurality of virtual images are being projected to a user.

In some embodiments, the scanning optical system **500** and/or components thereof may receive information, instructions, or the like from one or more remote electronic devices. Non-limiting examples of electronic devices include, without limitation an ultra-mobile device, a

20 mobile device, a personal digital assistant (PDA), a mobile computing device, a smart phone, a digital telephone, a cellular telephone, electronic readers (e.g., eBook readers, e-readers, etc.), a handset, a one-way pager, a two-way pager, a messaging device, a computer, a personal computer (PC), a desktop computer, a laptop computer, a notebook computer, a netbook computer, a handheld computer, a tablet computer, a server, a web server, a network server, an

25 Internet server, a work station, a mini-computer, a main frame computer, a supercomputer, a network appliance, a web appliance, a distributed computing system, multiprocessor systems, processor-based systems, consumer electronics, programmable consumer electronics, game devices, a television, digital television, set top box, wireless access point, machine, or combination thereof.

30 The scanning optical system **500** may include one or more transceivers **502** for managing wired or wireless communication via one or more communication protocols between the scanning optical system **500** and the electronic devices. Non-limiting examples of communication protocols may include Bluetooth as defined by the Bluetooth Special Interest Group, an infra-red (IR) system, an Institute of Electrical and Electronics Engineers (IEEE)

35 802.15 system, a DASII7 system, wireless universal serial bus (USB), wireless high-definition

(HD), an ultra-side band (UWB) system, an IEEE 802.xx series of protocols, such as the IEEE 802.11a/b/g/n series of standard protocols and variants (also referred to as “WiFi”). It may be appreciated that other wireless techniques may be implemented, and the embodiments are not limited in this context.

5 For example, the image processor component **535c** may receive data and/or instructions from a server, game system, or the like for generating a virtual image and/or a modified-transmissivity zone. In another example, the transmissivity component **535d** may receive user input from a computing device (e.g., a smartphone) to turn on/off the generation of virtual images and/or modified-transmissivity zones.

10 Included herein is a set of flow charts representative of exemplary methodologies for performing novel aspects of the disclosed architecture. While, for purposes of simplicity of explanation, the one or more methodologies shown herein, for example, in the form of a flow chart or flow diagram, are shown and described as a series of acts, it is to be understood and appreciated that the methodologies are not limited by the order of acts, as some acts may, in
15 accordance therewith, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all acts illustrated in a methodology may be required for a novel implementation

20 FIG. 6 depicts an illustrative logic flow according to a first embodiment. More specifically, FIG. 6 illustrates one embodiment of a logic flow **600**. The logic flow **600** may be representative of some or all of the operations executed by one or more embodiments described herein. For example, the logic flow **600** may illustrate operations performed by the virtual image projection system **100**, virtual image projection system **200**, virtual image projection system **300**,
25 and/or virtual image projection system **500**.

In the illustrated embodiment shown in FIG. 6, the logic flow **600** may receive zone information at block **602**. For example, the transmissivity component **535d** may receive and/or generate zone information for specifying various properties of a modified-transmissivity zone including, without limitation, location, size, duration, transmissivity reduction, or the like. In
30 one example, the transmissivity component **535d** may generate zone information indicating a location and a size of a modified-transmissivity zone on a projection surface. In one example, the zone information may include a trigger to start/stop generating a particular modified-transmissivity zone. In some embodiments, at least a portion of the zone information may be generated based on image information indicating, for example, a location, size, color, or the like
35 of a virtual image being or to be displayed to a user. The transmissivity component **535d** may

generate zone information to correspond with the virtual image, for instance, to ensure that the virtual image is superimposed over the modified-transmissivity zone. The transmissivity component **535d** may process and/or transmit the zone information to the controller **530** for use by the virtual image projection system **500**.

5 The logic flow **600** may apply a stimulus to a projection element to generate a modified-transmissivity zone based on the zone information at block **604**. For example, the controller **530** may instruct a stimulus source **525a-n** to apply a stimulus to at least a portion of a variable-transmissivity material of a projection surface (e.g., projection surface **105**) to generate a modified-transmissivity zone (e.g., modified-transmissivity zone **170**) on a portion of the
10 projection surface. In some embodiments, the controller **530** instructions to the stimulus source **525a-n** may be determined based on information and/or instructions from the transmissivity component **535d**. Attributes of the modified-transmissivity zone may be based on the zone information. For instance, the location and size of the transmissivity zone may be specified by the zone information. The stimulus may operate to change a property of the variable-
15 transmissivity material to modify the transmissivity of the portion of the projection surface within the modified-transmissivity zone. For example, the stimulus may operate to change a color of the projection surface within the modified-transmissivity zone (e.g., from transparent to yellow). In another example, the stimulus may operate to reduce the transmissivity (e.g., tint, darken, or the like) of the projection surface, for instance, by 20% compared with a non-
20 modified zone of the projection surface. The modified-transmissivity zone may be generated such that at least a portion of the virtual image is superimposed over at least a portion of the modified-transmissivity zone. Accordingly, the brightness of at least a portion of the ambient light (e.g., ambient light **124**) that is incident on the eye (e.g., eye **155**) to generate the real-world view (e.g., real-world view **210**) behind the virtual image (e.g., virtual image **150**) may be
25 reduced or otherwise modified as compared with ambient light (e.g., ambient light **122**) that does not pass through the modified-transmissivity zone.

 The logic flow **600** may project light onto a projection zone of the projection element to generate a virtual image at block **606**. For example, the controller **530** may instruct the scanning optical system **505** and/or elements thereof (e.g., light source **510** and/or mirror **515**) to project
30 light (e.g., light **140**) onto a projection zone (e.g., projection zone **145**) of a projection surface of the virtual image projection system **500** to generate a virtual image for observation by an eye of a user. In some embodiments, the controller **530** instructions to the scanning optical system **505** may be determined based on information and/or instructions from the image processor component **535c** and/or the transmissivity component **535d**. At least a portion of the virtual
35 image may be superimposed over at least a portion of the modified-transmissivity zone.

FIG. 7 depicts an illustrative logic flow according to a second embodiment. More specifically, FIG. 7 illustrates one embodiment of a logic flow **700**. The logic flow **700** may be representative of some or all of the operations executed by one or more embodiments described herein. For example, the logic flow **700** may illustrate operations performed by the virtual image projection system **100**, virtual image projection system **200**, virtual image projection system **300**, and/or virtual image projection system **500**.

In the illustrated embodiment shown in FIG. 7, the logic flow **700** may measure the brightness of environmental light at block **702**. For example, the light measurement component **535b** may receive information from one or more light sensors (e.g., light sensor **190**). The light sensors may be configured to measure the amount, intensity, brightness, or the like of the ambient light (e.g., ambient light **120**) external to the virtual image projection system **500** and/or the brightness of internal ambient light (e.g., ambient light **122**, **124**) that has passed through a projection surface of the virtual image projection system **500**. The information from the light sensors may be used by the virtual image projection system **500** to generate brightness information and/or brightness differential information to provide the components of the virtual image projection system **500** with an indication of the brightness and/or the degree of non-uniform brightness of the external and/or internal ambient light.

The logic flow **700** may locate an eye gaze position of a user at block **704**. For example, the eye tracking component **535a** may receive information from one or more eye gaze trackers (e.g., eye gaze trackers **175**) and/or head position trackers (e.g., head position tracker **180**), such as eye gaze information and/or head position information. The eye tracking component **535a** may use the eye gaze information and/or head position information to determine the location on a projection surface that is being looked at by a user (e.g., eye gaze location **185**). In one example, the eye gaze location may be used to determine the placement location of a virtual image and/or modified transmissivity zone. In another example, the eye gaze location may be used to derive the brightness of ambient light being viewed by a user.

The logic flow **700** may determine an image brightness level of a virtual image at block **706**. For example, the image processor component **535b** may operate to determine a brightness level (e.g., luminous intensity) of one or more projected light beams (e.g., projected light **140**) for generating the virtual image. In general, the image brightness level may be determined to ensure that a distinct, quality virtual image is visible to the user. In some embodiments, the brightness level may be determined, at least in part, based on the brightness of the external ambient light and/or internal ambient light. For instance, the image processor component **535b** may increase the intensity of one or more projected light beams for brighter external ambient

light and/or internal ambient light as compared to less-bright external ambient light and/or internal ambient light.

