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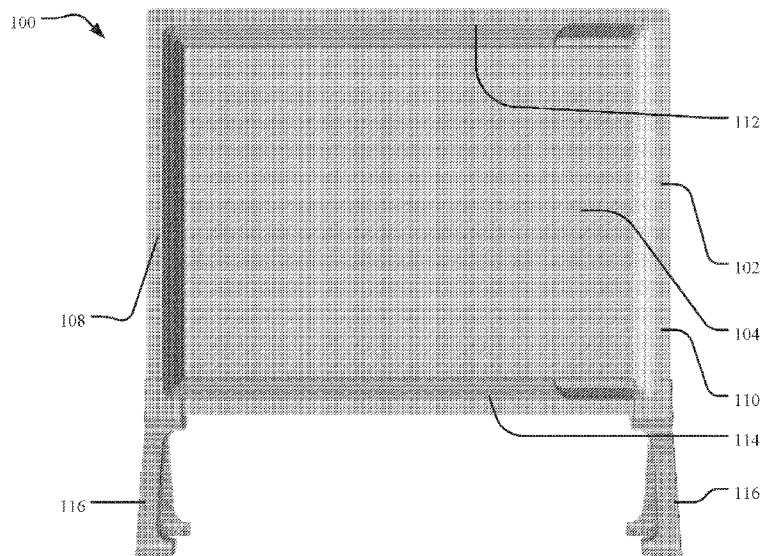


FIG. 1

(57) Abstract: The systems and methods of the present disclosure provide solar-powered signs with one or more display regions. The solar-powered sign includes an outer diffusion film, an internal light guide, a light source, an internal solar panel, and one or more processors receiving power generated via the internal solar panel. The solar-powered sign includes a display region on the outer diffusion film. The display region can display content provided via the one or more processors. The light source illuminates at least a portion of the outer diffusion film. The display region may be a bistable display, such as an e-ink display.



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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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## **SOLAR POWERED SIGNS WITH DYNAMIC DIGITAL OVERLAYS**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

**[0001]** The present application claims priority to and benefit of U.S. Provisional Patent Application No. 63/505,559, titled “SOLAR-POWERED SIGNS WITH DYNAMIC DIGITAL OVERLAYS” filed on June 1, 2023, which is incorporated by reference in its entirety herein.

### **FIELD**

**[0002]** Aspects of the present disclosure relate generally to solar powered signs and more particularly to solar powered signs including interchangeable translucent prints illuminated by light sources utilizing solar power.

### **BACKGROUND**

**[0003]** Signs may be used for various purposes to convey information, such as advertising, marketing, event promotions, vehicular or pedestrian traffic management, and/or the like. Conventional signs often require external light sources to be visible at night. Signs can be illuminated by lighting sources. For example, a stop sign may include a border composed of red light-emitting diodes, and a post capped with a mounted solar panel. However, it can be challenging to properly illuminate graphics uniformly. Further, it is challenging to properly illuminate graphics while compensating for ambient brightness. Additionally, such signs are cumbersome, expensive, challenging to manufacture, and not aesthetically appropriate for all contexts. It is with these observations in mind, among others, that various aspects of the present disclosure were conceived and developed.

### **SUMMARY**

**[0004]** The systems and methods of this technical solution provide a self-contained, self-illuminating solar sign with an integrated solar panel, battery, and control electronics.

**[0005]** In one example, a solar-powered sign is described. The solar-powered sign includes an outer diffusion film, an internal light guide, a light source, a solar panel, and one

or more processors receiving power generated via the solar panel, and a display region configured to display content provided via the one or more processors while the light source illuminates at least a portion of the outer diffusion film.

[0006] In another example, an overlay is described, the overlay including a display region configured to display content and circuitry configured to receive one or more commands from one or more processors of a solar-powered sign, and control the content displayed via the display region based on the one or more commands.

[0007] Other implementations are also described and recited herein. Further, while multiple implementations are disclosed, still other implementations of the presently disclosed technology will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative implementations of the presently disclosed technology. As will be realized, the presently disclosed technology is capable of modifications in various aspects, all without departing from the spirit and scope of the presently disclosed technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not limiting.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 illustrates an example solar sign.

[0009] FIG. 2A depicts a perspective view of the example solar sign.

[0010] FIG. 2B depicts a side view of the example solar sign.

