SYSTEM INCLUDING FOR CONTROLLING NON-LIGHT-EMITTING VARIABLE TRANSMISSION DEVICES CAPABLE OF GRADIENT TRANSMISSIONS

FIELD OF THE DISCLOSURE

[0001] The present disclosure is directed to systems for controlling non-light-emitting variable transmission devices, and more specifically to non-light-emitting variable transmission devices capable of a continuous graded transmission state.

BACKGROUND

[0002] A non-light-emitting variable transmission device can reduce glare and the amount of sunlight entering a room. Buildings can include many non-light-emitting variable transmission devices that may be controlled locally (at each individual or a relatively small set of devices), for a room, or for a building (a relatively large set of devices). Not all non-light-emitting variable transmission devices are capable of being in a continuously graded transmission state and there may be situations when such a state is not desired. However, controlling the transmission state of a non-light-emitting, variable transmission device capable of a continuously graded transmission state is more complicated than a device capable of uniform tinting. As such, there is a need for improved control of non-light-emitting variable transmission devices capable of a continuous graded transmission state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Embodiments are illustrated by way of example and are not limited in the accompanying figures.

[0004] FIG. 1 includes a schematic depiction of a system for controlling a set of non-light-emitting, variable transmission devices in accordance with an embodiment.

[0005] FIG. 2 flow diagram for operating the system of FIG. 1 in accordance with one embodiment.

[0006] FIG. 3 includes an illustration of a cross-sectional view of a portion of a substrate, a stack of layers for a non-light-emitting variable transmission device, and bus bars, according to one embodiment.

[0007] FIG. 4 includes an illustration of a top view of the substrate, the stack of layers, and the bus bars.

[0008] Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the invention.

DETAILED DESCRIPTION

[0009] The following description in combination with the figures is provided to assist in understanding the teachings disclosed herein. The following discussion will focus on specific implementations and embodiments of the teachings. This focus is provided to assist in describing the teachings and should not be interpreted as a limitation on the scope or applicability of the teachings.

[0010] The terms “normal operation” and “normal operating state” refer to conditions under which an electrical component or device is designed to operate. The conditions may be obtained from a data sheet or other information regarding voltages, currents, capacitances, resistances, or other electrical parameters. Thus, normal operation does not include operating an electrical component or device well beyond its design limits.

[0011] As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having,” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0012] The use of “a” or “an” is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural, or vice versa, unless it is clear that it is meant otherwise.

[0013] The use of the word “about”, “approximately”, or “substantially” is intended to mean that a value of a parameter is close to a stated value or position. However, minor differences may prevent the values or positions from being exactly as stated. Thus, differences of up to ten percent (10%) for the value are reasonable differences from the ideal goal of exactly as described.

[0014] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The materials, methods, and examples are illustrative only and not intended to be limiting. To the extent not described herein, many details regarding specific materials and processing acts are conventional and may be found in textbooks and other sources within the glass, vapor deposition, and electrochromic arts.

[0015] A system can include a non-light-emitting, variable transmission device configured to produce a continuously graded transmission state; a management system that includes a logic element configured to: determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; receive state information, wherein the state information comprises a first voltage necessary to produce a first tint state of a first half of the non-light-emitting, variable transmission device, a light irradiance, and a temperature measurement; prioritize the received state information; and send signals to a controller in response to input corresponding to prioritized state information, wherein the controller is configured to tint a second half of the non-light-emitting, variable transmission device to match the first tint level of the first half of the non-light-emitting, variable transmission device.

[0016] The systems and methods are better understood after reading the specification in conjunction with the figures. System architectures are described and illustrated, followed by an exemplary construction of a non-light-emitting, variable transmission device, and a method of controlling the system. The embodiments described are illustrative and not meant to limit the scope of the present invention, as defined by the appended claims.

[0017] Referring to FIG. 1, a system for controlling a set of non-light-emitting, variable transmission devices is illustrated and is generally designated 100. As depicted, the system 100 can include a building management system 110. In a particular aspect, the building management system 110 can include a computing device such as a desktop computer, a laptop computer, a tablet computer, a smartphone, some other computing device, or a combination thereof. The building management system 110 can be used to control the heating ventilation air condition

(HVAC) system of the building, interior lighting, exterior lighting, emergency lighting, fire suppression equipment, elevators, escalators, alarms, security cameras, access doors, another suitable component or sub-system of the building, or any combination thereof.

[0018] As illustrated in FIG. 1, the system 100 can include a router 120 connected to the building management system 110 via a control link 122. The control link 122 can be a wired connection or a wireless connection. For example, the wired connection can include a cable such as a Category 3 cable, a Category 5 cable, a Category 5e cable, a Category 6 cable, or another suitable cable that can be used in the transmission of control signals or a combination of power and control signals. In an embodiment, wired connections can comply with the IEEE 802.3 (Ethernet) family of standards. In another embodiment, the control link 122 can use a wireless local area network connection operating according to one or more of the standards within the IEEE 802.11 (Wi-Fi) family of standards. In a particular aspect, the wireless connections can operate within the 2.4 GHz ISM radio band, within the 5.0 GHz ISM radio band, or a combination thereof.

[0019] Regardless of the type of control link 122, the building management system 110 can provide control signals to the router 120 via the control link 122. The control signals can be used to control the operation of one or more non-light-emitting variable transmission devices that are indirectly, or directly, connected to the router 120 and described in detail below. As indicated in FIG. 1, the router 120 can be connected to an alternating current (AC) power source 124. The router 120 can include an onboard AC-to-direct current (DC) converter (not illustrated). The onboard AC-to-DC converter can convert the incoming AC power from the AC power source 124, approximately 120 Volts (V) AC, to a DC voltage that is at most 60 VDC, 54 VDC, 48 VDC, 24 VDC, at most 12 VDC, at most 6 VDC, or at most 3 VDC.

[0020] As further illustrated in FIG. 1, the system 100 can include controllers 130, 132, 134, and 136 connected to the router 120. The router 120 can be configured to provide power and control signals to the controllers 130, 132, 134, and 136. In a particular aspect, the router 120 can include a power inlet port and a control signal port. The router 120 can be configured to receive power via a power inlet port 124 and provide power to any or all of the controllers 130, 132, 134, and 136 and receive control signals via a control link and provide control signals to any or all of the controllers 130, 132, 134, and 136. The onboard AC-to-DC converter within the router 120 can be coupled to the power input port of the router 120. The router 120 can further include a component that is configured to reduce a voltage of power received over the power input port to voltages of power transmitted over the controller port. The component can include a transformer or a voltage regulator.

[0021] Each of the controllers 130, 132, 134, and 136 can include a plurality of connectors. As illustrated in FIG. 1, a plurality of cables 140 can be used to connect the controllers 130, 132, 134, and 136 to the router 120. Each of the cables 140 can include a Category 3 cable, a Category 5 cable, a Category 5e cable, a Category 6 cable, or another suitable cable. In an embodiment, the plurality of cables 140 can include twisted pair conductors, such as twisted pair wires. In another embodiment, each cable 140 can be configured to transmit at least 4 W of power, and in another embodiment, each cable can be configured to transmit at most 200 W of power. In another embodiment, each cable 140 can be configured to support a data rate of at least 3 Mb/s, and in another embodiment, each cable can be configured to support a data rate of at most 100 Gb/s. While the system 100 of FIG. 1 is illustrated with four controllers 130, 132, 134, and 136, the system 100 may include more or fewer controllers.