The logic flow **700** may determine a modified-transmissivity zone at block **706**. For example, the transmissivity component **535d** may receive and/or generate zone information for
5 defining various attributes of a modified-transmissivity zone. The zone information may be based on various information, including, without limitation, the brightness information, the brightness differential information, the image information, the eye gaze location, or the like. In some embodiments, the transmissivity component **535d** may process the brightness information, the brightness differential information, the image information, the eye gaze location, and/or the
10 like to determine the appropriate zone information based on the environmental conditions, the anticipated virtual image, user preferences, or the like. In some embodiments, the zone information may be used by the controller **530** to generate instructions for the transmissivity modification system **520** to generate a modified-transmissivity zone having attributes specified by the zone information.

15 The logic flow **700** may project light onto a projection element to generate a virtual image at block **710**. For example, the controller **530** may instruct the scanning optical system **505** and/or elements thereof (e.g., light source **510** and/or mirror **515**) to project light (e.g., light **140**) onto a projection zone (e.g., projection zone **145**) of a projection surface of virtual image projection system **500** to generate a virtual image. The location of the projection zone may be
20 determined based on the eye gaze location, for example, to locate the virtual image in a position visible to the user. For instance, the projection zone may be determined so that the projected light reflects off of the projection zone and is incident on the eye of the user to generate the virtual image. In some embodiments, various attributes of the projected light, including, without
25 limitation, the intensity and/or the particular colors, may be selected based at least in part on the brightness information.

The logic flow **700** may apply a stimulus to the projection element to generate a modified-transmissivity zone at block **712**. For example, the controller **530** may instruct a stimulus source **525a-n** to apply a stimulus to at least a portion of a variable-transmissivity material of a
projection surface (e.g., projection surface **105**) to generate a modified-transmissivity zone (e.g.,
30 modified-transmissivity zone **170**) on a portion of the projection surface. In one example, the projection surface may include an LCD layer configured to reduce the transmissivity of the projection surface responsive to the application of a current to the LCD layer. Various attributes of the modified-transmissivity zone may be determined based on the zone information. In some
embodiments, the scanning optical system **505** and/or the image processor component **535c** may
35 send a signal, information, instructions or the like to the transmissivity component **535d**

indicating that a virtual image is being generated. Accordingly, the transmissivity component **535d** may initiate the generation of a corresponding modified-transmissivity zone responsive to the signal, information, instructions, or the like. The modified-transmissivity zone may be located and/or sized such that at least a portion of the light incident on the eye to form the virtual
5 image is superimposed over at least a portion of internal ambient light passing through the modified-transmissivity zone (i.e., the reduced-transmissivity light). Accordingly, at least a portion of the virtual image may be superimposed over at least a portion of the modified-transmissivity zone.

FIG. 8 depicts an illustrative computer readable medium according to an embodiment.
10 More specifically, FIG. 8 illustrates an embodiment of a storage medium **800**. The storage medium **800** may comprise an article of manufacture. In some examples, the storage medium **800** may include any non-transitory computer readable medium or machine readable medium, such as an optical, magnetic or semiconductor storage. The storage medium **800** may store various types of computer executable instructions. In some examples, the storage medium **800**
15 may store various types of computer executable instructions to implement logic flow **600**, logic flow **700**, and/or variants thereof.

Examples of a computer readable or machine readable storage medium may include any tangible media capable of storing electronic data, including volatile memory or non-volatile memory, removable or non-removable memory, erasable or non-erasable memory, writeable or
20 re-writeable memory, and so forth. Examples of computer executable instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, object-oriented code, visual code, and the like. The examples are not limited in this context.

FIG. 9 depicts an illustrative device according to an embodiment. More specifically, FIG.
25 9 is a diagram of an exemplary system embodiment and in particular, depicts a platform **900**, which may include various elements. For instance, this figure depicts that platform (system) **900** may include a processor/graphics core **902**, a chipset/platform control hub (PCH) **904**, an input/output (I/O) device **906**, a random access memory (RAM) (such as dynamic RAM (DRAM)) **908**, and a read only memory (ROM) **910**, display electronics **920**, projector **922** (e.g.,
30 light projector **135**), and various other platform components **914** (e.g., a fan, a cross flow blower, a heat sink, DTM system, cooling system, housing, vents, and/or the like). System **900** may also include wireless communications chip **916** and graphics device **918**. The embodiments, however, are not limited to these elements.

As depicted, I/O device **906**, RAM **908**, and ROM **910** are coupled to processor **902** by way of chipset **904**. Chipset **904** may be coupled to processor **902** by a bus **912**. Accordingly, bus **912** may include multiple lines.

Processor **902** may be a central processing unit comprising one or more processor cores and may include any number of processors having any number of processor cores. The processor **902** may include any type of processing unit, such as, for example, CPU, multi-processing unit, a reduced instruction set computer (RISC), a processor that have a pipeline, a complex instruction set computer (CISC), digital signal processor (DSP), and so forth. In some embodiments, processor **902** may be multiple separate processors located on separate integrated circuit chips. In some embodiments processor **902** may be a processor having integrated graphics, while in other embodiments processor **902** may be a graphics core or cores.

Some embodiments may be described using the expression “one embodiment” or “an embodiment” along with their derivatives. These terms mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment. Further, some embodiments may be described using the expression “coupled” and “connected” along with their derivatives. These terms are not necessarily intended as synonyms for each other. For example, some embodiments may be described using the terms “connected” and/or “coupled” to indicate that two or more elements are in direct physical or electrical contact with each other. The term “coupled,” however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other. Furthermore, aspects or elements from different embodiments may be combined.

It is emphasized that the Abstract of the Disclosure is provided to allow a reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein,” respectively.

Moreover, the terms "first," "second," "third," and so forth, are used merely as labels, and are not intended to impose numerical requirements on their objects.

What has been described above includes examples of the disclosed architecture. It is, of course, not possible to describe every conceivable combination of components and/or methodologies, but one of ordinary skill in the art may recognize that many further combinations and permutations are possible. Accordingly, the novel architecture is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. The detailed disclosure now turns to providing examples that pertain to further embodiments. The examples provided below are not intended to be limiting

10 Example 1. An apparatus, comprising: a projection surface comprising a variable-transmissivity material to modify a transmissivity of the projection surface to ambient light responsive to one or more stimuli being applied to the variable-transmissivity material; a projection unit to project light onto the projection surface to generate a virtual image; and one or more stimulus sources to apply the one or more stimuli to at least a portion of the variable-
15 transmissivity material to generate one or more modified-transmissivity zones on the projection surface.

Example 2. The apparatus of example 1, the variable-transmissivity material comprising at least one of a photochromic material, an electrochromic material, and a thermochromic material.

20 Example 3. The apparatus of example 1, the variable-transmissivity material comprising a photochromic material, the photochromic material comprising at least one of silver, spiropyran, spirobenzopyran, benzopyran, naphthopyran, spiroxazine, fulgide, fulgimide, dithienylethene, azobenzene, azulene, stilbene, chromene, and diarylethene.

Example 4. The apparatus of example 1, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising ultraviolet light.

25 Example 5. The apparatus of example 4, the projection surface comprising a filter layer to filter ultraviolet light from external ambient light.

Example 6. The apparatus of example 1, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising a light beam of the light projected by the projection unit.

30 Example 7. The apparatus of example 6, the light beam comprising visible light.

Example 8. The apparatus of example 6, the light beam comprising at least one of red light, blue light, and green light.

Example 9. The apparatus of example 1, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising infrared light.

Example 10. The apparatus of example 1, the variable-transmissivity material comprising an electrochromic material and the one or more stimulus sources comprising a laser.

5 Example 11. The apparatus of example 1, the variable-transmissivity material comprising a thermochromic material, the thermochromic material comprising at least one of leuco dyes, spirolactones, spiropyrans, fluorans, fulgides, thermochromic liquid crystals, cholesteryl nonanoate, and cyanobiphenyls.

10 Example 12. The apparatus of example 1, the variable-transmissivity material comprising an electrochromic material and the one or more stimuli comprising an electric signal.

Example 13. The apparatus of example 1, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising at least one of a transition metal oxide, tungsten oxide, nickel oxide, polyaniline, pollythiophene, polyoxotungstate, polyoxometallate, a viologen, indium tin oxide, a metal hydride, 15 metallohexacyanate, niobium pentoxide, molybdenum trioxide, Iridium oxide, metallophthalocyanine, metal hexacyanometallate, a liquid crystal material.

Example 14. The apparatus of example 1, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising a liquid crystal display (LCD) material.

20 Example 15. The apparatus of example 1, the projection unit comprising a light projector.

Example 16. The apparatus of example 15, the light projector comprising at least one light source, the at least one light source comprising at least one of a laser light source and a light emitting diode (LED) light source.