[0011] FIG. 3 depicts an exploded view of the example solar sign.

[0012] FIG. 4 illustrates an exploded view of an example solar sign having a printable surface and a housing.

[0013] FIG. 5 illustrates a cross-sectional view of the example solar sign of FIG. 4.

[0014] FIG. 6 illustrates an exploded view of an example printable solar sign sheet.

[0015] FIG. 7 illustrates a cross-sectional view of the example printable solar sign sheet shown in FIG. 6.

[0016] FIG. 8A illustrates a front view of the example printable solar sign sheet shown in FIGS. 6 and 7.

[0017] FIG. 8B illustrates a side view of the example printable solar sign shown in FIGS. 6, 7, and 8A.

[0018] FIGS. 9A and 9B illustrate front and cross-sectional views of an example system that may be utilized to implement solar powered signs that include one or more active display regions.

[0019] FIG. 10 illustrates a block diagram of an example computing system that may implement various aspects of the presently disclosed technology.

#### DETAILED DESCRIPTION

[0020] The various concepts introduced above and discussed in greater detail below may be implemented in any of numerous ways, as the described concepts are not limited to any particular manner of implementation. Examples of specific implementations and applications are provided primarily for illustrative purposes.

[0021] Solar-powered illuminated signs are gaining popularity. In general, conventional signs can be used for traffic management and can include multiple externally connected components. Common solar signs can include stop signs with a border composed of red light-emitting diodes and a post capped with a mounted solar panel. However, these signs are cumbersome, expensive and from a design standpoint, ugly. The techniques described in the present disclosure provide a printable sheet, with no external components. The sheet can be illuminated internally at night, or during dark conditions. The techniques described herein provide a thin (e.g., less than 5 mm thick, etc.) board with a print ready surface. The print-ready surface can be printed upon using a printer, such as an inkjet printer or a large-format latex inkjet printer.

[0022] The solar-powered signs described herein can operate to react to a variety of external conditions, including but not limited to changes in weather, the position of the sun, movement from indoors to outdoors and vice-versa, as well as general changes in ambient

brightness. The internal light source that illuminates the sign can be dynamically adjust to compensate for various ambient conditions or to conserve the battery such that the sign may remain lit for a requested duration of time. These changes in brightness can be controlled by changing the intensity of the light source used to illuminate the solar signs. Such light sources include internal light-emitting diodes (LEDs), which transmit light through an internal light guide of the solar sign to uniformly illuminate the surface of the sign.

**[0023]** The solar signs described herein may be integrated with internal or external overlays, which may provide dynamic display of content that may be updated by the control electronics of the solar powered sign. Such dynamic overlays may be constructed from a variety of materials, such as a bistable display (e.g., an e-ink display), a light-emitting diode (LED) display, or an organic light-emitting diode (OLED) display. Different types of displays may be controlled to display dynamic imagery and may be illuminated by the components of the solar-powered sign, as described herein.

**[0024]** The systems and methods described herein can implement techniques to control the brightness and operational characteristics of the solar-powered signs described herein. The solar-powered signs can include components, such as processor(s) and non-transitory memory. The solar-powered signs can implement an operating system and can include sensors and communication devices. The software (e.g., the operating system, etc.) executed by the solar-powered sign can include as computer-executable instructions that can correlate information from the sensors, memory, or other data sources, and provide one or more output signals or messages that control the behavior of the sign (e.g., changes the intensity of lighting based on the ambient light of the area in which the solar sign is located).

**[0025]** An e-ink or similar bistable display may be provided as, or as a part of, one or more overlays that may be placed on or integrated within the various solar powered signs described herein. The bistable display may be partially transparent (e.g., with pixels arranged in a halftone) or opaque. One advantage of bistable displays is they require less power than other types of digital displays, because power is only required when changing a state of a pixel. The bistable display may be a two-color or a multicolor display. The bistable display may be coupled to internal circuitry of the solar powered sign, which may implement an operating system or other software that controls imagery displayed by the bistable display.

**[0026]** Overlays may be utilized in conjunction with the illuminated sheets of the solar-powered sign. In some implementations, the overlays may include, or may be coupled to, digital displays, such as e-ink displays or bistable displays, or other types of displays such as OLED displays. An e-ink or similar bistable display may be provided as, or as a part of, one or more overlays that may be placed on or integrated within the various solar powered signs described herein. The bistable display portions may be partially transparent (e.g., with pixels arranged in a halftone) or opaque.