[0022] Still referring to FIG. 1, the system 100 can also include a window frame panel 150 electrically connected to the controllers 130, 132, 134, and 136 via a plurality of sets of frame cables 152. The window frame panel 150 can include a plurality of non-light-emitting, variable transmission devices, each of which may be connected to its corresponding controller via its own frame cable. In the embodiment as illustrated, the non-light-emitting, variable transmission devices are oriented in a 3 x 9 matrix. In another embodiment, a different number of non-light-emitting, variable transmission devices, a different matrix of the non-light-emitting, variable transmission devices, or both may be used. Each of the non-light-emitting, variable transmission devices may be on separate panes. In another embodiment, a plurality of non-light-emitting, variable transmission devices can share a glazing. For example, a glazing may correspond to a column of non-light-emitting, variable transmission devices in FIG. 1. A glazing may correspond to a plurality of columns of non-light-emitting, variable transmission devices. The non-light-emitting, variable transmission device 160 can be one of the devices further described below. In another embodiment, the glazings in the window frame panel 150 can have different sizes, such glazings can have a different number of non-light-emitting, variable transmission devices. In one embodiment, the non-light-emitting, variable transmission device 160 could be capable of maintaining a graded transmission state. Since the window frame panel 150 can have various sized, shaped, or characteristic non-light-emitting, variable transmission devices 160, controlling such devices can require a more complex method. In one embodiment, that method can include a master controller 112, as described below. After reading this specification, skilled artisans will be able to determine a particular number and organization of non-light-emitting, variable transmission devices for a particular application.

[0023] As seen in FIG. 1, the system 100 can further include a master controller 112 between the building management system 110 and a router 120. In a particular embodiment, a plurality of routers may be coupled to the master controller 112, and a plurality of master controllers can be coupled to the building management system. The master controller 112 can provide control signals to the one or more routers coupled to the master controller 112. The master controller 112 can be connected to the building management system 110 via a control link 114. Further, the router 120 can be connected to the master controller 112 via a control link 126. The control links 114 and 126 can be wired connections or wireless connections. For example, the wired connection can include a cable such as a Category 3 cable, a Category 5 cable, a Category 5e cable, a Category 6 cable, or another suitable cable that can be used in the transmission of power and control signals. In an embodiment, wired connections can comply with the IEEE 802.3 (Ethernet) family of standards. In another embodiment, the control link 126 can use a wireless local area network connection operating according to one or more of the standards within the IEEE 802.11 (Wi-Fi) family of standards. In a particular aspect, the wireless connections can operate within the 2.4 GHz ISM radio band, within the 5.0 GHz ISM radio band, or a combination thereof. Regardless of the type of control links 114 and 126, the building management system 110 can provide control signals to the master controller 112 via the control link 114, and the master controller 112 can provide the control signals to the router 120 via the control link 126.

[0024] FIG. 2 includes a flow chart for a method 200 of operating the system 100 illustrated in FIG. 1. In operation, the method can begin at operation 210 by determining whether to turn on or off a functionality of the non-light-emitting, variable transmission device. In one embodiment, the master controller 112 can determine whether to turn on or off the functionality of the non-light-emitting, variable transmission device. In one embodiment, the functionality could include maintaining the non-light-emitting, variable transmission device at a continuously graded transmission state. In another embodiment, the functionality could include only allowing uniform transmission states. In other words, while the non-light-emitting, variable transmission device can be maintained at a continuously graded transmission state, there could be an override command to turn off this functionality so that the non-light-emitting, variable transmission device can only be tinted in a uniform manner, either at fully clear, full tint, or a uniform transmission state in between fully clear and full tint. In one embodiment, the master controller 112, which can include a logic element, can receive a command from an external source to turn off the functionality.

[0025] The method can continue at operation 220 by receiving state information. The state information received could include external commands regarding the transmission states of the non-light-emitting, variable transmission device. In one embodiment, while the functionality to be maintained at a continuously graded transmission state is turned off, the non-light-emitting, variable transmission device can still be controlled based on the other state information received, such as light intensity, an occupancy of a controlled space corresponding to the window, a physical configuration of the controlled space, a temperature, an operating mode of a heating or cooling system, a sun position, color rendering information, a time of day, a calendar day, an elapsed time since a scene has been changed, heat load within the controlled space, a contrast level between relatively bright and relatively dark objects within a field of view where an occupant is normally situated within the controlled space, whether an orb of the sun is in the field of view where the occupant is normally situated within the controlled space, whether a reflection of the sun is in the field of view where the occupant is normally situated within the controlled space, a level of cloudiness, or another suitable parameter, or any combination thereof. In other words, while the device can only be tinted in a uniform manner, once the functionality to be maintained at a continuously graded transmission state is turned off, the tinting or transmission level of the device can still be controlled by other factors, such as those listed above.

[0026] The master controller 112 can receive state information from the building management system 110 or an external source. The master controller 112 can include logic to control the operation of the building environment, via the building management system 110, and facility controls, such as heating, ventilation, and air conditioning (HVAC), lights, and scenes for EC devices, via one of the controllers 130, 132, 134, 136. The logic for the master controller 112 can be in the form of hardware, software, or firmware. In an embodiment, the logic may be stored in a field programmable gate array (FPGA), an application-specific integrated circuit (ASIC), a hard drive, a solid state drive, or another persistent memory. In an embodiment, the master controller 112 may include a processor that can execute instructions stored in memory within the system 100 in response to state information received from an external source. In one embodiment, the external source can include a rooftop device. The device can be mounted on the roof of a building that contains the non-light emitting, variable transmission devices. In one embodiment, the external source can be one or more devices that include 360-degree sensors. In another embodiment, the external source can be one or more devices that include 180-degree sensors. The device can include an outer covering and one or more sensors. Each sensor can be spaced around a central axis and point in a different direction. Each sensor can be spaced apart by between 5 and 25 degrees. The one or more sensors can be oriented around the central point such that sensors surround the central point by 360 degrees. Each sensor can have a range from 45 to 180 degrees. In one embodiment, the device can include at least 4 sensors, such as at least 5 sensors, at least 7 sensors, at least 10 sensors. In one embodiment, the device can include no more than 30 sensors. Each sensor can return measurements on LUX, temperature, irradiance, direction, levels of light, weather measurements, and more. The device can include a compass to orient the one or more sensors. In one embodiment, the sensor can be powered by either 24 VA or power over Ethernet (POE). By combining the data from the plurality of sensors, the device can receive data from a 360-degree field of view. In one embodiment, data from a single sensor can be taken. As such, the device can receive data from between a 5-degree and 360-degree field of view based from a central point of the device. Each sensor can include one or more filters and may or may not be visible through the outer covering.

[0027] The collection of state information may occur nearly continuously, such as from a motion sensor, light sensor, or the like, on a periodic basis, such as once a minute, every ten minutes, hourly, or the like, or a combination thereof. This state information can be received at the master controller 112. This information may be contained within an ID tag on each device, a look-up table provided in conjunction with these devices, information provided by the building management system 110, or an external source.