25 Example 17. The apparatus of example 15, the light projector comprising a microelectromechanical system (MEMS).

Example 18. The apparatus of example 15, the light projector comprising a digital light processing (DLP) system.

30 Example 19. The apparatus of example 1, the one or more modified-transmissivity zones having a zone area that is less than a surface area of the projection surface.

Example 20. The apparatus of example 1, the modified-transmissivity zone being generated responsive to a brightness of ambient light being above a threshold value.

35 Example 21. The apparatus of example 1, the modified-transmissivity zone being generated responsive to a brightness differential of ambient light being above a threshold value.

Example 22. The apparatus of example 1, the modified-transmissivity zone comprising a zone location determined based on an eye gaze location.

Example 23. The apparatus of example 1, the projection surface comprising a plurality of variable-transmissivity materials, each of the plurality of variable-transmissivity materials to modify a transmissivity of the projection surface to ambient light responsive to a different stimulus.

Example 24. The apparatus of example 1, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.

Example 25. The apparatus of example 1, the projection surface comprising an optical lens of a head-worn display.

Example 26. The apparatus of example 1, comprising a processor circuit operably connected to the one or more stimulus sources, the processor circuit to transmit instructions to the one or more stimulus sources to apply the one or more stimuli.

Example 27. The apparatus of example 26, comprising a transceiver operably connected to the processor circuit, at least a portion of the instructions formed based on data received via the transceiver.

Example 28. A method to project a virtual image superimposed over a real-world view, the method comprising: generating a modified-transmissivity zone by modifying a transmissivity of a projection surface to ambient light by applying one or more stimuli to at least a portion of a variable-transmissivity material of the projection surface; and projecting light onto the projection surface to generate a virtual image, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.

Example 29. The method of example 28, the variable-transmissivity material comprising at least one of a photochromic material, an electrochromic material, and a thermochromic material.

Example 30. The method of example 28, the variable-transmissivity material comprising a photochromic material, the photochromic material comprising at least one of silver, spiropyran, spirobenzopyran, benzopyran, naphthopyran, spiroxazine, fulgide, fulgimide, dithienylethene, azobenzene, azulene, stilbene, chromene, and diarylethene.

Example 31. The method of example 28, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising ultraviolet light.

Example 32. The method of example 31, the projection surface comprising a filter layer to filter ultraviolet light from external ambient light.

Example 33. The method of example 28, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising a light beam of the light projected by the projection unit.

Example 34. The method of example 33, the light beam comprising visible light.

5 Example 35. The method of example 33, the light beam comprising at least one of red light, blue light, and green light.

Example 36. The method of example 28, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising infrared light.

10 Example 37. The method of example 28, the variable-transmissivity material comprising an electrochromic material and the one or more stimulus sources comprising a laser.

Example 38. The method of example 28, the variable-transmissivity material comprising a thermochromic material, the thermochromic material comprising at least one of leuco dyes, spirolactones, spiropyrans, fluorans, fulgides, thermochromic liquid crystals, cholesteryl nonanoate, and cyanobiphenyls.

Example 39. The method of example 28, the variable-transmissivity material comprising an electrochromic material and the one or more stimuli comprising an electric signal.

20 Example 40. The method of example 28, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising at least one of a transition metal oxide, tungsten oxide, nickel oxide, polyaniline, pollythiophene, polyoxotungstate, polyoxometallate, a viologen, indium tin oxide, a metal hydride, metallohexacyanate, niobium pentoxide, molybdenum trioxide, Iridium oxide, metallophthalocyanine, metal hexacyanometallate, a liquid crystal material.

25 Example 41. The method of example 28, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising a liquid crystal display (LCD) material.

Example 42. The method of example 28, the projection unit comprising a light projector.

30 Example 43. The method of example 42, the light projector comprising at least one light source, the at least one light source comprising at least one of a laser light source and a light emitting diode (LED) light source.

Example 44. The method of example 43, the light projector comprising a microelectromechanical system (MEMS).

Example 45. The method of example 43, the light projector comprising a digital light processing (DLP) system.

Example 46. The method of example 28, the one or more modified-transmissivity zones having a zone area that is less than a surface area of the projection surface.

5 Example 47. The method of example 28, the modified-transmissivity zone being generated responsive to a brightness of ambient light being above a threshold value.

Example 48. The method of example 28, the modified-transmissivity zone being generated responsive to a brightness differential of ambient light being above a threshold value.

10 Example 49. The method of example 28, the modified-transmissivity zone comprising a zone location determined based on an eye gaze location.

Example 50. The method of example 28, the projection surface comprising a plurality of variable-transmissivity materials, each of the plurality of variable-transmissivity materials to modify a transmissivity of the projection surface to ambient light responsive to
15 a different stimulus.

Example 51. The method of example 28, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.

Example 52. The method of example 28, the projection surface comprising an optical lens of a head-worn display.

20 Example 53. An apparatus, comprising means for performing a method to project a virtual image superimposed over a real-world view according to any of examples 28 to 52.

Example 54. A system, comprising: the apparatus of example 1; and at least one processor circuit.

Example 55. The system of example 54, comprising at least one transceiver operably
25 connected to the at least one processor circuit.

Example 56. The system of any of examples 54 to 55, comprising a plurality of projection surfaces.

Example 57. A heads-up display device, comprising: a projection surface comprising a
30 variable-transmissivity material to modify a transmissivity of the projection surface to ambient light responsive to one or more stimuli being applied to the variable-transmissivity material; a projection unit to project light onto the projection surface to generate a virtual image superimposed onto a real-world view; one or more stimulus sources to apply the one or more stimuli to at least a portion of the variable-transmissivity material; and logic, at least partially implemented in hardware, the logic to: receive zone information comprising
35 at least one property of a modified-transmissivity zone, and control the one or more

stimulus sources to apply the one or more stimuli to generate the modified-transmissivity zone based on the zone information.

Example 58. The heads-up display device of example 57, the zone information comprising a location and a size of the modified-transmissivity zone.

5 Example 59. The heads-up display device of example 57, the logic to generate the modified-transmissivity responsive to a brightness of ambient light being above a threshold value.

10 Example 60. The heads-up display device of example 57, the logic to generate the modified-transmissivity responsive to a brightness differential of ambient light being above a threshold value.

Example 61. The heads-up display device of example 57, the logic to generate the modified-transmissivity at a zone location determined based on an eye gaze location.

15 Example 62. The heads-up display device of example 57, the variable-transmissivity material comprising at least one of a photochromic material, an electrochromic material, and a thermochromic material.

Example 63. The heads-up display device of example 57, the variable-transmissivity material comprising a photochromic material, the photochromic material comprising at least one of silver, spiropyran, spirobenzopyran, benzopyran, naphthopyran, spiroxazine, fulgide, fulgimide, dithienylethene, azobenzene, azulene, stilbene, chromene, and diarylethene.

20 Example 64. The heads-up display device of example 57, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising ultraviolet light.

Example 65. The heads-up display device of example 64, the projection surface comprising a filter layer to filter ultraviolet light from external ambient light.

25 Example 66. The heads-up display device of example 57, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising a light beam of the light projected by the projection unit.

Example 67. The heads-up display device of example 66, the light beam comprising visible light.

30 Example 68. The heads-up display device of example 66, the light beam comprising at least one of red light, blue light, and green light.

Example 69. The heads-up display device of example 57, the variable-transmissivity material comprising a photochromic material and the one or more stimuli comprising infrared light.

Example 70. The heads-up display device of example 57, the variable-transmissivity material comprising an electrochromic material and the one or more stimulus sources comprising a laser.

5 Example 71. The heads-up display device of example 57, the variable-transmissivity material comprising a thermochromic material, the thermochromic material comprising at least one of leuco dyes, spirolactones, spiropyrans, fluorans, fulgides, thermochromic liquid crystals, cholesteryl nonanoate, and cyanobiphenyls.

10 Example 72. The heads-up display device of example 57, the variable-transmissivity material comprising an electrochromic material and the one or more stimuli comprising an electric signal.

Example 73. The heads-up display device of example 57, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising at least one of a transition metal oxide, tungsten oxide, nickel oxide, polyaniline, pollythiophene, polyoxotungstate, polyoxometallate, a viologen, indium tin oxide, a metal
15 hydride, metallohexacyanate, niobium pentoxide, molybdenum trioxide, Iridium oxide, metallophthalocyanine, metal hexacyanometallate, a liquid crystal material.

Example 74. The heads-up display device of example 57, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising a liquid crystal display (LCD) material.