**[0027]** Such digital displays may be a two-color or a multicolor display and may utilize additional backlight features to illuminate one or more portions of the display. In some implementations, the diffusion films of the solar powered signs described herein may be utilized as a backlight for the digital display portions of the solar powered signs. The digital display portions of the solar powered signs may be coupled to internal circuitry of the solar powered sign that provides power and control signals to the digital display. An operating system or other software may control imagery displayed by the bistable display.

**[0028]** Various portions of the solar signs described herein may be printable. In some implementations, an entire solar sign may be passed through a printer (e.g., an inkjet printer) as a print media. The printable solar sign may be integrated with the various display portions described herein before or after printing. In some implementations, a printing process may in-part define the display portion. For example, OLED printing may be utilized to define an OLED display portion on a surface of the solar powered signs described herein. Similar techniques may be utilized to define various conductive circuitry (e.g., electric traces) that electrically couple the display portion (or the components thereof) to control circuitry of the solar powered sign.

**[0029]** The printable illuminated sign sheet described herein can include a stack of thin, functional layers. The layer exposed to an external environment can include a diffusion film with micron-scale surface features that facilitate extreme light turning or diffusion. As a result, the surface of the sheet can appear white, when in actuality the sheet can transmit more than 80% of the incident light into the underlying layers. Below the print-ready diffusion surface sits a thin light guide plate (LGP) that emits uniform lighting produced by light emission from edge mounted light sources, such as LEDs. A solar panel or film can be coupled to the light

guide plate and can be electrically coupled to an electronics module. The electronics module can be in the sign sheet on same layer as, or on a layer proximate to, the solar panel or film in the light illuminated sign sheet.

**[0030]** Sunlight, or another external light, can traverse the diffusion surface of the printable layer and pass through the optically clear LGP and finally contact the underlying solar film or panel, which in turn generates electron flow. These electrons are subsequently forwarded to the internal battery to be stored as power for night illumination.

**[0031]** To begin a detailed description of systems and methods for illuminating content, reference is made to FIGs. 1-3, in which a solar sign 100 is depicted. In some implementations, the solar sign 100 includes a frame 102 and a solar sign sheet 104. The frame 102 further includes first side rail 108, second side rail 110, top rail 112 and bottom rail 114. In some examples, the first side rail 108, second side rail 110, top rail 112 and bottom rail 114 may be integrated into one piece, or they may be formed separately and joined together to form the frame 102. Further, the solar sign 100 includes a support structure 116 which is attached to the frame 102.

**[0032]** In some examples, the solar sign 100 includes a solar panel assembly 120 mounted on an exterior of the frame 102. For example, the solar panel assembly 120 may be mounted in a U-configuration along the first side rail 108, the top rail 112, and the second side rail 110. The solar panel assemblies collect sunlight, or other external light, and generate electricity which can be stored in a battery 122, as described in further detail below. The battery 122 may be integrated into the solar sign 100. The battery 122 may power light sources of the solar sign to illuminate the sign. The solar sign 100 further includes circuitry designed to selectively turn on the light sources to light the solar sign 100.

**[0033]** The solar sign 100 includes a dual-sided display including the solar sign sheet 104. The solar sign sheet 104 is a sheet of material configured be printed or otherwise manufactured to include a design that can be illuminated in low-light environments. Example construction of the solar sign sheet is described in further detail with reference to FIGs. 6 and 7.

**[0034]** Referring now to FIG. 4, illustrated is an exploded view of an example solar sign 200 having a printable surface and a housing, in accordance with one or more implementations. Solar sign 100 may be incorporated to have features similar to those of solar

sign 200. The solar sign 200 can include at least one frame 1 (sometimes referred to as a “housing 1”), a battery 2, a solar panel 3, a printed circuit board (PCB) 4, a light guide 5, an inner diffusion film 6, a spacer 7, an outer diffusion film 8, and a border 9. As described herein, each of the components of the solar sign depicted in FIG. 4 can form a portion, or the entirety of, a layer of the solar sign. The layers can be stacked and coupled to one another, for example, using an adhesive or mechanical coupling or connector. In some implementations, the layers can be coupled to one another via mechanical force.

