

ONE-WAY VISION PRIVACY WINDOW BASED ON LIGHT EMITTING DIODES AND SWITCHABLE GLASS

PRIORITY CLAIM

[0001] This application claims priority from Singapore Patent Application No. 10201508608T filed on 16 October 2015.

TECHNICAL FIELD

[0002] The present invention generally relates to methods and apparatuses for one-way vision privacy windows, and more particularly relates to a switchable window whose transmittance is synchronized with indoor LED lighting to prevent viewing through the window in one direction while allowing viewing in the other direction.

BACKGROUND OF THE DISCLOSURE

[0003] Privacy is always a concern for people. The traditional method to prevent a person outside a room from seeing inside a room or a private space is by using curtains or blinds. However, this method completely blocks the light from outside which may not be desirable in some situations. For example, if the person inside the room wants to view outside or wants sunlight to enter the room, closing the curtains or blinds would prevent this. One solution to address this issue is to use semi-transparent glass such as tinted glass or attach perforated films to the windows. For example, one proposal uses a patterned polyvinyl chloride window screen to protect the privacy without obstructing a view of the outside. However, this method disadvantageously requires the inside to be much dimmer than the outside in order to

achieve good performance and this is counter to many situations where indoor lights need to be on such as offices inside a building or homes at night-time.

[0004] To achieve privacy without adjusting the brightness condition or even if the inside is brighter than outside, one proposal discloses a window treatment that mounts a light source in the window headrail to illuminate the covering materials on the window. The covering materials are designed to strongly reflect illuminated light towards the outside thereby providing the person inside a clear view of the outside while causing a person on the outside high difficulty in seeing through the covering to the inside. Although this design can protect privacy and provide one-way viewing at both day-time and night-time, the uniformity of the illumination is limited and the energy consumption is high. In addition, the reflected light may also cause undesirable effects on the outside, such as in crowded residential areas.

[0005] Thus, what is needed is a method and one-way vision privacy window that can address the above issues. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[0006] According to at least one embodiment of the present invention, a method for controlling directional visibility through a switchable window located between a first space and a second space, the window having a transmitting condition, in which there is visibility through the window, and a non-transmitting condition in which there is reduced visibility through the window is provided. The method includes the steps of providing a first switchable light source in the first space and a controller for

controlling switching of the first switchable light source and the switchable window and synchronising switching of the first light source, between an ON condition and an OFF condition, to switching of the window to control visibility from the first space into the second space. In accordance with the method, the first light source is switched to the ON condition depending on whether the window is in the transmitting condition or the non-transmitting condition, and wherein the synchronized switching is at a rate greater than a frame rate of a human eye.

[0007] According to another embodiment of the present invention, a system for controlling directional visibility between a first space and a second space is provided. The system includes a switchable window, a first switchable light and a controller. The switchable window is located between the first space and the second space and has a transmitting condition in which there is visibility through the window and a non-transmitting condition in which there is reduced visibility through the window. The first switchable light source is located in the first space. The controller controls switching of the first switchable light source and the switchable window and is configured to synchronise switching of the first light source between an ON condition and an OFF condition to switching of the window to control visibility from the first space into the second space, so that the first light source is switched to the ON condition depending on whether the window is in the transmitting condition or the non-transmitting condition. The controller switches the window and the first light source between respective said conditions at a rate greater than a frame rate of a human eye.

[0008] According to a further embodiment of the present invention a system for controlling directional visibility between a first space and a second space is provided. The system includes a switchable window located between the first space and the

second space, a first switchable light source located in the first space and a controller for controlling switching of the first switchable light source and the switchable window. The switchable window has a transmitting condition in which there is visibility through the window and a non-transmitting condition in which there is reduced visibility through the window. The controller is configured to synchronise switching of the first light source between an ON condition and an OFF condition to switching of the window to control visibility from the first space into the second space, so that the first light source is switched to the ON condition depending on whether the window is in the transmitting condition or the non-transmitting condition, the controller switching the window and the first light source between respective said conditions at a rate greater than a frame rate of a human eye.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to illustrate various embodiments and to explain various principles and advantages in accordance with a present embodiment.

[0010] FIG. 1 depicts a front left top perspective view of a privacy window system in accordance with a present embodiment that only allows viewing from inside to outside.

[0011] FIG. 2 depicts graphs of modulation signals, window transmittance of the switchable window of FIG. 1 and intensity of light emitting diodes (LEDs) of FIG. 1 in accordance with the present embodiment.