20 Example 75. The heads-up display device of example 57, the projection unit comprising a light projector.

Example 76. The heads-up display device of example 75, the light projector comprising at least one light source, the at least one light source comprising at least one of a laser light source and a light emitting diode (LED) light source.

25 Example 77. The heads-up display device of example 75, the light projector comprising a microelectromechanical system (MEMS).

Example 78. The heads-up display device of example 75, the light projector comprising a digital light processing (DLP) system.

30 Example 79. The heads-up display device of example 57, the one or more modified-transmissivity zones having a zone area that is less than a surface area of the projection surface.

Example 80. The heads-up display device of example 57, the modified-transmissivity zone being generated responsive to a brightness of ambient light being above a threshold value.

Example 81. The heads-up display device of example 57, the modified-transmissivity zone being generated responsive to a brightness differential of ambient light being above a threshold value.

5 Example 82. The heads-up display device of example 57, the modified-transmissivity zone comprising a zone location determined based on an eye gaze location.

Example 83. The heads-up display device of example 57, the projection surface comprising a plurality of variable-transmissivity materials, each of the plurality of variable-transmissivity materials to modify a transmissivity of the projection surface to ambient light responsive to a different stimulus.

10 Example 84. The heads-up display device of example 57, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.

Example 85. At least one machine-readable storage medium comprising a plurality of instructions that in response to being executed on a computing device, cause the computing
15 device to: generate a modified-transmissivity zone by modifying a transmissivity of a projection surface to ambient light by applying one or more stimuli to at least a portion of a variable-transmissivity material of the projection surface; and project light onto the projection surface to generate a virtual image, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone

20 Example 86. The least one machine-readable storage medium of example 85, the plurality of instructions, in response to being executed on a computing device, cause the computing device to receive zone information comprising at least one property of the modified-transmissivity zone.

Example 87. The least one machine-readable storage medium of example 85, the zone
25 information comprising a location and a size of the modified-transmissivity zone.

Example 88. The least one machine-readable storage medium of example 85, the plurality of instructions, in response to being executed on a computing device, cause the computing device to generate the modified-transmissivity responsive to a brightness of ambient light being above a threshold value.

30 Example 89. The least one machine-readable storage medium of example 85, the plurality of instructions, in response to being executed on a computing device, cause the computing device to generate the modified-transmissivity responsive to a brightness differential of ambient light being above a threshold value.

Example 90. The least one machine-readable storage medium of example 85, the
35 plurality of instructions, in response to being executed on a computing device, cause the

computing device to generate the modified-transmissivity at a zone location determined based on an eye gaze location.

Example 91. An apparatus, comprising: a projection means to project a virtual image; a variable-transmissivity means to modify a transmissivity of the apparatus to ambient light
5 responsive to one or more stimuli; a projection means to project light to generate the virtual image; and a stimulus means to apply the one or more stimuli to generate one or more modified-transmissivity zones.

Example 92. The apparatus of example 91, the stimulus means to apply the one or more stimuli to generate one or more modified-transmissivity zones responsive to a
10 brightness of ambient light being above a threshold value.

Example 93. The apparatus of example 91, the stimulus means to apply the one or more stimuli to generate one or more modified-transmissivity zones responsive to a brightness differential of ambient light being above a threshold value.

Example 94. The apparatus of example 91, comprising a transceiver means for
15 receiving zone information.

Example 95. The apparatus of example 94, receive zone information comprising at least one property of the modified-transmissivity zone.

Example 96. The apparatus of example 94, the stimulus means to apply the one or more stimuli to generate one or more modified-transmissivity zones based on the zone
20 information.

Example 97. The apparatus of example 91, the projection means to generate the virtual image superimposed over at least a portion of the one or more modified-transmissivity zones.

CLAIMS

What is claimed is:

1. An apparatus, comprising:
 - a projection surface comprising a variable-transmissivity material to modify a
 - 5 transmissivity of the projection surface to ambient light responsive to one or more stimuli being applied to the variable-transmissivity material;
 - a projection unit to project light onto the projection surface to generate a virtual image; and
 - one or more stimulus sources to apply the one or more stimuli to at least a portion of
 - 10 the variable-transmissivity material to generate one or more modified-transmissivity zones on the projection surface.
2. The apparatus of claim 1, the variable-transmissivity material comprising at least one of a photochromic material, an electrochromic material, and a thermochromic material.
3. The apparatus of claim 1, the variable-transmissivity material comprising a
- 15 photochromic material and the one or more stimuli comprising ultraviolet light.
4. The apparatus of claim 3, the projection surface comprising a filter layer to filter ultraviolet light from external ambient light.
5. The apparatus of claim 1, the variable-transmissivity material comprising a thermochromic material and the one or more stimulus sources comprising a laser.
- 20 6. The apparatus of claim 1, the variable-transmissivity material comprising an electrochromic material and the one or more stimuli comprising an electric signal.
7. The apparatus of claim 1, the variable-transmissivity material comprising an electrochromic material, the electrochromic material comprising a liquid crystal display (LCD) material.
- 25 8. The apparatus according to any of claims 1-7, the one or more modified-transmissivity zones having a zone area that is less than a surface area of the projection surface.
9. The apparatus according to any of claims 1-7, the modified-transmissivity zone being generated responsive to a brightness of ambient light being above a threshold value.
- 30 10. The apparatus according to any of claims 1-7, the modified-transmissivity zone being generated responsive to a brightness differential of ambient light being above a threshold value.

11. The apparatus according to any of claims 1-7, the modified-transmissivity zone comprising a zone location determined based on an eye gaze location.
12. The apparatus according to any of claims 1-7, the projection surface comprising a plurality of variable-transmissivity materials, each of the plurality of variable-transmissivity materials to modify a transmissivity of the projection surface to ambient light responsive to a different stimulus.
13. A method to project a virtual image superimposed over a real-world view, the method comprising:
- generating a modified-transmissivity zone by modifying a transmissivity of a projection surface to ambient light by applying one or more stimuli to at least a portion of a variable-transmissivity material of the projection surface; and
- projecting light onto the projection surface to generate a virtual image, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.
14. The method of claim 13, the variable-transmissivity material comprising at least one of a photochromic material, an electrochromic material, and a thermochromic material.
15. The method of claim 13, the one or more modified-transmissivity zones having a zone area that is less than a surface area of the projection surface.
16. The method according to any of claims 13-15, the modified-transmissivity zone being generated responsive to a brightness of ambient light being above a threshold value.
17. The method according to any of claims 13-15, the modified-transmissivity zone being generated responsive to a brightness differential of ambient light being above a threshold value.
18. The method according to any of claims 13-15, the modified-transmissivity zone comprising a zone location determined based on an eye gaze location.
19. The method according to any of claims 13-15, the projection surface comprising a plurality of variable-transmissivity materials, each of the plurality of variable-transmissivity materials to modify a transmissivity of the projection surface to ambient light responsive to a different stimulus.
20. At least one machine-readable storage medium comprising a plurality of instructions that in response to being executed on a computing device, cause the computing device to:
- generate a modified-transmissivity zone by modifying a transmissivity of a projection surface to ambient light by applying one or more stimuli to at least a portion of a variable-transmissivity material of the projection surface; and

project light onto the projection surface to generate a virtual image, at least a portion of the virtual image being superimposed over at least a portion of the modified-transmissivity zone.

21. The least one machine-readable storage medium of claim 20, the plurality of instructions, in response to being executed on a computing device, cause the computing
5 device to receive zone information comprising at least one property of the modified-transmissivity zone.
22. The least one machine-readable storage medium of claim 20, the zone information comprising a location and a size of the modified-transmissivity zone.
23. The least one machine-readable storage medium according to any of claims 20-22,
10 the plurality of instructions, in response to being executed on a computing device, cause the computing device to generate the modified-transmissivity responsive to a brightness of ambient light being above a threshold value.
24. The least one machine-readable storage medium according to any of claims 20-22, the plurality of instructions, in response to being executed on a computing device, cause the
15 computing device to generate the modified-transmissivity responsive to a brightness differential of ambient light being above a threshold value.
25. The least one machine-readable storage medium according to any of claims 20-22, the plurality of instructions, in response to being executed on a computing device, cause the computing device to generate the modified-transmissivity at a zone location determined
20 based on an eye gaze location.