[0028] Alternatively, this information can be obtained by an analog method, e.g., a resistance associated with each of these devices or the transmission state of the device. In one embodiment, the state information can be based on a simulation or 3D model algorithm that anticipates the conditions of the non-light-emitting, variable transmission device. This state information can be manually input into a building management system, and the building management system 110 can push this information to the master controller 112 or router 120 while the system 100 is being initially configured, reconfigured, or during a system reboot. In one embodiment, an I/O unit can be coupled to the controllers 130, 132, 134, and 136 through the router 120. The I/O unit can provide to a control device signals corresponding to state information that can include a light intensity, an occupancy of a controlled space corresponding to the window, a physical configuration of the controlled space, a temperature, an operating mode of a heating or cooling system, a sun position, color rendering information, a time of day, a calendar day, an elapsed time since a scene has been changed, heat load within the controlled space, a contrast level between relatively bright and relatively dark objects within a field of view where an occupant is normally situated within the controlled space, whether an orb of the sun is in the field of view where the occupant is normally situated within the controlled space, whether a reflection of the sun is in the field of view where the occupant is normally situated within the controlled space, a level of cloudiness, or another suitable parameter, or any combination thereof. The state information may be collected at the I/O unit from sources of state information, such as sensors, a calendar, a clock, a weather forecast, or the like. The controlled space can be an area surrounding a window of the EC device. The controlled space may be a room, such as a meeting room or an office, or may be part of a floor of a building. The EC device can then affect light, glare, or temperature of the controlled space.

[0029] The method can continue with operation 230 by prioritizing the state information received. After receiving the state information, the I/O unit can include logic to categorize and prioritize the state information. In one embodiment, the prioritization of state information can be to include the information into categories such as glare control, daylight transmission, color rendering, energy saving, or uniformity. The prioritization of the categories can be assigned based on criteria set prior to installation of the non-light-emitting, variable transmission devices. The prioritized information can then be used to control the non-light-emitting, variable transmission device 160.

[0030] The method can continue by sending instructions to control the non-light-emitting, variable transmission device 160, at operation 230. In one embodiment, the master controller 112 receives a first command to tint the non-light-emitting variable transmission device to a gradient transmission while the functionality of graded transmission is off. In one embodiment, sending instructions to control the non-light-emitting, variable transmission device 160 can include the master controller 112 overriding the first command when the functionality to maintain the non-light-emitting, variable transmission device 160 is turned off. The master controller 112 can send a second command when the first command is overridden. In one embodiment, the second command can be to maintain the non-light-emitting, variable transmission device 160 in a uniform state, as will be described in more detail below. In an embodiment, the prioritized state information may be used to send instructions to the controllers 130, 132, 134, and 136. One or more control devices may be adjacent to an IGU, and another local control device may be within the controlled space and spaced apart from the IGU. Such other local control devices may be near light switches, a thermostat, or a door for the controlled space. Logic operations are described below with respect to particular control devices with respect to an embodiment. In another embodiment, a logic operation described with respect to a particular control device may be performed by another control device or be split between the control devices. After reading this specification, skilled artisans will be able to determine a particular configuration that meets the needs or desires for a particular application.

[0031] In one embodiment, the instructions to control the non-light-emitting variable transmission device 160 can include making a transmission state of the non-light-emitting, variable transmission device 160 uniform. The master controller 112 can send commands based on a two-number system, where the first number is a transmission state of the first half of the non-light-emitting, variable transmission device 160 and the second number is the transmission state of a second half of the non-light-emitting, variable transmission device 160. For example, in one embodiment, a command can be “00” meaning that the transmission state of the first half and the second half of the non-light-emitting, variable transmission device 160 are the same. In another embodiment, a command can be "01" meaning that the transmission state of the first half and the transmission state of the second half of the non-light-emitting, variable transmission device 160 are different. In one embodiment, in order to make the transmission state of the non-light-emitting, variable transmission device 160 capable of graded transmission uniform, the master controller 112 determines the first transmission state of the first half of the non-light-emitting, variable transmission device and matches a second half of the non-light-emitting, variable transmission device 160 to the first half. For example, if the master controller 112 determined that the non-light-emitting, variable transmission device 160 had a transmission state of "01", equating to a continuous graded transmission state, then the master controller 112 would send a command to change the transmission state to "00", equating to a uniform transmission state on both the first half and the second half of the device. The command sent from the master controller 112 can then go to the controller 130, via the router 120, to determine what voltage is being applied to the non-light-emitting, variable transmission device 160 to produce "0" transmission state. A second voltage can then be sent to the second half of the non-light-emitting, variable transmission device 160 to produce a second transmission state to match the transmission state of the first half of the non-light-emitting, variable transmission device 160. In one embodiment, in order to make the transmission state of the non-light-emitting, variable transmission device 160 capable of graded transmission uniform, a measurement of a first tint state of a first half of the non-light-emitting, variable transmission device 160 can be taken, a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device 160 is determined, and a second voltage to a second half of the non-light-emitting, variable transmission device 160 to produce a second tint level, where the second tint level is the same as the first tint level is sent.

[0032] Once the first transmission state of the first half of the non-light-emitting, variable transmission device 160 matches the second half of the non-light-emitting, variable transmission device 160, the master controller 112 can reevaluate whether to turn on or off the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state. In one embodiment, the master controller 112 can reevaluate whether to turn on or off the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state after a time period, such as 1 hour, or such as 1 week, such as 1 month, or such as 1 year, or such as 10 years. In one embodiment, the master controller 112 can reevaluate whether to turn on or off the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state after a time period between 1 minute and 100 years. In one embodiment, the master controller 112 can reevaluate whether to turn on or off the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state after receiving a manual request to reevaluate.

[0033] The system can be used with a wide variety of different types of non-light-emitting variable transmission devices. In a particular, non-limiting embodiment, the window frame panel 150 can include one or more non-light-emitting, variable transmission devices 160 coupled to the controller 130 via a set of frame cables 152. The controllers 130, 132, 134, and 136 can provide power to the non-light-emitting, variable transmission devices 160 connected thereto via the sets of frame cables 152. The power provided to the non-light-emitting, variable transmission device 160 can have a voltage that is at most 12 V, at most 6 V, or at most 3 V. During operation, the non-light-emitting, variable transmission devices 160 can act similarly to capacitors. Thus, most of the power is consumed when the non-light-emitting, variable transmission devices 160 are in their switching states, not in their static states. In one example, the router 120 may have a power rating of 500 W, and each of the controllers 130, 132, 134, and 136 can have a power rating of 80 W. However, the number of controllers, with power ratings of 80 W each, may exceed the router's power rating of 500 W.

[0034] The description with respect to FIGs. 3 and 4 provide exemplary embodiments of a glazing that includes a glass substrate and a non-light-emitting variable transmission device disposed thereon. In the description below, a non-light-emitting variable transmission device will be described as operating with voltages on bus bars being in a range of 0 V to 3 V. Such description is used to simplify concepts as described herein. Other voltage may be used with the non-light-emitting variable transmission device or if the composition or thicknesses of layers within an electrochromic stack are changed. The voltages on bus bars may both be positive (1 V to 4 V), both negative (-5 V to -2 V), or a combination of negative and positive voltages (-1 V to 2 V), as the voltage difference between bus bars are more important than the actual voltages. Furthermore, the voltage difference between the bus bars may be less than or greater than 3 V.

After reading this specification, skilled artisans will be able to determine voltage differences for different operating modes to meet the needs or desires for a particular application. The embodiments are exemplary and not intended to limit the scope of the appended claims.