[0012] FIG. 3 depicts a graph of the switchable window transmittance for different durations of the transmissive state “T” and the opaque state “O” of the switchable window of FIG. 1 in accordance with the present embodiment.

[0013] FIG. 4 depicts a front left top perspective view of a privacy window system in accordance with the present embodiment for rooms or offices inside a building.

[0014] FIG. 5 depicts a front left top perspective view of a privacy window system in accordance with the present embodiment that only allows viewing from outside to inside.

[0015] FIG. 6 depicts a front left top perspective view of a privacy window in accordance with the present embodiment wherein the direction of one-way vision is selectable.

[0016] FIG. 7 depicts graphs of modulation signals in accordance with the present embodiment for the switchable window and the LEDs on both sides of the switchable window for (a) inside viewing outside only, (b) outside viewing inside only, (c) both sides can see each other, (d) both sides cannot see each other, and (e) both sides see each other in a different transparency.

[0017] FIG. 8 depicts views of a privacy window system test setup in accordance with a present embodiment wherein FIG. 8(a) depicts a front left top perspective view of the test setup and FIG. 8(b) depicts a photograph of both inside and outside the test setup room.

[0018] FIG. 9 depicts views through the switchable window in the privacy window system of FIG. 8 in accordance with the present embodiment wherein FIG. 9(a) depicts the view from inside to outside, FIG. 9(b) depicts the view from outside to inside when the privacy protection is activated, and FIG. 9(c) depicts the view from outside to inside when the privacy protection is deactivated.

[0019] FIG. 10 depicts graphs of transmittance of the liquid crystal glass of the switchable window in accordance with the present embodiment wherein FIG. 10(a) depicts a graph of the transmittance of the liquid crystal glass at the transmissive and the opaque state and FIG. 10(b) depicts the averaged transmittance of the of the liquid crystal glass as a function of t_2/t_1 .

[0020] FIG. 11 depicts side planar views of the system for controlling directional visibility configured to only allow the indoor person viewing outside while those outdoor cannot see indoor in accordance with the present embodiment wherein at least one LED or fluorescent light source and at least one switchable window are installed in the room, a controller communicating with the light sources and the switchable window through a wire connection in FIG. 11(a) and through a WiFi connection in FIG. 11(b).

[0021] FIG. 12 depicts a side planar view of the system for controlling directional visibility configured to only allow the indoor person viewing outside while those outdoor cannot see indoor in accordance with the present embodiment wherein at least one LED light source, a photodetector, and at least one switchable window are installed in the room, the LED light source being modulated by a LED driver and the switchable window being controlled by a controller coupled to the photodetector.

[0022] FIG. 13 depicts side planar views of the system for controlling directional visibility configured to be used in a room inside a building to only allow the person inside the room to view outside while those outside cannot see into the room in accordance with the present embodiment wherein at least one LED or fluorescent light source and at least one switchable window are installed in the room, a controller communicating with the light sources and the switchable window through a wire connection in FIG. 13(a) and through a WiFi connection in FIG. 13(b).

[0023] FIG. 14 depicts a side planar view of the system for controlling directional visibility configured to be used in a room inside a building to only allow the person inside the room to view outside while those outside cannot see into the room in accordance with the present embodiment wherein a controller communicates with the light sources and the switchable window through a photodetector.

[0024] FIG. 15 depicts side planar views of the system for controlling directional visibility configured to only allow a person outside to view inside while those inside cannot see outside in accordance with the present embodiment wherein at least one LED or fluorescent light source and at least one switchable window are installed outside the room, a controller communicating with the light sources and the switchable window through a wire connection in FIG. 15(a) and through a WiFi connection in FIG. 15(b).

[0025] FIG. 16 depicts a side planar view of the system for controlling directional visibility configured to only allow a person outside to view inside while those inside cannot see outside in accordance with the present embodiment wherein a controller communicates with light sources and the switchable window through a photodetector.

[0026] And FIG. 17 depicts side planar views of the system for controlling directional visibility configured to separate two places inside a building and be able to turn a privacy place into an observation place or an observation place into a privacy place in accordance with the present embodiment wherein LED or fluorescent light sources are installed on either side of at least one switchable window and the light sources and the switchable window are modulated by a controller coupled through a wire connection in FIG. 17(a), through a WiFi connection in FIG. 17(b) or a combination of both connection methods in FIG. 17(c).

[0027] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale.