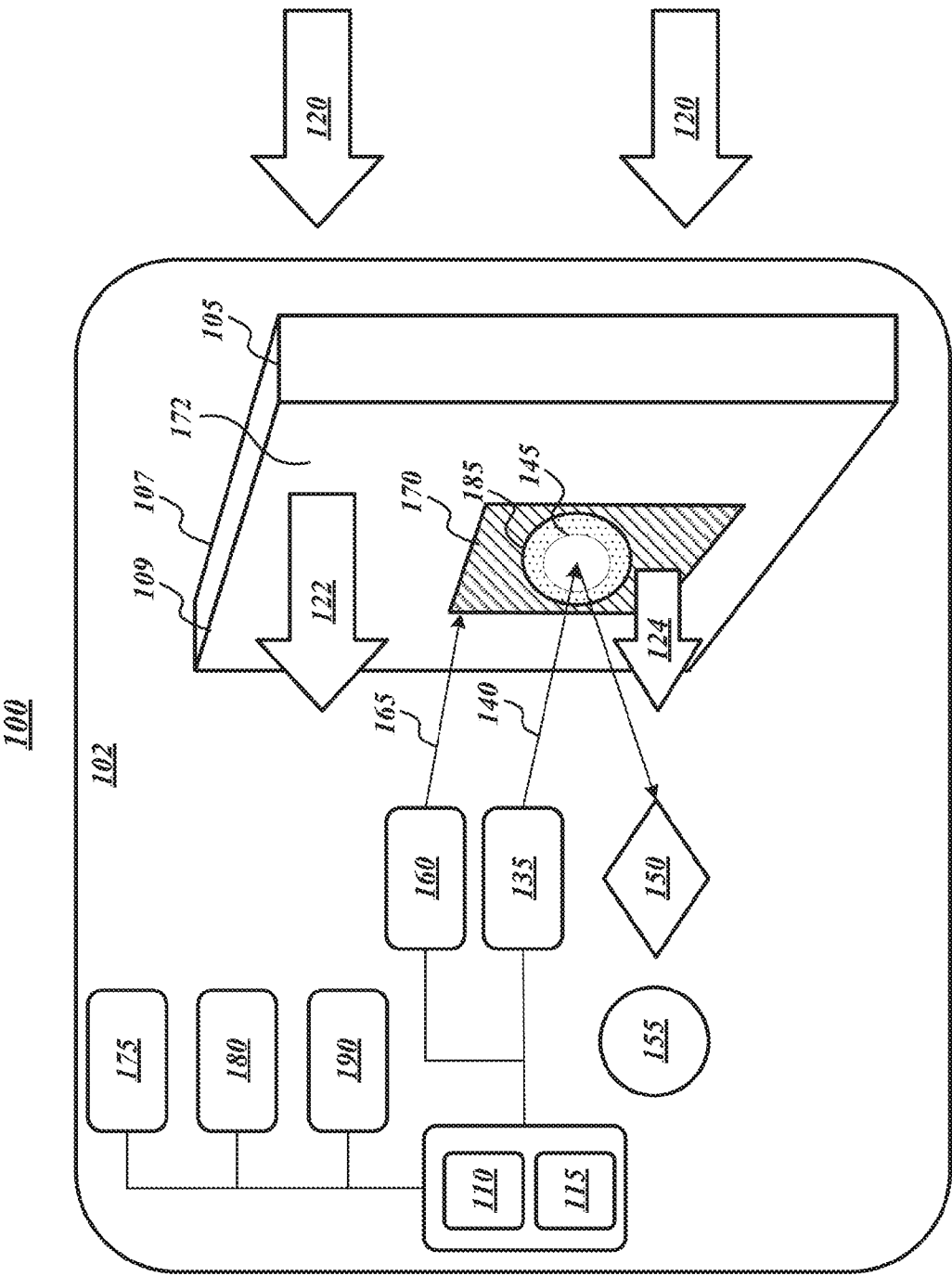


FIG. 1

2/9

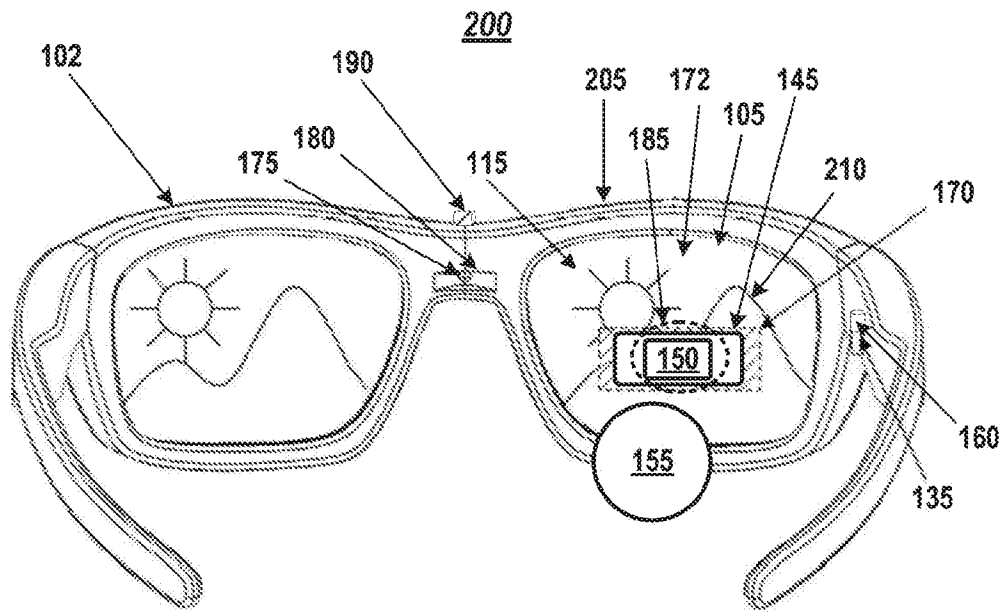
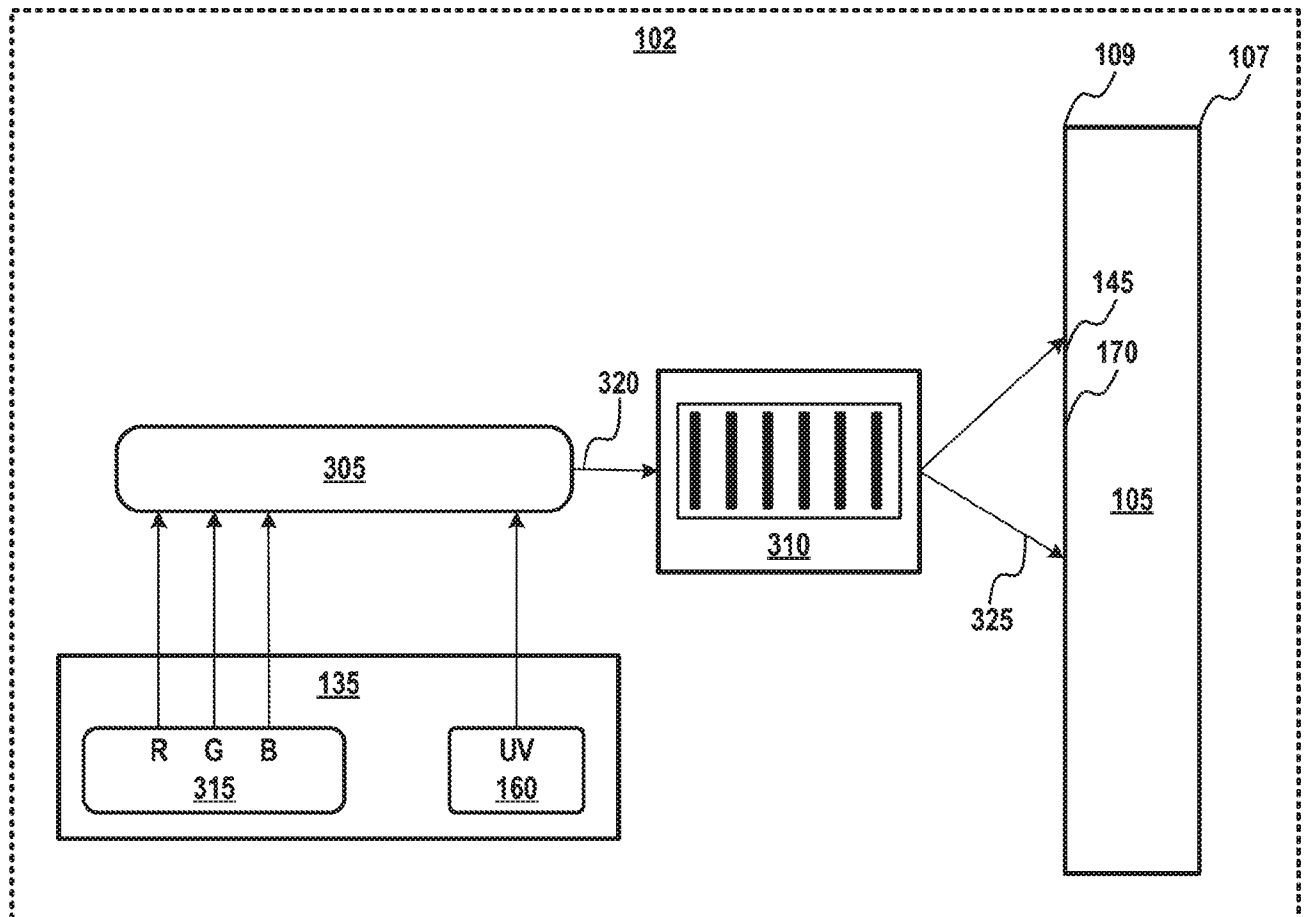