[0035] FIG. 3 includes a cross-sectional view of a portion of a non-light-emitting, variable transmission device with a stack of layers and bus bars, according to one embodiment. In one embodiment, the non-light-emitting, variable transmission device 324 can be similar as the non-light-emitting, variable transmission device 160 of FIG. 1. The non-light-emitting, variable transmission device 324 can include a first transparent conductive layer 312, a cathodic non-light-emitting, variable transmission device layer 314, an anodic non-light-emitting, variable transmission device layer 318, and a second transparent conductive layer 322. The device 324 can also include an ion conducting layer 316 between the cathodic non-light-emitting, variable transmission device layer 314 and the anodic non-light-emitting, variable transmission device layer 318. The first transparent conductive layer 312 can be between the substrate 300 and the cathodic non-light-emitting, variable transmission device layer 314. The cathodic non-light-emitting, variable transmission device layer 314 can be between the first transparent conductive layer 312 and the anodic non-light-emitting, variable transmission device layer 318. The anodic non-light-emitting, variable transmission device layer 318 can be between the cathodic non-light-emitting, variable transmission device layer 314 and the second transparent conductive layer 322.

[0036] The substrate 300 can include a glass substrate, a sapphire substrate, an aluminum oxynitride substrate, a spinel substrate, or a transparent polymer. In a particular embodiment, the substrate 300 can be float glass or a borosilicate glass and have a thickness in a range of 0.025 mm to 4 mm thick. In another particular embodiment, the substrate 300 can include ultra-thin glass that is a mineral glass having a thickness in a range of 10 microns to 300 microns. The first transparent conductive layer 312 and the second transparent conductive layer 322 can include a conductive metal oxide or a conductive polymer. Examples can include an indium oxide, tin oxide or a zinc oxide, either of which can be doped with a trivalent element, such as Sn, Sb, Al, Ga, In, or the like, or polyaniline, polypyrrole, a sulfonated polymer, such as poly(3,4-ethylenedioxythiophene), or the like or one or several metal layer(s) or a metal mesh or a nanowire mesh or graphene or carbon nanotubes or a combination thereof. The transparent conductive layers 312 and 322 can have the same or different compositions.

[0037] The cathodic non-light-emitting, variable transmission device layer 314 and the anodic non-light-emitting, variable transmission device layer 318 can be electrode layers. In one embodiment, the cathodic non-light-emitting, variable transmission device layer 314 can be an electrochromic layer. In another embodiment, the anodic non-light-emitting, variable transmission device layer 318 can be a counter electrode layer. The electrochromic layer can include an inorganic metal oxide non-light-emitting, variable transmission device active material, such as WO_3, V_2O_5, MoO_3, Nb_2O_5, TiO_2, CuO, Ir_2O_3, Cr_2O_3, Co_2O_3, Mn_2O_3, or any combination thereof and have a thickness in a range of 20 nm to 2,000 nm. The counter electrode layer can include any of the materials listed with respect to the electrochromic layer and may further include nickel oxide (NiO, Ni_2O_3, or a combination of the two) or iridium oxide, and Li, Na, H, or another ion and have a thickness in a range of 20 nm to 1,000 nm. The ion conductive layer 316 (sometimes called an electrolyte layer) can be optional and can have a thickness in a range of 1 nm to 1,000 nm in the case of an inorganic ion conductor or 5 microns to 1,000 microns in the case of an organic ion conductor. The ion conductive layer 316 can include a silicate with or without lithium, aluminum, zirconium, phosphorus, boron; a borate with or without lithium; a tantalum oxide with or without lithium; a lanthanide-based material with or without lithium; another lithium-based ceramic material particularly $Li_xMO_yN_z$ where M is one or a combination of transition metals or the like.

[0038] The first bus bar 330 can be electrically connected to the first transparent conductive layer 312. In one embodiment, the first transparent conductive layers 312 includes portions removed 352, so that the first bus bar 330 is not electrically connected to the second bus bar 310. In one embodiment, the first bus bar 330 is on one side of the stack of layers of the electrochemical device 324 and the second bus bar 310 is on the opposite side of the stack of layers of the electrochemical device 324. The second bus bar 310 can be electrically connected to the second transparent conductive layer 322. The second transparent conductive layer 322 can include portions 350 removed so that the second bus bar 310 is not electrically connected to the first bus bar 330 via the second transparent conductive layer 322. The first bus bar 330 can be electrically connected to the cathodic non-light-emitting, variable transmission device layer 314 via the first transparent conductive layer 312. The second bus bar 310 can be electrically connected to the anodic non-light-emitting, variable transmission device layer 318 via the second transparent conductive layer 322. In one embodiment, the first bus bar 330 can extend along more than one side of the substrate 300. In one embodiment, the first bus bar 330 and the second bus bar 310 can include multiple segments. In one embodiment, the first bus bar 330 and the second bus bar 310 can include multiple discontinuous segments. The number of bus bars is not limited to the configuration as shown in FIG. 4. While an exemplary bus bar configuration, shown in FIG. 4, can produce a continuous gradient transmission state, the present disclosure can work with any bus bar configuration capable of producing a continuous gradient transmission state and is not limited to the configuration of FIG 4.

[0039] The first bus bar 330 and the second bus bar 310 can include a conductive material. In an embodiment, each of the bus bars 330 and 310 can be formed using a conductive ink, such as a silver frit, that is printed over the transparent conductive layer 312, 322. In another embodiment, one or more of the bus bars 330 and 310 can include a metal-filled polymer, such as a silver-filled epoxy.

[0040] The non-light-emitting, variable transmission device 160, 324 can be processed into an insulated glazing unit (IGU). The IGU can further include a counter substrate and a solar control film disposed between the substrate of the device 324 and the counter substrate. The counter substrate can be also coupled to a glass pane. Each of the counter substrate and pane can be a toughened or a tempered glass and have a thickness in a range of 2 mm to 9 mm. A low-emissivity layer can be disposed along an inner surface of the pane. An internal space of the IGU may include a relatively inert gas, such as a noble gas or dry air. In another embodiment, the internal space may be evacuated. The IGU can include an energy source, a control device, and an input/output (I/O) unit. In an embodiment, the energy source may include a photovoltaic cell, a battery, another suitable energy source, or any combination thereof. The control device can include logic to control the operation of the device 324. The logic for the control device can be in the form of hardware, software, or firmware. In an embodiment, the logic may be stored in a field programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or another persistent memory. In an embodiment, the control device may include a processor that can execute instructions stored in memory within the control device or received from an external source. The I/O unit can be coupled to the control device. The I/O unit can provide information from sensors, such as light, motion, temperature, another suitable parameter, or any combination thereof. The I/O unit may provide information regarding the non-light emitting, variable transmission device 324, the energy source, or control device to another portion of the system or to another destination outside the system.

[0041] FIG. 4 includes a top view of the substrate 300 and a non-light-emitting variable transmission device 324 that includes the layers as described with respect to FIG. 3. The bus bar 310 lies along a side 402 of the substrate 300, and the bus bar 330 lies along a side 404 that is opposite the side 402. Each of the bus bars 310 and 330 has a length that extends a majority of the distance between a side 406 and a side 408 that is opposite the side 406. In a particular embodiment, each of the bus bars 310 and 330 has a length that is at least 75%, at least 90%, or at least 95% of the distance between the sides 406 and 408. The bus bars and are substantially parallel to each other. As used herein, substantially parallel is intended to mean that the lengths of the bus bars 310 and 330 are within 10 degrees of being parallel to each other. Along the length, each of the bus bars has a substantially uniform cross-sectional area and composition. Thus, in such an embodiment, the bus bars 310 and 330 have a substantially constant resistance per unit length along their respective lengths.