DETAILED DESCRIPTION

[0028] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description. It is the intent of the present embodiment to present

[0029] As used herein, the term “non-transmitting condition” refers to a state of a switchable window in which visibility through the window is significantly reduced, such as a translucent condition in which shapes on one side of the window are not discernible from the other side of the window, and an opaque condition. Conversely, the term “transmitting condition” refers to a state of a switchable window in which visibility is permitted through the window, such as a translucent condition where shapes are visible through the window, and a transparent condition.

[0030] As used herein, the term “directional visibility” refers to use of the systems and methods taught herein to selectively provide visibility either one of two directions through a switchable window, no visibility in either direction, or visibility in both directions.

[0031] As used herein, the term “lighting cycle”, in relation to a light source that is switched between an ON condition and an OFF condition in alternating sequence, refers to the time from when the light source is switched to the ON condition to the next time the light source is switched to the ON condition.

[0032] As used herein, the term “low-light condition” and similar refer to light in a space being sufficiently low that the space cannot be clearly viewed from inside a lit space – where a switchable window is located between the spaces – when the switchable window is being switched at a rate faster than the frame rate of a human eye.

[0033] Where the term “switching” is recited, where context requires that two contradictory conditions be satisfied, such as: permitting visibility from a first space into a second space while inhibiting visibility from the second space into the first space; and permitting visibility from the second space into the first space while inhibiting visibility from the first space into the second space, the term “switching” means that switching of the light source(s) and switchable window is controlled or synchronised such that for a first period of time one of the two conditions is satisfied and, for a second period of time, the other of the two conditions is satisfied. Where use of the term “switching” is provided in such a context, it may be replaced with “selectively switching” or ‘synchronising switching of the relevant light source with the window, for a first period of time, such that the first condition is achieved, and synchronising switching of the relevant light source or another light source with the window, for a second period of time, such that the second condition is achieved’, and such replacement will similarly be given the meaning intended above.

[0034] It is the intention of this detailed description to present a privacy window and methods to realize such. Present embodiments allow one-way vision: people sitting inside a room can see outside while people outside are not able to see inside the room, or vice versa, without changing the brightness level inside and outside the room. The one-way vision is achieved by modulating a light source, such as light emitting diodes (LEDs), and switchable glass in a privacy window, or switchable window.

The privacy window can function as an electrical curtain in homes and offices, or in any room that requires one-way vision.

[0035] Conventional solutions use partially transparent panels or perforated films to achieve one-way vision at specific brightness conditions that require the brightness level on the private side to be much lower than the public side, which is not applicable for office in a building or night-time when lights are on. Another typical solution mounts a lighting system on the window to reduce the transparence for the person on the outside. But this solution causes high energy loss and also affects the surrounding residents. Recently, switchable windows or smart windows have been used for privacy protection. This type of window allows active control of transmission using for example electrochromic layers, liquid crystals or suspended particles. However, such windows block the light from both sides and thus do not allow people on the private side seeing outside.

[0036] The privacy switchable window design in accordance with the present embodiment utilizes LED lights and switchable glass to achieve privacy protection. A key advantage of the present embodiment is that it provides one-way vision without requiring the private side to be dimmer than the public side. In addition, this switchable window shows low energy consumption, tunable transmittance and no adverse effect in high density residential neighborhoods.

[0037] In accordance with a first aspect of the present embodiment, the switchable window can provide one-way vision without changing the brightness level of the public or private side, even if the brightness level in the private side is higher than the public side, thereby providing one-way vision so that people on the private side can see the public side while people on the public side cannot see the private side. In accordance with a second aspect, the switchable window can allow the public side

(outside of the room) to see the private side (inside the room) while those inside cannot see outside, without changing the brightness level of either sides.

[0038] The transmission of the window is tunable and can be controlled by users. In addition, the system utilizing the switchable window in accordance with the present embodiment shows low energy consumption, and a wide range of switchable windows with certain modulation bandwidths can be used in accordance with the present embodiments as described herein.

[0039] Present embodiments described herein utilize LED lights and electrically switchable glass to achieve privacy protection in a non-typical and unconventional manner. The key advantage of systems and operation in accordance with the present embodiments is that they provide one-way vision without requiring changing of the brightness on either sides of the window. In addition, these methods and systems show low energy consumption and tunable transmittance.