FIG. 2

3/9

300*FIG. 3*

4/9

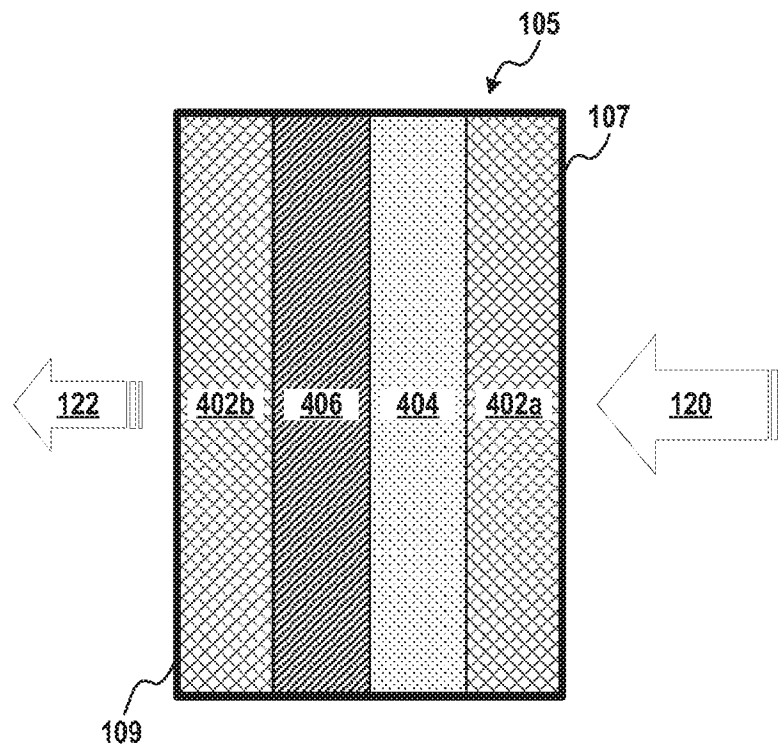


FIG. 4A

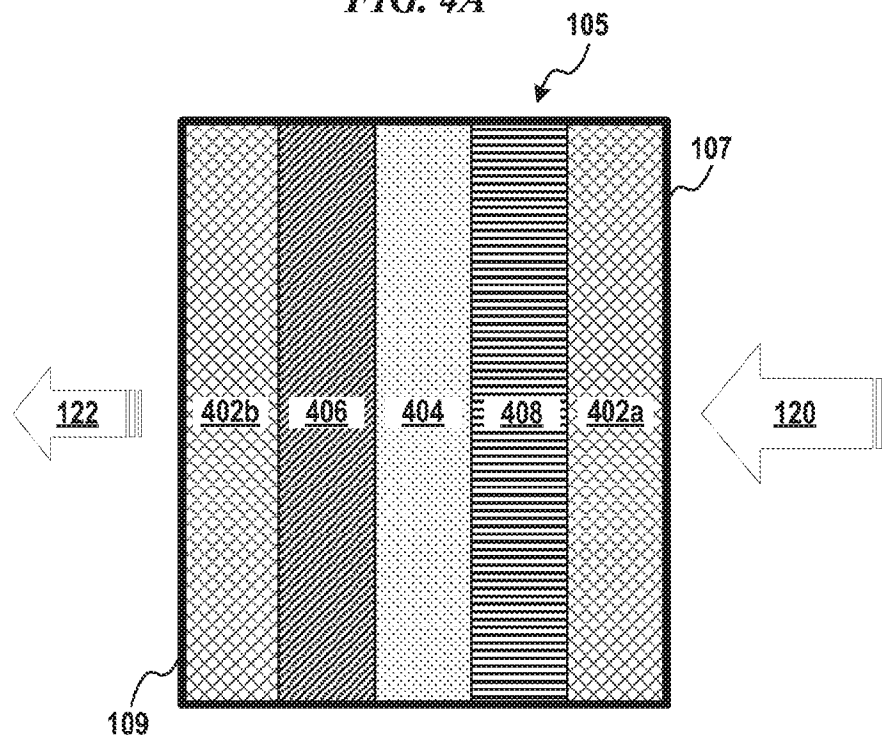
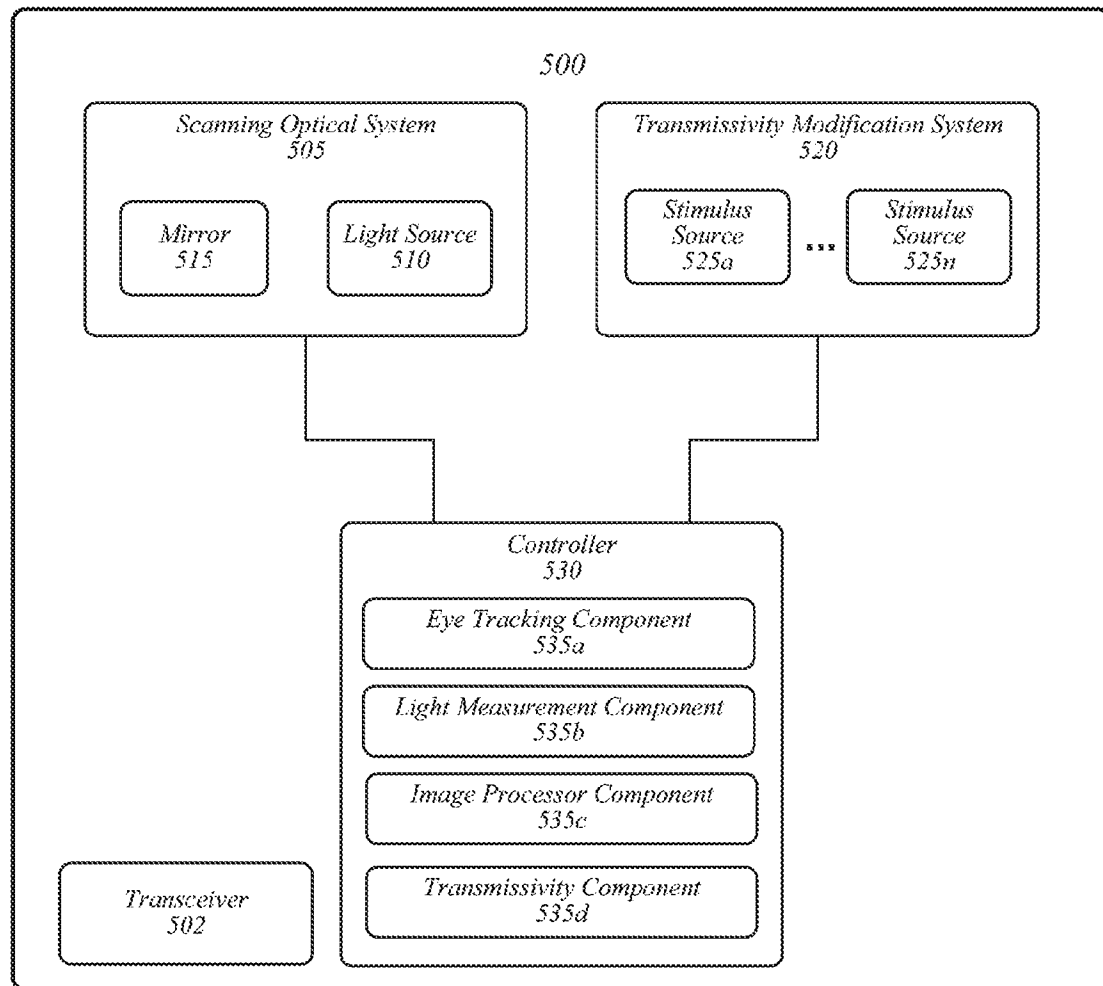
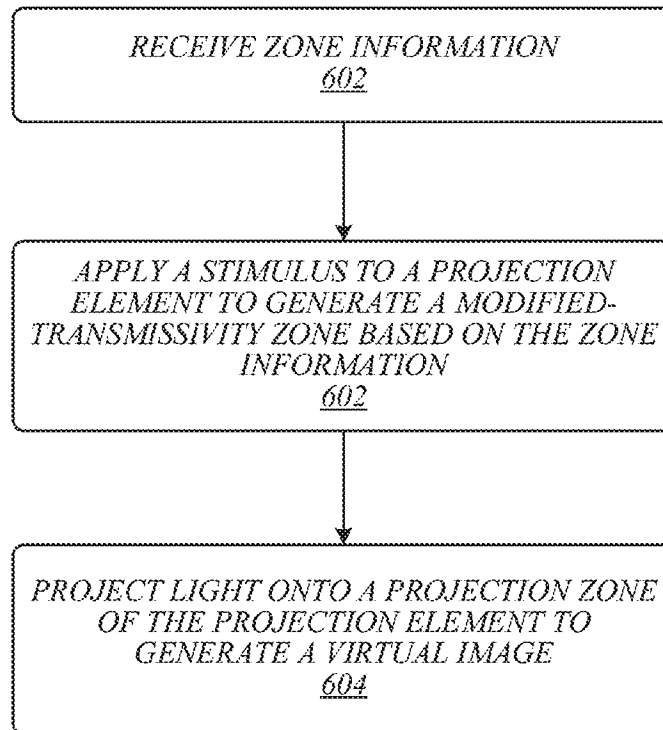