[0042] Embodiments as described above can provide benefits over other systems with non-light-emitting, variable transmission devices. A controller or router may be replaced without any tools. A comparative system may require a screwdriver, a solder gun, electrical tape or the like. Further, the male/female connections save significantly on the time needed to change the configuration. Individual wires do not need to be traced for the entire signal path to the non-light-emitting, variable transmission devices. The likelihood of incorrect wiring is significantly reduced.

[0043] The methods as described herein can change the functionality of a non-light-emitting, variable transmission device capable of maintaining a graded transmission state.

[0044] Many different aspects and embodiments are possible. Some of those aspects and embodiments are described below. After reading this specification, skilled artisans will appreciate that those aspects and embodiments are only illustrative and do not limit the scope of the present invention. Exemplary embodiments may be in accordance with any one or more of the embodiments as listed below.

[0045] Embodiment 1. A method of controlling a non-light-emitting, variable transmission device, can include: providing the non-light-emitting, variable transmission device configured to be maintained at a continuously graded transmission state; receiving a first command to maintain the non-light-emitting, variable transmission device at a continuously graded transmission state; overriding the first command; and sending a second command to a controller to tint the non-light-emitting, variable transmission device uniformly.

[0046] Embodiment 2. The method of embodiment 1, where overriding the first command can include intercepting the first command before it reaches the controller.

[0047] Embodiment 3. The method of embodiment 1, where a master controller receives the first command and sends the second command.

[0048] Embodiment 4. The method of embodiment 1, further can include: determining a first tint state of a first half of the non-light-emitting, variable transmission device; and determining a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device; and sending a second voltage to a second half of the non-light-emitting, variable transmission device to produce a second tint level, where the second tint level is the same as the first tint level.

[0049] Embodiment 5. The method of embodiment 4, where the first voltage is different from the second voltage.

[0050] Embodiment 6. A method of controlling a non-light-emitting, variable transmission device, can include: determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; turning off, via a master controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; receiving a first command to maintain the non-light-emitting, variable transmission device at the continuously graded transmission state; override the first command; and sending a second command to a controller to tint the non-light-emitting, variable transmission device uniformly.

[0051] Embodiment 7. The method of embodiment 6, further can include determining a first tint state of a first half of the non-light-emitting, variable transmission device; and determining a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device; and sending a second voltage to a second half of the non-light-emitting, variable transmission device to produce a second tint level, where the second tint level is the same as the first tint level.

[0052] Embodiment 8. The method of embodiment 7, where the first tint state is a fully clear transmission state.

[0053] Embodiment 9. The method of embodiment 7, where the first tint state is a fully tinted transmission state.

[0054] Embodiment 10. The method of embodiment 7, where the first half of the non-light-emitting, variable transmission device is a top half.

[0055] Embodiment 11. The method of embodiment 7, where the first half of the non-light-emitting, variable transmission device is a bottom half.

[0056] Embodiment 12. The method of embodiment 7, where the first tint state is a partially tinted transmission state.

[0057] Embodiment 13. A system, can include: a non-light-emitting, variable transmission device configured to produce a continuously graded transmission state; a master controller that includes a logic element configured to: determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

[0058] Embodiment 14. The system of embodiment 13, where the logic element of the master controller can further: receive state information, where the state information can include a first voltage necessary to produce a first tint state of a first half of the non-light-emitting, variable transmission device, a light irradiance, and a temperature measurement; prioritize the received state information; and send signals to a controller in response to input corresponding to prioritized state information, where the controller is configured to tint a second half of the non-light-emitting, variable transmission device to match the first tint level of the first half of the non-light-emitting, variable transmission device.

[0059] Embodiment 15. The system of embodiment 13, further can include the logic element further determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; and turning off, via a controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

[0060] Embodiment 16. The system of embodiment 13, further can include the logic element further reevaluating whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; and turning on, via a controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

[0061] Embodiment 17. The system of embodiment 16, where reevaluating whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state is done after a time period.

[0062] Embodiment 18. The system of embodiment 13, further can include sending a signal to a first controller in response to input corresponding to prioritized state information, where the first controller is configured to tint the first half of the non-light-emitting, variable transmission device to a predetermined tint state before tinting the second half of the non-light-emitting, variable transmission device to match the first tint level of the first half of the non-light-emitting variable transmission state.

[0063] Embodiment 19. The system of embodiment 13, where the non-light-emitting, variable transmission device can include: a substrate; a first transparent conductive layer; a second transparent conductive layer; a cathodic non-light-emitting, variable transmission device layer between the first transparent conductive layer and the second transparent conductive layer; and an anodic non-light-emitting, variable transmission device layer over the electrochromic layer between the first transparent conductive layer and the second transparent conductive layer.

[0064] Embodiment 20. The system of embodiment 19, further can include an ion conducting layer between the cathodic non-light-emitting, variable transmission device layer and the anodic non-light-emitting, variable transmission device layer.

[0065] Embodiment 21. The system of embodiment 19, where the substrate can include a material selected from the group consisting of glass, sapphire, aluminum oxynitride, spinel, polyacrylic compound, polyalkene, polycarbonate, polyester, polyether, polyethylene, polyimide, polysulfone, polysulfide, polyurethane, polyvinylacetate, another suitable transparent polymer, co-polymer of the foregoing, float glass, borosilicate glass, or any combination thereof.

[0066] Embodiment 22. The system of embodiment 19, where cathodic non-light-emitting, variable transmission device layer can include a material selected from the group consisting of

WO_3, V_2O_5, MoO_3, Nb_2O_5, TiO_2, CuO, Ni_2O_3, NiO, Ir_2O_3, Cr_2O_3, Co_2O_3, Mn_2O_3, mixed oxides (e.g., W-Mo oxide, W-V oxide), lithium, aluminum, zirconium, phosphorus, nitrogen, fluorine, chlorine, bromine, iodine, astatine, boron, a borate with or without lithium, a tantalum oxide with or without lithium, a lanthanide-based material with or without lithium, another lithium-based ceramic material, or any combination thereof.

[0067] Embodiment 23. The system of embodiment 19, where anodic non-light-emitting, variable transmission device layer can include a material selected from the group consisting of WO_3, V_2O_5, MoO_3, Nb_2O_5, TiO_2, CuO, Ir_2O_3, Cr_2O_3, Co_2O_3, Mn_2O_3, Ta_2O_5, ZrO_2, HfO_2, Sb_2O_3, a lanthanide-based material with or without lithium, another lithium-based ceramic material, a nickel oxide (NiO, Ni_2O_3, or combination of the two), and Li, nitrogen, Na, H, or another ion, any halogen, or any combination thereof.

[0068] Embodiment 24. The system of embodiment 19, where the first transparent conductive layer can include a material selected from the group consisting of indium oxide, indium tin oxide, doped indium oxide, tin oxide, doped tin oxide, zinc oxide, doped zinc oxide, ruthenium oxide, doped ruthenium oxide, silver, gold, copper, aluminum, and any combination thereof.

[0069] Embodiment 25. The system of embodiment 19, where the second transparent conductive layer can include a material selected from the group consisting of indium oxide, indium tin oxide, doped indium oxide, tin oxide, doped tin oxide, zinc oxide, doped zinc oxide, ruthenium oxide, doped ruthenium oxide and any combination thereof.

[0070] Embodiment 26. The system of embodiment 20, where the ion-conducting layer can include a material selected from the group consisting of lithium, sodium, hydrogen, deuterium, potassium, calcium, barium, strontium, magnesium, oxidized lithium, Li_2WO_4, tungsten, nickel, lithium carbonate, lithium hydroxide, lithium peroxide, or any combination thereof.