[0040] Referring to FIG. 1, a top left front perspective view 100 depicts a privacy window system in accordance with a present embodiment which includes at least one LED light source 102, a switchable window 104 and a controller 106 that synchronizes the LED light source 102 with the switchable window 104. Both the LED light source 102 and the switchable window 104 are connected to the controller 106. The controller 106 sends a modulation signal 107 to the LED light source 102, making it blink at a frequency that is unnoticeable to human eyes. Meanwhile, the switchable window 104 is also modulated by the modulation signal 107 from the controller 106, switching between an opaque state and a transmissive state at the same frequency as the LED light source 102. In this manner, a person 108 on an inside area 110 can see through the switchable window 104 to an outside area 112, while a person

114 in the outside area 112 cannot see through the switchable window 104 into the inside area 110.

[0041] The uniqueness of the privacy window system in accordance with a present embodiment is that the one-way vision is achieved by the synchronization between the LED light source 102 and the switchable window 104. Referring to FIG. 2, graphs 202, 204, 206 depict synchronization of the modulation signals 107, window transmittance of the switchable window 104 and intensity of LED light sources 102, respectively, in accordance with the present embodiment. The window transmittance of the switchable window 104 is synchronized with the intensity of the LED light source 102 such that the switchable window 104 is set to be opaque (“O”) when the LED light source 102 is “ON” (corresponds to “State 1”) and is set to be transmissive (“T”) when the LED light source 102 is “OFF” (corresponds to “State 2”).

[0042] This synchronization provides two states for the privacy window. In State 1, the modulation signal 107 is “High”, the LED light source 102 intensity is L_0 (i.e., in the "ON" state) and the switchable window 104 is set to be opaque (“O”). In accordance with the present embodiment, in State 1, the switchable window 104 completely blocks the light from both sides and thus does not allow the person 112 outside seeing inside. In State 2, the modulation signal 107 is “Low”, the LED light source 102 intensity is in the "OFF" state and the switchable window 104 is set to be transmissive (i.e., T_0 is the window transmittance when it is at the transmissive state). Thus, in State 2, the inside 110 is dimmer than the outside 114 so that the person 112 on the outside 114 is still not able to see inside. However, the person 108 inside the room can have a clear view of the outside 114 since the light from the outside 114 can pass through the switchable window 104. By switching the switchable window 104 between State 1 and State 2 at a high speed faster than the response speed of human

eyes, the person 108 inside the room will not notice any flickering of the LED light source 102 and will always have a view of the outside 114, but those persons 112 outside the room cannot always see inside even if the inside 110 is brighter than the outside 114. Table 1 summarizes the effects of State 1 and State 2 on viewing.

	State 1 (LED is on, window is opaque)	State 2 (LED is off, window is transparent)	Overall effect
Outside seeing inside	No, because light is blocked	No, because inside is totally dark	No
Inside seeing outside	No, because light is blocked	Yes	Yes, but transparency is reduced by half

TABLE 1

[0043] Besides the one-way view, this privacy window system also allows users to control the transparency of the window by adjusting the time durations of the two states. Since the window is modulated at a speed much faster than the response of human eyes, persons 108 inside the room only see an averaged transmission of light through the switchable window 104. The averaged transmittance of the switchable window 104 is given by Equation 1:

$$\bar{T} = T_0 \cdot \frac{1}{1+t_2/t_1} \quad (1)$$

where T_0 is the transmittance when the switchable window 104 is at the transmissive state, t_1 and t_2 are the time durations of the transmissive state and the opaque state of the switchable window 104 in a cycle, respectively.

[0044] Referring to FIG. 3, a graph 300 of the switchable window transmittance for different durations of the transmissive state “T” and the opaque state “O” of the switchable window 104 in accordance with the present embodiment. When $t_1 > t_2$, as shown in square wave trace 302, the switchable window 104 will show a high averaged transmittance for the person 108 inside, which is preferable for night-time.

When $t_1 < t_2$, as shown in square wave trace 304, the window will exhibit a low transmittance, which can be applied during daytime when the sunlight in the outside 114 is strong.

[0045] Referring to FIG. 4, a front left top perspective view 400 of a privacy window system in accordance with the present embodiment for rooms or offices inside a building is depicted. Since the brightness levels at both sides are usually comparable for a room inside a building, conventional methods using tinted glass or perforated films cannot achieve one-way vision. The privacy window system in accordance with the present embodiments, however, does not depend on the brightness level on both sides and provides a one-way vision no matter whether the inside 402 is dimmer or brighter than the outside 404. An LED light source 406 at the inside 402 and a switchable window 408 are modulated by a modulation signal 407 from a controller 409 to allow a person 410 inside the room to see the outside 404 the room while preventing or allowing a person 412 to see the inside 402 of the room.