**[0035]** The frame 1 can be a waterproof container that contains each of the layers depicted in FIG. 4. The frame 1 can prevent unwanted materials (e.g., water, dust, debris, etc.) from entering the sign and causing electrical issues or blocking light paths. The frame 1 can be constructed from a polymer material, a metal material, or a composite material. As shown in the exploded view of FIG. 4, each of the components of the solar sign 200 (e.g., the battery 2, the solar panel 3, the printed circuit board (PCB) 4, the light guide 5, the inner diffusion film 6, the spacer 7, the outer diffusion film 8, the border 9, etc.) can be positioned in or coupled to the housing, for example, in one or more layers of a stack. The components can be coupled to one another, for example, by one or more mechanical features (e.g., each of the components can be manufactured to fit together tightly within the frame 1, etc.), such as connectors, fasteners, or other mechanical coupling features. In some implementations, one or more of the components of the solar sign can be coupled to one another via an adhesive or other non-mechanical coupling agent. In some implementations, the adhesive can be an optically transparent adhesive. The outer portion of the frame 1 can be coupled to the supporting hardware, such as an A-frame. In some implementations, the frame 1 can include one or more connectors to couple to other solar signs or other support features. In some examples, some of the components, such as the battery 2, the solar panel 3, the PCB 4, may be mounted on or coupled to the frame 1.

**[0036]** The battery 2 can be a thin, flat battery that can provide electrical power to one or more of the electronic components of the solar sign 200, as described herein. The battery 2 can be a re-chargeable battery, such as a lithium-ion battery, a lithium-polymer battery, a nickel-cadmium battery, or another type of high-density re-chargeable battery with a thin form factor. The battery 2 can receive electric power from the solar panel 3, for example, via

charging circuitry present on the PCB 4. The battery 2 can discharge electrical energy through one or more light sources, such as light-emitting diodes, that are present in the solar sign 200. In some implementations, the battery 2 can be positioned in the solar sign 200 such that it is easily removable. In such implementations, the components of the solar sign 200 can fit together such that the solar sign 200 can be disassembled, and the battery 2 can be replaced.

**[0037]** In some examples, the solar panel 3 can be coupled to the battery 2, and the light guide 5, and can absorb light that passes through the outer diffusion film 8, the spacer 7, and the inner diffusion film 6, and the light guide 5. The solar panel 3 can provide electric power to the other components of the solar sign 200 described herein. Light emitted from an external light source (e.g., the sun, etc.) can pass through the layers of the diffusion film, the spacer, and the light guide 5, and contact the surface of the solar panel 3. Photons in the light can be absorbed by the solar panel 3 and converted into an electron flow that is stored in the battery 2 (e.g., via power circuitry on the PCB 4, etc.).

**[0038]** As described above, with reference to FIGs. 1-3, the solar panel 3 may be incorporated into an exterior of the frame 1. In some examples, the solar panel 3 may be U-shaped and/or formed to the shape of the frame 1 to take advantage of the exterior surface area of the frame 1 so that the light comes into direct contact with the solar panel 3.

**[0039]** The battery 2 can store a charge over the course of a day (e.g., via the solar panel 3 absorbing energy from an external light source, etc.). Then, in circumstances of low light (e.g., each evening if the solar sign is positioned outside, etc.), the solar panel 3 can generate a decreased electron flow (e.g., a decreased voltage from what was produced during periods of high external light, etc.) The solar panel 3 can be any sort of photovoltaic cell or photovoltaic film having a thin form factor. The solar panel 3 can be constructed from semiconducting materials, such as doped silicon.

**[0040]** The PCB 4 can include electronics, such as power electronics that can control the flow of electrons output by the solar panel 3. As described herein above, the PCB 4 can be electrically coupled to the solar panel 3 via one or more electrical connections (not shown). The PCB 4 can include one or more voltage sensors that can monitor voltage signals produced by the solar panel 3. In some implementations, the PCB 4 can include one or more voltage

sensors that monitor the voltage level of the battery. For example, each of the voltage sensors can output a signal (e.g., an electrical signal, etc.) that indicates an amount of voltage generated by the solar panel 3 or the battery 2. The signals can be received, for example, by a controller on the PCB 4.