FIG. 4B

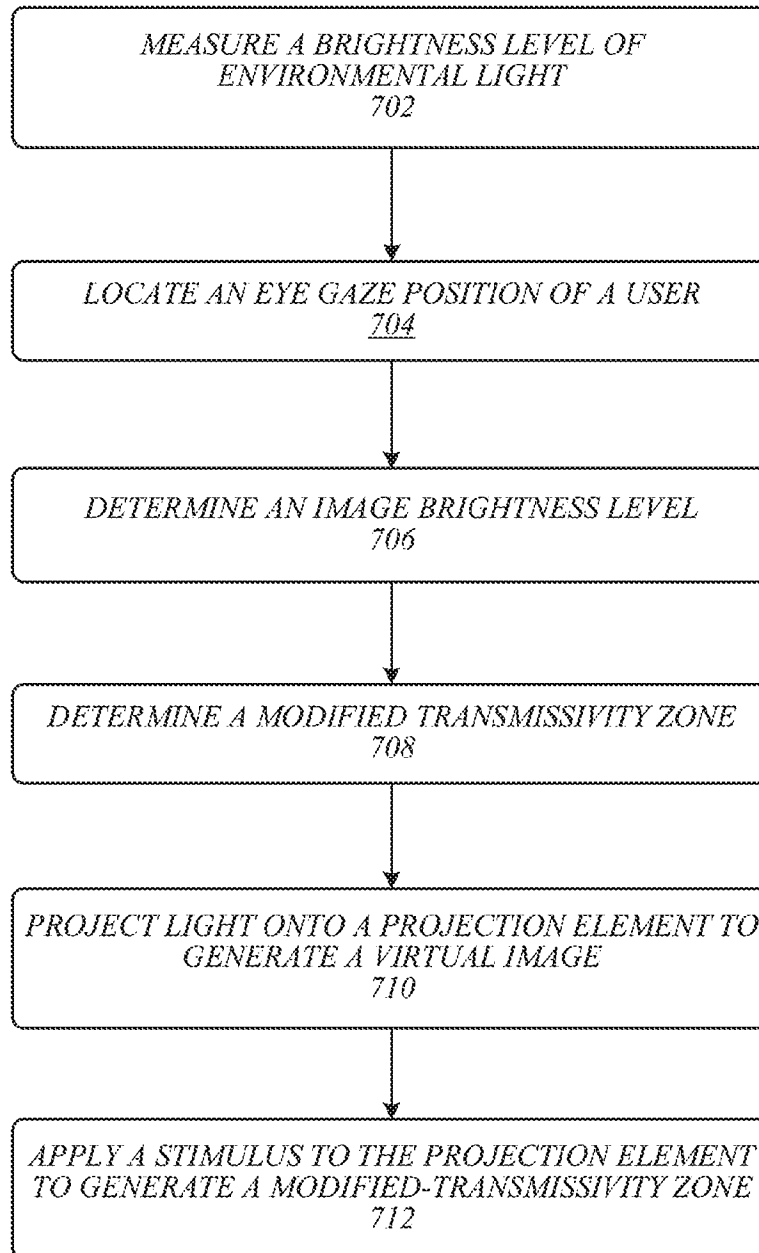
5/9

**FIG. 5**

6/9

600**FIG. 6**

7/9

700**FIG. 7**

8/9

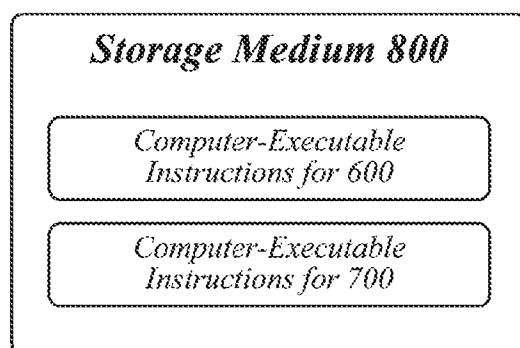


FIG. 8

900

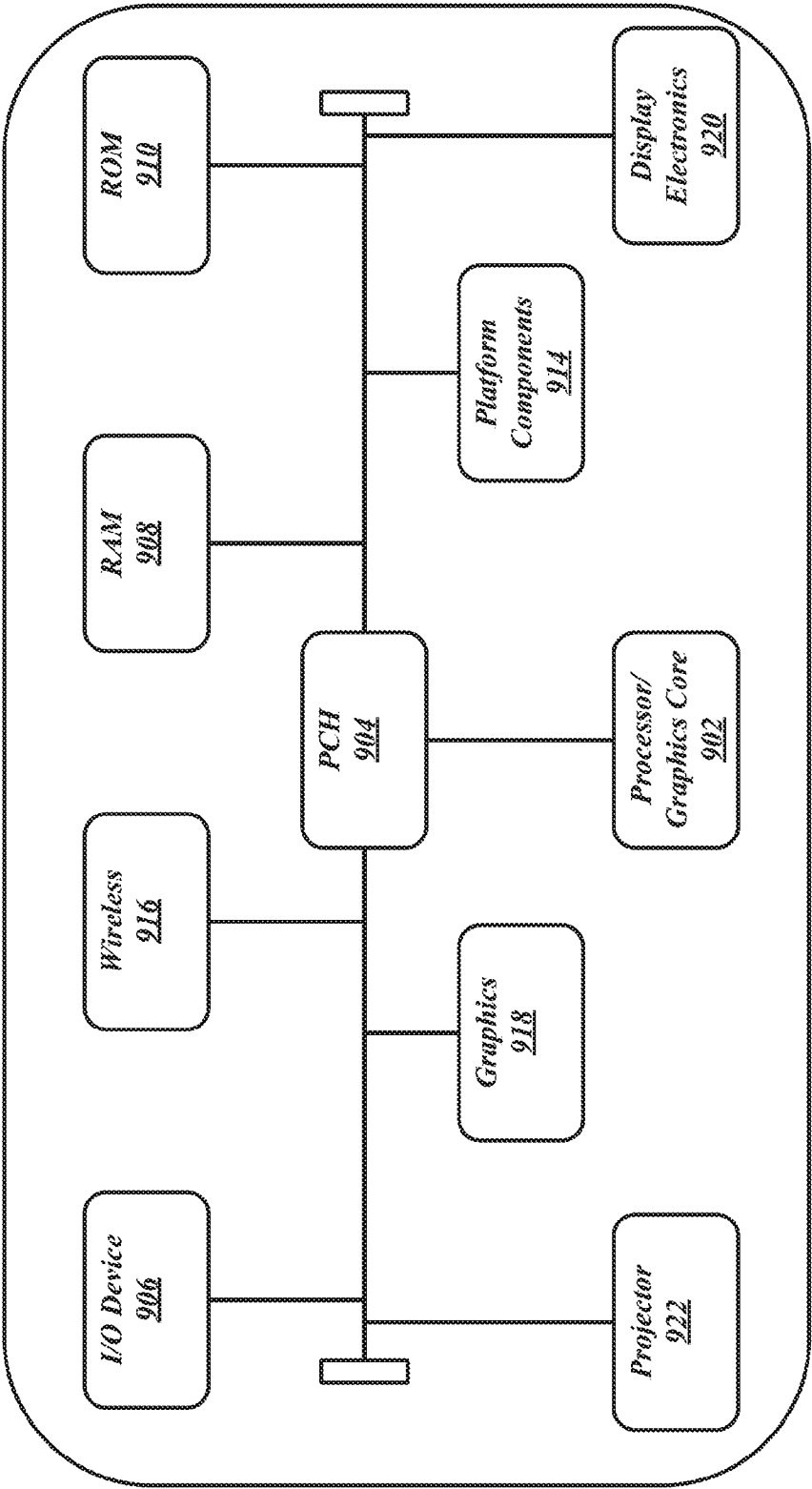


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/035644**A. CLASSIFICATION OF SUBJECT MATTER****G02B 27/01(2006.01)i, G02B 27/00(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 27/01; G09G 5/02; H04N 5/222; G02F 1/153; G09G 5/00; G02B 27/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: variable, transmissivity, projection, photochromic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0260991 A1 (GOOGLE INC.) 17 September 2015 See paragraphs [0012]–[0024]; claim 1; and figure 1A.	1–25
Y	US 2012-0242678 A1 (BORDER et al.) 27 September 2012 See paragraphs [0150], [0250]–[0258]; and figures 1, 9.	1–25
A	US 2013-0113973 A1 (MIAO) 09 May 2013 See figures 1–4.	1–25
A	US 6130772 A (CAVA) 10 October 2000 See figures 1–4.	1–25
A	WO 2014-129109 A1 (SONY CORPORATION) 28 August 2014 See claims 1–5; and figures 1–5.	1–25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

28 July 2017 (28.07.2017)

Date of mailing of the international search report

31 July 2017 (31.07.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

KANG, Sung Chul

Telephone No. +82-42-481-8405



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/035644

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015-0260991 A1	17/09/2015	US 9389423 B2	12/07/2016
US 2012-0242678 A1	27/09/2012	CA 2788421 A1	01/09/2011
		CA 2828407 A1	07/09/2012
		CA 2828413 A1	07/09/2012
		CN 102906623 A	30/01/2013
		CN 103946732 A	23/07/2014
		EP 2538831 A2	02/01/2013
		EP 2539759 A1	02/01/2013
		EP 2761362 A2	06/08/2014
		GB 2491072 A	21/11/2012
		IL 221291 A	31/10/2012
		JP 2013-521018 A	10/06/2013
		JP 2013-521576 A	10/06/2013
		JP 2015-504616 A	12/02/2015
		JP 5827961 B2	02/12/2015
		KR 10-2013-0000401 A	02/01/2013
		KR 10-2014-0066258 A	30/05/2014
		US 2011-0213664 A1	01/09/2011
		US 2011-0214082 A1	01/09/2011
		US 2011-0221656 A1	15/09/2011
		US 2011-0221657 A1	15/09/2011
		US 2011-0221658 A1	15/09/2011
		US 2011-0221659 A1	15/09/2011
		US 2011-0221668 A1	15/09/2011
		US 2011-0221669 A1	15/09/2011
		US 2011-0221670 A1	15/09/2011
		US 2011-0221671 A1	15/09/2011
		US 2011-0221672 A1	15/09/2011
		US 2011-0221793 A1	15/09/2011
		US 2011-0221896 A1	15/09/2011
		US 2011-0221897 A1	15/09/2011
		US 2011-0222745 A1	15/09/2011
		US 2011-0225536 A1	15/09/2011
		US 2011-0227812 A1	22/09/2011
		US 2011-0227813 A1	22/09/2011
		US 2011-0227820 A1	22/09/2011
		US 2011-0231757 A1	22/09/2011
		US 2011-0275923 A1	10/11/2011
		US 2012-0062445 A1	15/03/2012
		US 2012-0075168 A1	29/03/2012
		US 2012-0119978 A1	17/05/2012
		US 2012-0120103 A1	17/05/2012
		US 2012-0194418 A1	02/08/2012
		US 2012-0194419 A1	02/08/2012
		US 2012-0194420 A1	02/08/2012
		US 2012-0194549 A1	02/08/2012
		US 2012-0194550 A1	02/08/2012