[0046] Referring to FIG. 5, a front left top perspective view 500 of a privacy window system in accordance with the present embodiment that only allows viewing from outside to inside is depicted. Instead of modulating the LED light source 406 (FIG. 4) inside the room, a controller 504 synchronizes the outside LED light source 502 with the switchable window 408 by modulation signals 503. In this manner, the person 412 outside the room will have a clear view of the inside 402 while the person 410 inside the room cannot see the outside 404 without adjusting the brightness level outside the room.

[0047] In addition, the privacy window system in accordance with the present embodiment can be configured to provide active control on the direction of one-way vision, switching the private side to the public side, or vice versa. FIG. 6 depicts a

front left top perspective view 600 of a privacy window in accordance with the present embodiment wherein the direction of one-way vision is selectable. LED light sources 406, 502 are installed on both sides of the switchable window 408 and all are modulated by a modulation signal 603 from a controller 602. In this configuration, the switchable window 408 will have multiple functions under operation as shown in the graphs of FIG. 7: 1) only allowing the person 410 inside seeing the outside 404 while blocking the person 412 outside from seeing the inside 402 by modulating the LED light source 502 outside the room in the same phase as the window transmittance of the switchable window 408 but modulating the LED light source 406 inside in an opposite phase with the switchable window 408 (see graph 702 of FIG. 7(a)); 2) only allowing the person 412 outside seeing the inside 402 while blocking the person 410 inside from seeing the outside 404 by modulating the LED light source 406 inside the room in the same phase as the window transmittance of the switchable window 408 but modulating the LED light source 502 outside in an opposite phase with the switchable window 408 (see graph 704 FIG. 7(b)); 3) allowing the persons 410, 412 on both sides to see each other by modulating both the inside and the outside LED light sources 406, 502 in the same phase as the window transmittance of the switchable window 408 (see graph 706 of FIG. 7(c)); 4) blocking the light from both sides by modulating both the inside and the outside LED light sources 406, 502 in the opposite phase with the window transmittance of the switchable window 408 (see graph 708 of FIG. 7(d)); 5) providing different transparencies for each side by setting a modulation phase difference between the LED light sources 406, 502 and the window transmittance of the switchable window 408 (see graph 710 of FIG. 7(e)).

[0048] Referring to FIG. 8(a), a front left top perspective view 800 of a test setup of a privacy window system in accordance with the present embodiment is depicted,

while FIG. 8(b) depicts a photograph 802 of inside and a photograph 804 of outside a box 806 of the test setup of the privacy window system. In the box 806, a LED bulb 808 is installed on the roof to illuminate the inside 810 and a switchable glass is installed at one side of the box as a switchable window 812. The size of the switchable window 812 is 10cm by 10cm. Both the LED 808 and the glass of the switchable window 812 are modulated by a controller 814. To provide a view of outside, a web camera is placed inside the box 806, aiming at the switchable window 812. A printed logo 816 is placed on an inner wall of the box 806 as an object on the inside, and a green “rabbit” is used as an object 818 on the outside

[0049] FIG. 9 depicts views 900 (FIG. 9(a)), 902 (FIG. 9(b)), 904 (FIG. 9(c)) through the switchable window 812 in the privacy window setup of FIG. 8 in accordance with the present embodiment. The view 900 from inside the box can clearly see the object 818 on the outside. However, the view 902 from the outside cannot see any object on the inside 810 of the box 806 when the LED light source 808 and the switchable window 812 are synchronized for privacy protection. For comparison, the view 902 depicts the inside 810 of the box 806 when the privacy protection is deactivated. Since the LED light source 808 and the switchable window 812 are unsynchronized, privacy is not protected and the logo 816 inside the box 806 can be seen.

[0050] In the test setup of FIG. 8 a liquid crystal (LC) based switchable glass is used in the switchable window 812. FIG. 10 depicts graphs 1000, 1002 of transmittance of the liquid crystal glass of the switchable window in accordance with the present embodiment wherein FIG. 10(a) depicts a graph of the transmittance of the liquid crystal glass at the transmissive and the opaque state and FIG. 10(b) depicts the averaged transmittance of the of the liquid crystal glass as a function of t_2/t_1 .

[0051] The graph 1000 shows the transmittance of the LC glass at the opaque state and the transmissive state. In the visible range (400nm -700nm), this glass shows an averaged transmittance of 27% for the transmissive state and 0.3% for the opaque state. The graph 1002 shows the averaged transmittance as a function of the ratio t_2/t_1 , where t_1 and t_2 are the time durations of the transmissive state and the opaque state in a cycle. The transmittance decreases as the ratio increases. By adjusting the ratio t_2/t_1 , the light entering the room can be controlled.