**[0041]** The PCB 4 can include one or more light sources that can illuminate the solar sign 200 via the light guide 5 (described in further detail herein). The light sources can be any sort of light source that can emit light in response to receiving electric energy. The light sources can be electrically coupled to and receive electric power from the battery, for example, via power circuitry (e.g., voltage converters, etc.) on the PCB 4. The light sources can emit light with an intensity that is proportional to the amount of electric power received from the power circuitry. Thus, the power circuitry can control the amount of electric power provided to the light sources, and thus the amount of light emitted by the light sources. The light sources can have a thickness that corresponds (e.g., about equal to, less than, etc.) to a thickness of the light guide 5. The light sources can be, for example, one or more LEDs or any other type of light source. The light source can be a bright source of light that uses a low amount of power.

**[0042]** The PCB 4 can include a controller that can monitor voltage signals produced by the voltage sensors and provide power controls to the electronic components (e.g., the light sources, the solar panel 3, etc.) of the solar sign 200. The controller can include at least one processor and a memory (e.g., a processing circuit, etc.). The memory can store processor-executable instructions that, when executed by processor, cause the processor to perform one or more of the operations described herein. The processor can include a microprocessor, a microcontroller, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a graphics processing unit (GPU), etc., or combinations thereof. The memory can include, but is not limited to, electronic, optical, magnetic, or any other storage or transmission device capable of providing the processor with program instructions. The memory can further include a memory chip, ASIC, FPGA, read-only memory (ROM), random-access memory (RAM), electrically erasable programmable ROM (EEPROM), erasable programmable ROM (EPROM), flash memory, optical media, or any other suitable memory from which the processor can read instructions. The instructions can include code from any suitable computer programming language. The PCB 4 can include or may be in communication

with the computing system 400 described in connection with FIG. 10 (e.g., which may be included with the solar sign sheet).

**[0043]** The processor of the electronics module can receive signals (e.g., via an interconnect or other communications bus, etc.) from the voltage sensors on the PCB 4 that correspond to the amount of light being received by the solar panel 3. Based on the amount of light received from the solar panel 3, the processor can provide signals to one or more switches (e.g., transistors, integrated circuits, etc.) that cause the battery 2 to provide electric power to the light sources connected to the PCB 4. For example, if the processor detects that the amount of voltage produced by the solar panel 3 has fallen below a predetermined threshold, the processor can determine that the solar sign is not properly or completely illuminated. Based on the signals from the voltage sensors, the processor can determine whether the amount of light striking the solar panel 3 represents a temporary blockage (e.g., an external light source is obscured temporarily, etc.), of the amount of light striking the solar panel 3 represents that the solar sign 200 is now in a dark environment (e.g., it is now night time, or the solar sign has been moved to a dark room, etc.). The processor can compensate for the low light levels by transitioning from an unilluminated (e.g., the light source is not receiving power, etc.) state to an illuminated (e.g., the light source is receiving power, etc.) state.

**[0044]** The processor can provide (e.g., via the power circuitry, transistors, switches, etc.) an amount of power that is proportional to the amount of light required to illuminate the solar sign. In some implementations, the processor can store information about the amount and the color of one or more graphical designs or printed images printed on the outer surface of the outer diffusion film 8. For darker images with more ink, the processor can provide more electric power to the light sources, thus providing more light to illuminate the darker graphic. Likewise, if a graphic on the solar sign is absent, or has light or small amounts of ink, the processor can provide slightly less electric power to the light sources, thus providing uniform illumination for the solar sign.

**[0045]** In some examples, the light guide 5 can be positioned adjacent to the solar panel 3, such that light passing through the light guide can strike the solar panel 3 and generate electric power. The light guide 5 can be a transparent plate of material that can both receive and guide light from one or more light sources, such as the light sources on the PCB 4 or an

external light source, such as the sun. As described herein, the surface of the light guide 5 (e.g., the surface coupled to the inner diffusion film 6, etc.) can include one or more light extraction features, such as lenses or lenslets. In some implementations, the surface of the light guide 5 opposite the surface coupled to the inner diffusion film 6 can include one or more light extraction features. The light extraction features can extract a portion of the light injected into the light guide 5, such as the light emitted by the light sources on the PCB 4. The light guide 5 can guide another portion of the light injected into the light guide towards an opposite edge of the light guide 5. The light extraction features can be precisely placed across the surface of the light guide 5 in a predetermined pattern, such that light is uniformly extracted, and thus emitted, across the entire surface of the light guide 5. Thus, the light guide 5 can uniformly illuminate the other layers of the solar sign (e.g., the inner diffusion film 6, the spacer 7, the outer diffusion film 8, etc.), including any graphical designed printed on the outer diffusion film.