[0071] Note that not all of the activities described above in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed is not necessarily the order in which they are performed.

[0072] Certain features that are, for clarity, described herein in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, reference to values stated in ranges includes each and every value within that range.

[0073] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

[0074] The specification and illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments. The specification and illustrations are not intended to serve as an exhaustive and comprehensive description of all of the elements and features of apparatus and systems that use the structures or methods described herein. Separate embodiments may also be provided in combination in a single embodiment, and conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, reference to values stated in ranges includes each and every value within that range. Many other embodiments may be apparent to skilled artisans only after reading this specification. Other embodiments may be used and derived from the disclosure, such that a structural substitution, logical substitution, or another change may be made without departing from the scope of the disclosure. Accordingly, the disclosure is to be regarded as illustrative rather than restrictive.

WHAT IS CLAIMED IS:

1. A method of controlling a non-light-emitting, variable transmission device, comprising:

providing the non-light-emitting, variable transmission device configured to be maintained at a continuously graded transmission state;

receiving a first command to maintain the non-light-emitting, variable transmission device at a continuously graded transmission state;

overriding the first command; and

sending a second command to a controller to tint the non-light-emitting, variable transmission device uniformly.

2. The method of claim 1, wherein overriding the first command comprises intercepting the first command before it reaches the controller.

3. The method of claim 1, wherein a master controller receives the first command and sends the second command.

4. The method of claim 1, further comprising:

determining a first tint state of a first half of the non-light-emitting, variable transmission device; and

determining a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device; and

sending a second voltage to a second half of the non-light-emitting, variable transmission device to produce a second tint level, wherein the second tint level is the same as the first tint level.

5. The method of claim 4, wherein the first voltage is different from the second voltage.

6. A method of controlling a non-light-emitting, variable transmission device, comprising:

determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state;

turning off, via a master controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state;

receiving a first command to maintain the non-light-emitting, variable transmission device at the continuously graded transmission state;

override the first command; and

sending a second command to a controller to tint the non-light-emitting, variable transmission device uniformly.

7. The method of claim 6, further comprising determining a first tint state of a first half of the non-light-emitting, variable transmission device; and

determining a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device; and

sending a second voltage to a second half of the non-light-emitting, variable transmission device to produce a second tint level, wherein the second tint level is the same as the first tint level.

8. The method of claim 7, wherein the first tint state is a fully clear transmission state.

9. The method of claim 7, wherein the first tint state is a fully tinted transmission state.

10. The method of claim 7, wherein the first half of the non-light-emitting, variable transmission device is a top half.

11. The method of claim 7, wherein the first half of the non-light-emitting, variable transmission device is a bottom half.

12. The method of claim 7, wherein the first tint state is a partially tinted transmission state.

13. A system, comprising:

a non-light-emitting, variable transmission device configured to produce a continuously graded transmission state;

a master controller that includes a logic element configured to:

determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

14. The system of claim 13, wherein the logic element of the master controller can further:

receive state information, wherein the state information comprises a first voltage necessary to produce a first tint state of a first half of the non-light-emitting, variable transmission device, a light irradiance, and a temperature measurement;

prioritize the received state information; and

send signals to a controller in response to input corresponding to prioritized state information, wherein the controller is configured to tint a second half of the non-light-emitting, variable transmission device to match the first tint level of the first half of the non-light-emitting, variable transmission device.

15. The system of claim 13, further comprising the logic element further determining whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; and

turning off, via a controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

16. The system of claim 13, further comprising the logic element further reevaluating whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state; and

turning on, via a controller, the functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state.

17. The system of claim 16, wherein reevaluating whether to turn on or off a functionality for the non-light-emitting, variable transmission device to be maintained at a continuously graded transmission state is done after a time period.

18. The system of claim 14, further comprising sending a signal to a first controller in response to input corresponding to prioritized state information, wherein the first controller is configured to tint the first half of the non-light-emitting, variable transmission device to a predetermined tint state before tinting the second half of the non-light-emitting, variable transmission device to match the first tint level of the first half of the non-light-emitting variable transmission state.

19. The system of claim 13, wherein the non-light-emitting, variable transmission device comprises:

a substrate;

a first transparent conductive layer;

a second transparent conductive layer;

a cathodic non-light-emitting, variable transmission device layer between the first transparent conductive layer and the second transparent conductive layer; and

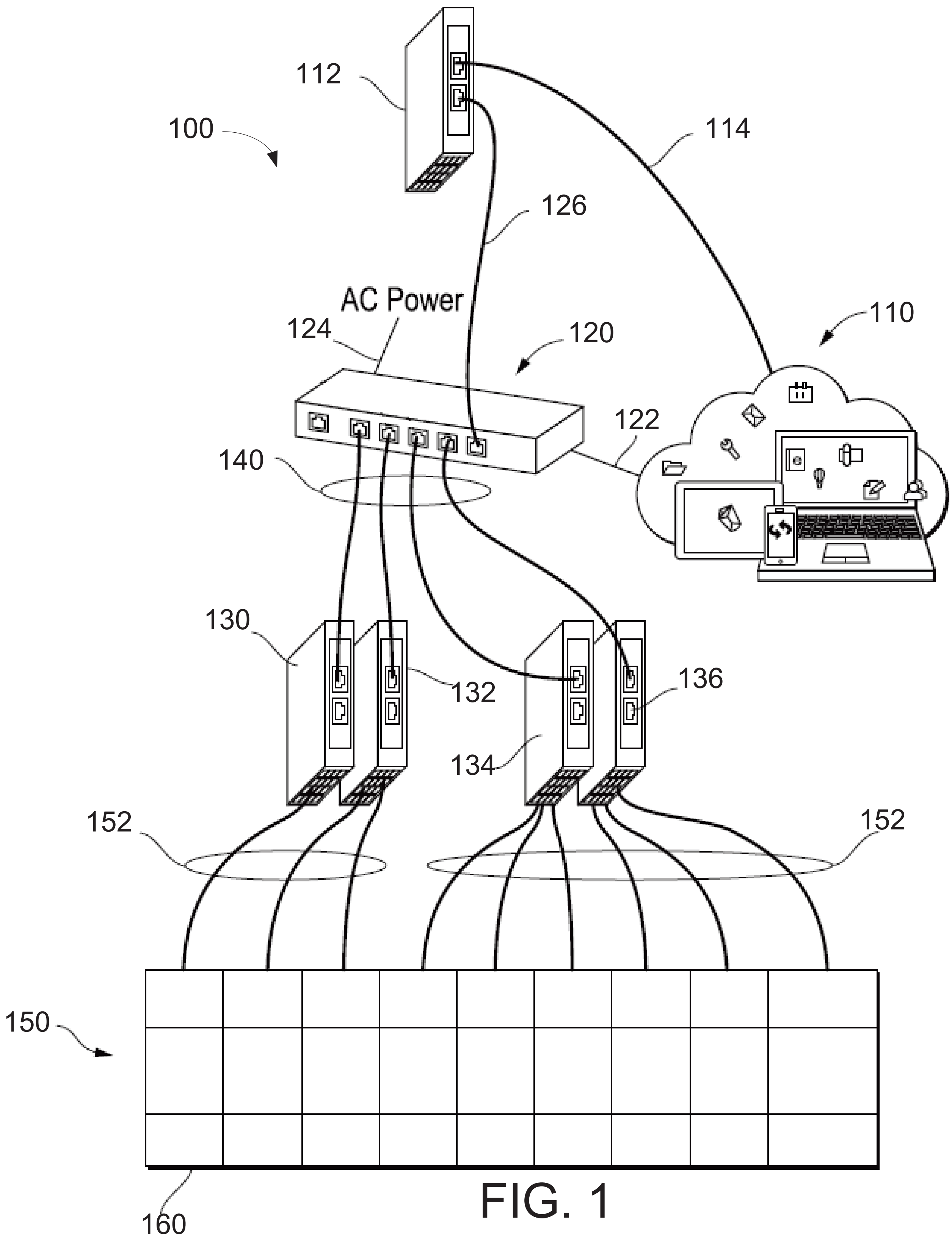
an anodic non-light-emitting, variable transmission device layer over the electrochromic layer between the first transparent conductive layer and the second transparent conductive layer.