[0052] The energy consumption of the switchable window 812 was measured by using a source meter (Keithley Model 2400) which showed an average power of 0.1W, equal to 0.36 kWh. Using the privacy window system in accordance with the present embodiment with a LED light source in the room of 10W and running for 8 hours a day, the electricity cost per day for the switchable window will be around S\$0.02 or 2 cents which is negligible for users. The material cost of the privacy window system in accordance with the present embodiment is estimated to around S\$320 per m², including S\$300 for switchable glass, S\$ 20 for the driving circuits. The current price of a switchable window in the market is S\$600-1300 per m².

[0053] While a liquid crystal glass switchable window 812 was used in the test setup of FIG. 8, types of switchable window based on suspended particles, polymer dispersed LC, electrochromic/photochromic/thermochromic materials and micro-blinds may also be used in accordance with the present embodiment.

[0054] Referring to FIGs. 11 to 17, side planar views depict operation of the privacy window system in accordance with the present embodiment. FIG. 11 depicts side planar views 1100, 1101 of the system for controlling directional visibility configured to only allow the indoor person viewing outside while those outdoor cannot see indoor in accordance with the present embodiment wherein at least one LED or

fluorescent light source and at least one switchable window are installed in the room, a controller communicating with the light sources and the switchable window through a wire connection in FIG. 11(a) and through a WiFi connection in FIG. 11(b). A privacy window system is configured to only allow the indoor person viewing outside while those outdoor cannot see indoor. At least one LED or fluorescent light source 1102 and at least one switchable window 1104 are installed in the room. A controller 1106 communicates with the light sources 1102 and the switchable window 1104 through (a) wire connection 1108 or (b) WiFi connection 1110.

[0055] FIG. 12 depicts a side planar view 1200 of the system for controlling directional visibility configured to only allow the indoor person viewing outside while those outdoor cannot see indoor in accordance with the present embodiment wherein at least one LED light source 1202, a photodetector 1204, and at least one switchable window 1206 are installed in the room, the LED light source 1202 being modulated by a LED driver 1208 and the switchable window 1206 being controlled by a controller 1210 coupled to the photodetector 1204. The LED light source 1202 is modulated by the LED driver 1208 which is blinking at a certain frequency. The photodetector 1204 is installed inside the room to convert the optical signal from the LED light source 1202 to an electrical signal and sends the signal to the controller 1210. The controller 1210 adjusts the window transmission accordingly to achieve the synchronization between the switchable window 1206 and the LED light source 1202.

[0056] FIG. 13 depicts side planar views 1300, 1302 of the system for controlling directional visibility configured to be used in a room inside a building to only allow the person inside the room to view outside while those outside cannot see into the room in accordance with the present embodiment wherein at least one LED or

fluorescent light source 1304 and at least one switchable window 1306 are installed in the room, a controller 1308 communicating with the light source(s) 1304 and the switchable window 1306 through a wire connection 1310 in FIG. 13(a) and through a WiFi connection 1312 in FIG. 13(b).

[0057] FIG. 14 depicts a side planar view 1400 of the system for controlling directional visibility configured to be used in a room inside a building to only allow the person inside the room to view outside while those outside cannot see into the room in accordance with the present embodiment wherein a controller 1402 communicates with the light sources 1404 and the switchable window 1406 through a photodetector 1408.

[0058] FIG. 15 depicts side planar views 1500, 1502 of the system for controlling directional visibility configured to only allow a person outside to view inside while those inside cannot see outside in accordance with the present embodiment wherein at least one LED or fluorescent light source 1504 and at least one switchable window 1506 are installed outside the room, a controller 1508 communicating with the light sources 1504 and the switchable window 1506 through a wire connection 1510 in FIG. 15(a) and through a WiFi connection 1512 in FIG. 15(b).

[0059] FIG. 16 depicts a side planar view 1600 of the system for controlling directional visibility configured to only allow a person outside to view inside while those inside cannot see outside in accordance with the present embodiment wherein a controller 1602 communicates with light sources 1604 and the switchable window 1606 through a photodetector 1608.

[0060] FIG. 17 depicts side planar views 1700, 1702, 1704 of the system for controlling directional visibility configured to separate two places inside a building and be able to turn a privacy place into an observation place or an observation place

into a privacy place without changing the brightness on either side in accordance with the present embodiment wherein LED or fluorescent light sources 1706 are installed on either side of at least one switchable window 1708 and the light sources 1706 and the switchable window 1708 are modulated by a controller 1710 coupled through a wire connection 1712 in FIG. 17(a), through a WiFi connection 1714 in FIG. 17(b) or a combination of both connection methods in FIG. 17(c).