**[0046]** The light guide 5 can be optically coupled to the light sources in the solar sign. In some implementations, the light sources can be positioned within a cavity formed in the light guide 5. The light source can emit light through the cavity and into the body of the light guide 5, thereby injecting light into the light guide 5. In some implementations, the light guide 5 does not include a cavity, and instead is a uniform rectangular plate that can receive light emitted from the light source via an edge of the light guide 5. In such implementations, the light sources can be positioned external to the light guide 5 and inject light into the light guide plate via the edge. The light guide 5 can have a shape that accommodates the light sources, for example, having one or more edges or corners that are “clipped” or removed from a uniform rectangular plate, as shown in FIG. 4.

**[0047]** The inner diffusion film 6 can be a sheet of partially transparent film that has a first surface coupled to a spacer 7 (e.g., which can be a transparent plastic spacer, for example, to achieve a desired structural thickness, etc.) and a second surface that is coupled to the light guide 5. The inner diffusion film 6 can be a partially transparent film that appears white, or another solid color, while still allowing an amount of light to pass through the diffusion film and into the light guide 5. For example, light emitted by an external light source (e.g., the sun, etc.) can pass through both the outer diffusion film 8, the spacer 7, and the inner diffusion film 6, striking the solar panel 3 where it is absorbed. The inner diffusion film 6 can be uniformly

illuminated by the light extracted by the light extraction features of light guide 5, such that the solar sign and any graphical designs printed thereon can be illuminated in low-light environments (e.g., at night time, etc.). In some implementations, the inner diffusion film 6 can have greater than 70% angular diffusion. In some implementations, the inner diffusion film 6 can have a light transmission rate that exceeds 80%. The inner diffusion film can aid in the operation of the light guide 5, which in some implementations can provide a more uniformly distributed light pattern when exposed to air. The inner diffusion film 6 can have a rough surface, and thus when coupled to the light guide 5, the majority of the surface of the light guide 5 is exposed directly to air, because the rough surface of the inner diffusion film 6 is not uniform or perfectly flat.

**[0048]** The spacer 7 can be a thin, flat portion of plastic that acts as a buffer between the inner diffusion film 6 and the outer diffusion film 8. The spacer 7 can be manufactured from a transparent material, such as glass, a transparent acrylic, or another type of transparent plastic. The spacer 7 can have similar dimensions to the inner diffusion film 6 and the outer diffusion film 8. The spacer 7 can have a thickness selected to allow each of the components of the solar sign to fit together in the frame 1 of the solar sign. The spacer 7 can have high transmissivity, such that light easily passes through the spacer 7. The spacer 7 can allow light diffused from the inner diffusion film 6 to pass largely uninterrupted to the outer diffusion film 8, thereby illuminating the solar sign. Likewise, the spacer 7 can receive light from an external light source (e.g., the sun, etc.) via the outer diffusion film 8, and allow the light to pass largely uninterrupted through the inner diffusion film 6, striking the solar panel 3.

**[0049]** The outer diffusion film 8 can be a sheet of partially transparent film that has a first surface exposed to an external environment and a second surface that is coupled to the spacer 7. The outer diffusion film 8 can include a light-turning imprinted surface (e.g., the surface facing the external environment, etc.). The outer diffusion film 8 can include a partially transparent surface that appears white, or another solid color, while still allowing an amount of light to pass through the diffusion film and into the light guide 5. Light from an external light source (e.g., the sun, etc.) can pass through the outer diffusion film 8, the spacer 7, the inner diffusion film 6, and the light guide 5, striking the solar panel 3 where it is absorbed. The outer diffusion film 8 can be a printable film, such that the outer diffusion film 8 can be made from

a material to which printer ink can be directly applied. Thus, in some implementations, the solar sign 200 can be passed through a printer, such as a wide format inkjet printer, which can print ink directly onto the outer diffusion film 8 of the solar sign 200. The solar sign 200 can be placed on or coupled to a template that guides the solar sign 200 through the printer to facilitate the printing process.