20. The system of claim 19, further comprising an ion conducting layer between the cathodic non-light-emitting, variable transmission device layer and the anodic non-light-emitting, variable transmission device layer.
21. The system of claim 19, wherein the substrate comprises a material selected from the group consisting of glass, sapphire, aluminum oxynitride, spinel, polyacrylic compound, polyalkene, polycarbonate, polyester, polyether, polyethylene, polyimide, polysulfone, polysulfide, polyurethane, polyvinylacetate, another suitable transparent polymer, co-polymer of the foregoing, float glass, borosilicate glass, or any combination thereof.
22. The system of claim 19, wherein cathodic non-light-emitting, variable transmission device layer comprises a material selected from the group consisting of WO3, V2O5, MoO3, Nb2O5, TiO2, CuO, Ni2O3, NiO, Ir2O3, Cr2O3, Co2O3, Mn2O3, mixed oxides (e.g., W-Mo oxide, W-V oxide), lithium, aluminum, zirconium, phosphorus, nitrogen, fluorine, chlorine, bromine, iodine, astatine, boron, a borate with or without lithium, a tantalum oxide with or without lithium, a lanthanide-based material with or without lithium, another lithium-based ceramic material, or any combination thereof.
23. The system of claim 19, wherein anodic non-light-emitting, variable transmission device layer comprises a material selected from the group consisting of WO3, V2O5, MoO3, Nb2O5, TiO2, CuO, Ir2O3, Cr2O3, Co2O3, Mn2O3, Ta2O5, ZrO2, HfO2, Sb2O3,a lanthanide-based material with or without lithium, another lithium-based ceramic material, a nickel oxide (NiO, Ni2O3, or combination of the two), and Li, nitrogen, Na, H, or another ion, any halogen, or any combination thereof.
24. The system of claim 19, wherein the first transparent conductive layer comprises a material selected from the group consisting of indium oxide, indium tin oxide, doped indium oxide, tin oxide, doped tin oxide, zinc oxide, doped zinc oxide, ruthenium oxide, doped ruthenium oxide, silver, gold, copper, aluminum, and any combination thereof.
25. The system of claim 19, wherein the second transparent conductive layer comprises a material selected from the group consisting of indium oxide, indium tin oxide, doped indium oxide, tin oxide, doped tin oxide, zinc oxide, doped zinc oxide, ruthenium oxide, doped ruthenium oxide and any combination thereof.

26. The system of claim 20, wherein the ion-conducting layer comprises a material selected from the group consisting of lithium, sodium, hydrogen, deuterium, potassium, calcium, barium, strontium, magnesium, oxidized lithium, Li2WO4, tungsten, nickel, lithium carbonate, lithium hydroxide, lithium peroxide, or any combination thereof.

ABSTRACT OF THE DISCLOSURE

A method of controlling a non-light-emitting, variable transmission device is disclosed. The method can include: maintaining the non-light-emitting, variable transmission device is a continuously graded transmission state; determining a first tint state of a first half of the non-light-emitting, variable transmission device; and determining a first voltage necessary to produce the tint level of the first half of the non-light-emitting, variable transmission device; and sending a second voltage to a second half of the non-light-emitting, variable transmission device to produce a second tint level, where the second tint level can be the same as the first tint level.


112
100
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AC Power
124
120
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140
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160

FIG. 1

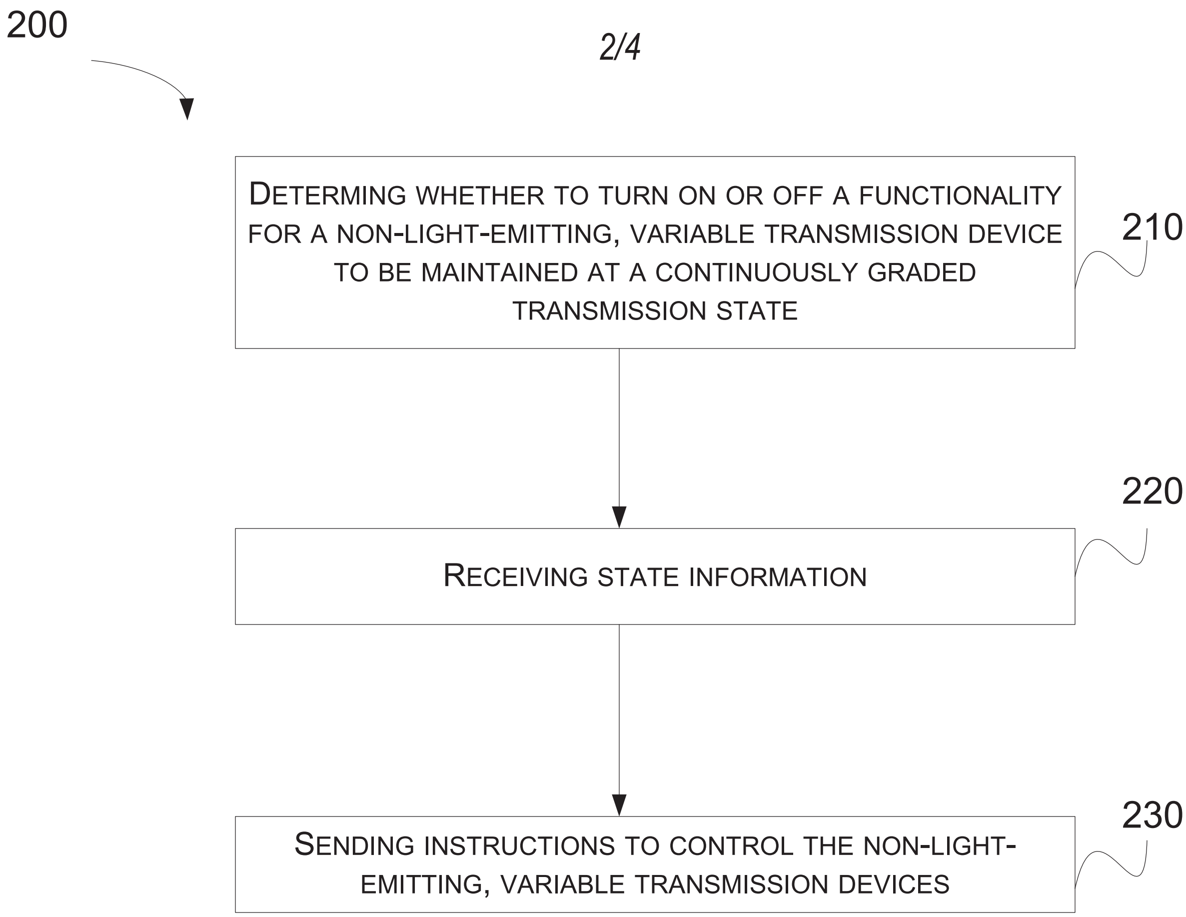
200
DETERMING WHETHER TO TURN ON OR OFF A FUNCTIONALITY FOR A NON-LIGHT-EMITTING, VARIABLE TRANSMISSION DEVICE TO BE MAINTAINED AT A CONTINUOUSLY GRADED TRANSMISSION STATE
210
RECEIVING STATE INFORMATION
220
SENDING INSTRUCTIONS TO CONTROL THE NON-LIGHT-EMITTING, VARIABLE TRANSMISSION DEVICES
230