[0061] Thus, it can be seen that the present embodiments can provide a technology that utilizes LED lights and switchable glass to achieve one-way vision. The key advantage of the present embodiments is that they provide one-way vision without changing the brightness level of the public (outside of the room) or private (inside the room) sides, even if the brightness level in the private side is higher than the public side. The switchable window in accordance with the present embodiments can also allow outside seeing the inside while the inside cannot see the outside without changing the brightness level of either sides. In addition, the present system and methods also enable low energy consumption, tunable transmission, and no harmful effect to surrounding areas or residents. Therefore, it can be seen that the present embodiments provide systems and methods which can overcome the shortcomings of current technologies and can be widely applied to many places that require privacy protection, such as residences, offices, observation rooms, and labs.

[0062] While exemplary embodiments have been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should further be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, operation, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an

exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of steps and method of operation described in the exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

Claims

What is claimed is:

1. A method for controlling directional visibility through a switchable window located between a first space and a second space, the switchable window having a transmissive state, in which there is visibility through the switchable window, and an opaque state in which there is no visibility through the switchable window, the method comprising:

providing a first switchable light source in the first space; and

synchronising switching of the first light source, between an ON state and an OFF state, to switching of the switchable window between the transmissive state and the opaque state to control visibility from the first space into the second space, wherein the synchronized switching is at a rate greater than a frame rate of a human eye wherein the first light source is modulated to switch between the ON state and the OFF state and back to the ON state at a frequency that is greater than the frame rate of the human eye while the switchable window is modulated to switch between the transmissive state and the opaque state and back to the transmissive state at the frequency that is the rate greater than the frame rate of the human eye, and wherein the visibility through the switchable window in the transmissive state is tuned by controlling a transmissive time duration the switchable window is in the transmissive state and an opaque time duration the switchable window is in the opaque state.

2. The method according to Claim 1, wherein the synchronising switching comprises selectively switching the first switchable light source to the ON state while switching the

switchable window to the opaque state to provide visibility from the first space into the second space and to inhibit visibility from the second space into the first space.

3. The method according to Claim 1, wherein the synchronising switching comprises selectively switching the first switchable light source to the ON condition while switching the switchable window to the transmissive state to inhibit visibility from the first space into the second space and to provide visibility from the second space into the first space.

4. The method according to Claim 2, wherein the synchronising switching comprises modulating switching of the first light source and window so that visibility from the second space into the first space is substantially prevented.

5. The method according to Claim 3, wherein the synchronising switching comprises modulating switching of the first light source and window so that visibility from the first space into the second space is provided.

6. The method according to any preceding claim, wherein the synchronising switching comprises modulating the first light source to switch between the ON state and the OFF state such that a length of time the light source is in the ON state is longer than a length of time the light source is in the OFF state.

7. The method according to any one of Claims 1 to 6, wherein the synchronising switching comprises modulating the first light source to switch between the ON state and the

OFF state such that a length of time the light source is in the ON state is shorter than a length of time the first light source is in the OFF state.

8. The method according to any one of Claims 1 to 6, wherein the synchronizing switching comprises tuning the visibility through the switchable window in the transmissive state in response to a lighting condition in the second space by controlling the transmissive time duration when compared with the opaque time duration depending on the lighting condition in the second space.

9. The method according to Claim 8, wherein tuning the visibility through the switchable window in the transmissive state in response to a lighting condition in the second space comprises increasing the transmissive time duration when compared with the opaque time duration as the lighting condition in the second space reduces.

10. The method according to Claim 8, wherein tuning the visibility through the switchable window in the transmissive state in response to a lighting condition in the second space comprises decreasing the transmissive time duration when compared with the opaque time duration as the lighting condition in the second space increases.

11. The method according to Claim 8, wherein the first space is a space internal to a building, and the second space is a space external to the building, and wherein tuning the visibility through the switchable window in the transmissive state in response to a lighting condition in the second space by increasing the transmissive time duration when compared with

the opaque time duration during night-time, and decreasing the transmissive time duration when compared with the opaque time duration during daytime.