**[0050]** The outer diffusion film 8 can be printed using a latex ink, a black ink, a white ink, or any other semi-transparent ink. The outer diffusion film 8 can be uniformly illuminated by the light extracted by the light extraction features of light guide 5, such that the solar sign 200 and any graphical designs printed thereon can be illuminated in low-light environments (e.g., at night time, etc.). In some implementations, and as described herein above, the outer diffusion film 8 can be coupled to an overlay film such that the illuminated outer diffusion film 8 provides uniform illumination through the overlay film. In some implementations, the outer diffusion film 8 can be easily removable and replaceable from the frame 1. Thus, different designs for the solar sign can easily be changed by exchanging the outer diffusion films 8 having graphical designs printed thereon.

**[0051]** The border 9 can provide a weatherproof border for the exposed edges of the solar sign, surrounding the outer diffusion film 8. As shown, the outer diffusion film 8 can be exposed to the external environment through the large opening in the border 9. The border 9 can be manufactured from a material similar to that used to manufacture the frame 1. The border 9 can be coupled to the border 9 to create a weatherproof seal, thereby preventing water, dust, or other debris from interfering with the internals of the solar sign 200. In some implementations, the border 9 can be removable, such that the outer diffusion film 8 can be easily removed and replaced. This can allow for different designs to be displayed on the same sign by exchanging different outer diffusion films 8 having different designs printed thereon. In some implementations, the frame 1 can include one or more brackets or connectors that couple the solar sign to a frame (not pictured). The frame can position the printable solar sign 200 at a predetermined angle from a light source, such as the sun. In doing so, the frame can position the solar sign such that the sign appears flat to a viewer (e.g., completely upright), while still absorbing a large percentage of light emitted by an external light source.

**[0052]** Referring now to FIG. 5, illustrated is a cross-sectional view of the solar sign 200 shown in FIG. 4, in accordance with one or more implementations. As shown in the cross-sectional view, each of the layers in the solar sign 200 can be pressed against one another firmly, such that they are fixed in place in the frame 1 of the solar sign 200. Also as shown, each of the components can fit within the frame 1 such that the components are coupled to the frame 1, for example, via mechanical or frictional force. In some implementations, an adhesive can be disposed between one or more of the layers of the solar sign. In some implementations, the adhesive can be an optically transparent adhesive with a similar index of refraction to other components of the solar sign (e.g., the light guide 5, etc.). Each of the components of the solar sign can be placed in the base in a particular order. As shown, the frame 1 can form a housing for the sign, and can include one or more attachment or guiding features (e.g., grooves, slots, etc.) into which the other components of the solar sign can fit or connect.

**[0053]** The battery 2 can first be positioned near the bottom of the frame 1. In some implementations, the battery 2 can fit into one or more slots, grooves, or recessed portions of the frame 1. Next, the solar panel 3 can be positioned top of, or adjacent to, the battery 2. As described above, the solar panel 3 may also be positioned around the exterior of the frame 1. The solar panel 3 can be electrically coupled to the battery 2. The PCB 4 can then be positioned in the frame 1 adjacent to the solar panel 3. The PCB 4 can be positioned such that any light sources present on the PCB 4 will be aligned with the light guide 5 when the light guide 5 is positioned in the solar sign. The light guide 5 can be positioned on top of the solar panel 3, such that light passing through the light guide 5 from an external light source can be passed to the surface of the solar panel 3. Further, the light guide 5 can be positioned in the frame 1 such that an edge of the light guide 5 can receive light from a light source, such as a light source positioned on or electrically coupled to the PCB 4. In some implementations, the light source can be electrically coupled to but physically separate from the PCB 4 (e.g., on a separate circuit board module, etc.).

**[0054]** The inner diffusion film 6 can be positioned on top of the light guide 5, such that the light emitted from the light sources and extracted by the light extraction features on the surface of the light guide 5 is diffused through the inner diffusion film, thereby evenly illuminating the solar sign. The spacer 7 can be positioned on top of the inner diffusion film

6. As shown, the spacer can provide additional depth to the stack of functional components of the solar sign, and provide a buffer through which light from the outer diffusion film 8 can pass before reaching the inner diffusion film 6. The outer diffusion film 8 can be positioned on top of the spacer 7. As described herein above, the outer diffusion film 8 can include a printable surface exposed to the external environment. Inks such as latex inks, or other types of inks, can be printed directly onto the printable surface of the outer diffusion film 8. Finally, the border 9 can create a seal between the outer diffusion film 8 and the frame 1, thereby creating a weatherproof, printable sign. It should be understood that the various signs described herein can be scaled to any appropriate dimension, and the entire sign as pictured in FIGS. 4 and 5 can have a profile passable through a printer such that the printer can print on the outer diffusion film 8.