FIG. 2

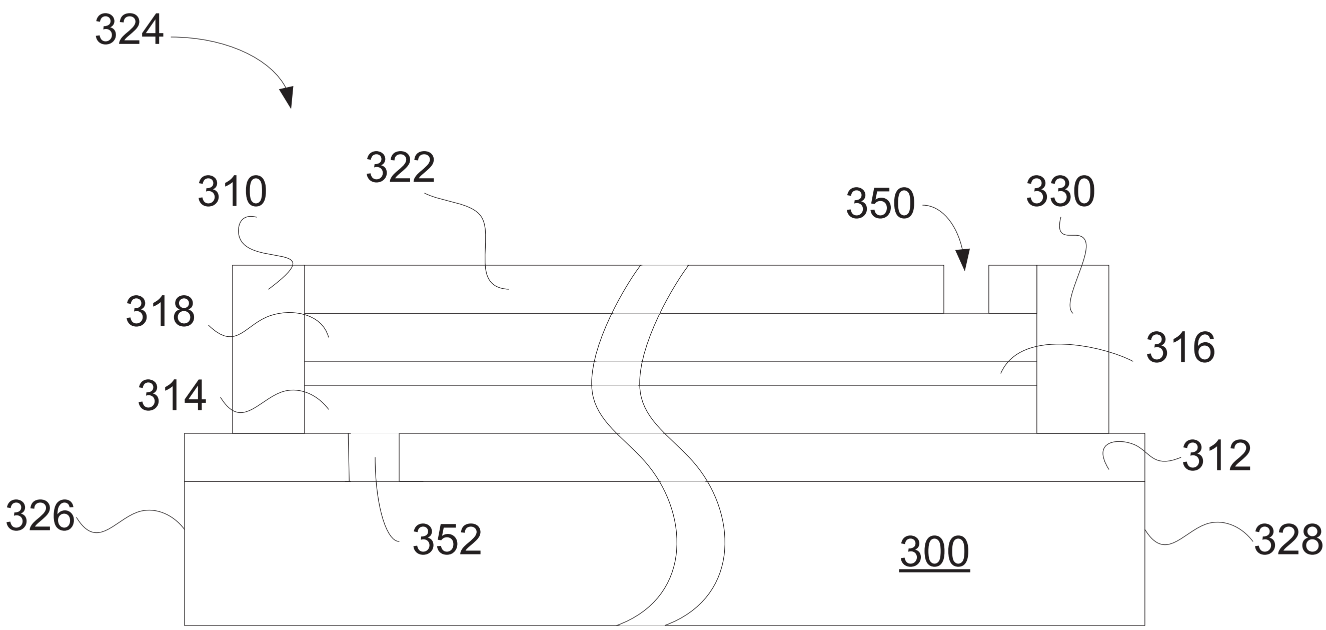

FIG. 3

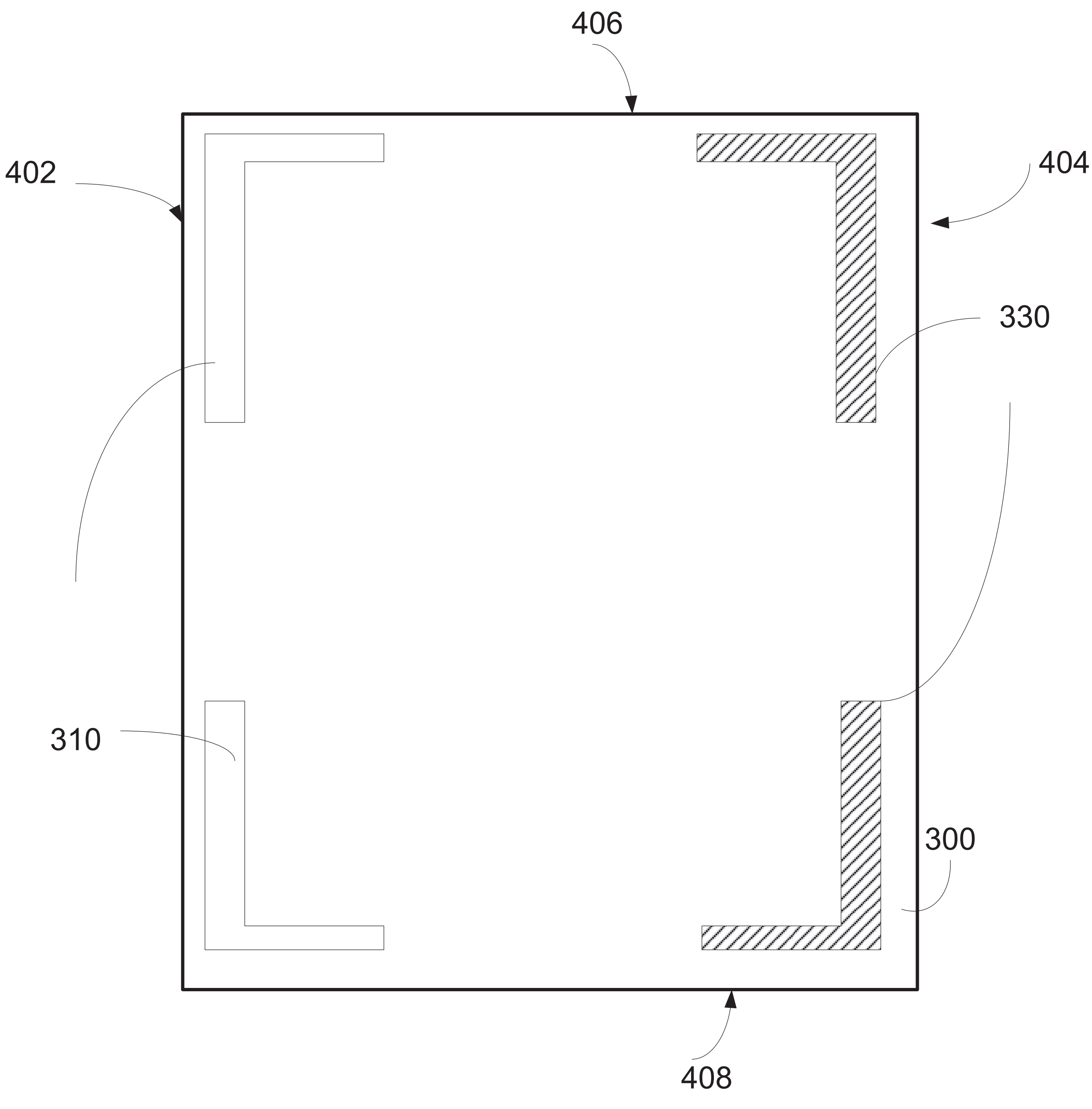

FIG. 4