12. The method according to Claim 1, further comprising:

providing a second switchable light source in the second space; and

synchronising switching of the second switchable light source, between an ON state and an OFF state, to switching of the switchable window between the transmissive state and the opaque state to control visibility from the second space into the first space, and wherein the synchronized switching of the second switchable light source is also at a rate greater than a frame rate of a human eye wherein the second switchable light source is modulated to switch between the ON state and the OFF state and back to the ON state at a frequency that is greater than the frame rate of the human eye while the switchable window is modulated to switch between the transmissive state and the opaque state and back to the transmissive state at the frequency that is the rate greater than the frame rate of the human eye.

13. The method according to Claim 1, further comprising:

providing a second switchable light source in the second space;

synchronising switching of the first switchable light source and the second switchable light source so that a lighting cycle of the first light source is similar to a lighting cycle of the second light source; and

controlling a length of time the first switchable light source is in the ON condition when compared with a length of time the second switchable light source is in the ON condition such

that visibility from the first space into the second space differs from visibility from the second space into the first space.

14. The method according to Claim 13, wherein the first light source and the second light source are both in the ON state when the window is in the non-transmitting condition.

15. A system for controlling directional visibility between a first space and a second space, the system comprising:

a switchable window located between the first space and the second space, the switchable window having a transmissive state, in which there is visibility through the switchable window, and an opaque state in which there is no visibility through the switchable window, wherein the switchable window is configured to be switchable between the transmissive state and the opaque state;

a first switchable light source located in the first space and configured to be switchable between an ON state and an OFF state; and

a controller coupled to the first switchable light source and the switchable window, wherein the controller is configured to synchronise switching of the first switchable light source, between the ON state and the OFF state, to switching of the switchable window between the transmissive state and the opaque state to control visibility from the first space into the second space by switching the first switchable light source to the ON state depending on whether the switchable window is in the transmissive state or the opaque state, wherein the controller is further configured to switch the switchable window and the first switchable light source between respective said states at a rate greater than a frame rate of a human eye, and wherein the

controller provides a modulation signal to the first switchable light source to cause the first switchable light source to switch between the ON state and the OFF state and back to the ON state at a frequency that is the rate greater than the frame rate of the human eye, and wherein the controller provides the modulation signal to the switchable window to cause the switchable window to switch between the transmissive state and the opaque state and ~~a~~ back to the transmissive state at the frequency that is the rate greater than the frame rate of the human eye, and wherein the controller is further configured to tune visibility through the switchable window in the transmissive state by controlling a transmissive time duration the switchable window is in the transmissive state and an opaque time duration the switchable window is in the opaque state.

16. The system according to Claim 15, wherein the controller is configured to synchronise switching of the first switchable light source to the ON state while switching the switchable window to the opaque state to provide visibility from the first space into the second space and to inhibit visibility from the second space into the first space.

17. The system according to Claim 15, wherein the controller is configured to synchronise switching of the first switchable light source to the ON condition while switching the switchable window to the transmissive state to inhibit visibility from the first space into the second space and to provide visibility from the second space into the first space.

18. The system according to any of Claims 15 to 17, wherein the controller is configured to tune the visibility through the switchable window in the transmissive state in response to a

lighting condition in the second space by controlling the transmissive time duration when compared with the opaque time duration depending on the lighting condition in the second space.

19. The system according to Claim 15, further comprising a second switchable light source in the second space, wherein the controller is coupled to the second switchable light source and is configured to also control switching of the second switchable light source between an ON state and an OFF state at a rate greater than the frame rate of the human eye, wherein the controller synchronizes switching of the second light source between the ON state and the OFF state with switching of the switchable window such that when the second switchable light source is in the ON state the switchable window is in the transmissive state, and when the second switchable light source is in the OFF state the switchable window is in the opaque state.

20. The system according to Claim 15, further comprising a second switchable light source in the second space, wherein the controller is configured to synchronize switching of the first switchable light source and second switchable light source so that a lighting cycle of the first switchable light source is similar to a lighting cycle of the second switchable light source, and wherein the controller is also configured to control a length of time the first switchable light source is in the ON condition when compared with a length of time the second switchable light source is in the ON condition such that visibility from the first space into the second space differs from visibility from the second space into the first space.

21. The system according to any one of Claims 15 to 20, further comprising a user input means coupled to the controller, wherein the controller tunes visibility through the switchable

window in the transmissive state by controlling the transmissive time duration and/or the opaque time duration in response to a user input received from the user input means.

22. A wall separating a first space from a second space, the wall comprising a body between the first space and the second space, the body comprising a system according to any one of Claims 15 to 21.

23. A building comprising a wall according to Claim 22.