		US 2012-0194551 A1	02/08/2012

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/035644

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2012-0194552 A1	02/08/2012
		US 2012-0194553 A1	02/08/2012
		US 2012-0200488 A1	09/08/2012
		US 2012-0200499 A1	09/08/2012
		US 2012-0200601 A1	09/08/2012
		US 2012-0206322 A1	16/08/2012
		US 2012-0206323 A1	16/08/2012
		US 2012-0206334 A1	16/08/2012
		US 2012-0206335 A1	16/08/2012
		US 2012-0206485 A1	16/08/2012
		US 2012-0212398 A1	23/08/2012
		US 2012-0212399 A1	23/08/2012
		US 2012-0212400 A1	23/08/2012
		US 2012-0212406 A1	23/08/2012
		US 2012-0212414 A1	23/08/2012
		US 2012-0212484 A1	23/08/2012
		US 2012-0212499 A1	23/08/2012
		US 2012-0218172 A1	30/08/2012
		US 2012-0218301 A1	30/08/2012
		US 2012-0235883 A1	20/09/2012
		US 2012-0235884 A1	20/09/2012
		US 2012-0235885 A1	20/09/2012
		US 2012-0235886 A1	20/09/2012
		US 2012-0235887 A1	20/09/2012
		US 2012-0235900 A1	20/09/2012
		US 2012-0236030 A1	20/09/2012
		US 2012-0236031 A1	20/09/2012
		US 2012-0242697 A1	27/09/2012
		US 2012-0242698 A1	27/09/2012
		US 2012-0249797 A1	04/10/2012
		US 2013-0085369 A1	04/04/2013
		US 2013-0127980 A1	23/05/2013
		US 2013-0278631 A1	24/10/2013
		US 2013-0314303 A1	28/11/2013
		US 2014-0063054 A1	06/03/2014
		US 2014-0063055 A1	06/03/2014
		US 2015-0309316 A1	29/10/2015
		US 2016-0187654 A1	30/06/2016
		US 2016-0209648 A1	21/07/2016
		US 2016-0217327 A1	28/07/2016
		US 8467133 B2	18/06/2013
		US 8472120 B2	25/06/2013
		US 8477425 B2	02/07/2013
		US 8482859 B2	09/07/2013
		US 8488246 B2	16/07/2013
		US 8814691 B2	26/08/2014
		US 8834368 B2	16/09/2014
		US 8964298 B2	24/02/2015
		US 9091851 B2	28/07/2015
		US 9097890 B2	04/08/2015

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/035644

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 9097891 B2	04/08/2015
		US 9128281 B2	08/09/2015
		US 9129295 B2	08/09/2015
		US 9134534 B2	15/09/2015
		US 9182596 B2	10/11/2015
		US 9223134 B2	29/12/2015
		US 9229227 B2	05/01/2016
		US 9285589 B2	15/03/2016
		US 9329689 B2	03/05/2016
		US 9341843 B2	17/05/2016
		US 9366862 B2	14/06/2016
		WO 2011-106797 A1	01/09/2011
		WO 2011-106798 A1	01/09/2011
		WO 2011-106799 A2	01/09/2011
		WO 2011-106799 A3	05/04/2012
		WO 2012-037290 A2	22/03/2012
		WO 2012-037290 A3	12/07/2012
		WO 2012-118573 A1	07/09/2012
		WO 2012-118575 A2	07/09/2012
		WO 2012-118575 A3	14/03/2013
		WO 2013-049248 A2	04/04/2013
		WO 2013-049248 A3	04/07/2013
US 2013-0113973 A1	09/05/2013	CN 104067334 A	24/09/2014
		CN 104067334 B	12/10/2016
		US 9087471 B2	21/07/2015
		WO 2013-066521 A1	10/05/2013
		WO 2013-066521 A8	31/07/2014
US 06130772 A	10/10/2000	None	
WO 2014-129109 A1	28/08/2014	CN 104520753 A	15/04/2015
		EP 2959333 A1	30/12/2015
		JP 2014-160169 A	04/09/2014
		JP 6123342 B2	10/05/2017
		KR 10-2015-0119837 A	26/10/2015
		RU 2015-134103 A	17/02/2017
		TW 201433824 A	01/09/2014
		US 2015-0370075 A1	24/12/2015
		US 2017-0184857 A1	29/06/2017