**[0055]** Referring now to FIG. 6, illustrated is an exploded view of an example printable solar sign sheet, in accordance with one or more implementations. The solar sign sheet shown in FIG. 6 can be a stack of functional materials, similar to the printable solar sign depicted in FIGS. 5 and 6. The printable solar sign shown in the view can include a top diffusion film 201, a spacer 202, a border 203, an inner diffusion film 204, a light guide 205, a battery 206, a solar panel 207, a filler 208, a PCB 209, a back plate 210, vinyl 211, a rail 212, and a corner piece 213. As described herein, each of the components of the solar sign depicted in FIG. 6 can form a portion, or the entirety of, a layer of the printable solar sign 200. The components can be coupled together, for example, via an adhesive or mechanical connectors, to form a sheet of layered, functional components. In some implementations, the layers can be coupled to one another via mechanical force such as friction.

**[0056]** The printable solar sign, including all of the components outlined above, can have a sheet structure that is thin, for example, less than five millimeters thick. The solar sign can be fed into a printer, for example, a wide format inkjet printer. Some examples of wide-format inkjet printers include the HP R1000 or the HP R2000 large-format latex inkjet printer. Said printers can print latex ink on the surface of the top diffusion film 201, thereby creating a design on the sign that can be illuminated in low-light environments. The design can be printed using a latex ink. Thus, the solar sign described herein can be an opto-electronic print media.

**[0057]** Starting from the bottom of the stack of functional components, the corner piece 13 and the rails 212 can form portions of the edges of the solar sign. The corner piece can include one or more pegs, or other types of connectors, that allow the corner piece 213 to be connected to two of the rails 212. Four corner pieces 13 can be used in conjunction with four rails 212 to define the edges of the solar sign. The corner pieces 13 and the rails 212 can be formed from any suitable material, for example, a polymer material, a metal material, or a composite material. In some implementations, the rails can be formed from aluminum or steel. In some implementations, the corner pieces 13 and the rails 212 can include one or more grooves, slots, or recesses into which one or more of the components of the solar sign can rest or be coupled. In some implementations, the rails 212 and the corner pieces can couple to the back plate 210. The vinyl 211 can be a sheet of vinyl that covers the back portion of the rails 212, the corner pieces 213, and the back plate 210, creating a weatherproof seal across the bottom of the solar sign. The back plate 210 can be a rigid plate onto which the other layers of the solar sign are stacked or coupled. The back plate 210 can be formed from any suitable material, including plastics, metals, or composite materials.

**[0058]** The battery 206, the solar panel 207, the filler 208, and the PCB 209 can together form the next layer of the solar sign. As described above, in some examples, solar panel 207 may instead be located on the exterior of the frame. The battery 206 can be similar to and include any of the structure of functionality of the battery 2 described herein above in connection with FIGS. 4 and 5. The battery 206 can be a thin, flat battery that can provide electrical power to one or more of the electronic components of the solar sign, as described herein. The battery 206 can be a re-chargeable battery, such as a lithium-ion battery, a lithium-polymer battery, a nickel-cadmium battery, or another type of high-density re-chargeable battery with a thin form factor. In some implementations, the battery 206 can be less than about 3 millimeters thick. The battery 206 can receive electric power from the solar panel 207, for example, via charging circuitry present on the PCB 209. The battery 206 can discharge electrical energy through one or more light sources, such as light-emitting diodes, that are present in the solar sign. In some implementations, the battery 206 can be positioned in the solar sign such that it is easily removable. In such implementations, the components of the solar sign can fit together such that the solar sign can be disassembled, and the battery 206 can be replaced.

**[0059]** Likewise, the solar panel 207 can be similar to and include any of the structure and functionality of the solar panel 3 described herein above in connection with FIGS. 4 and 5. The solar panel 207 can be coupled to the battery 2, and the light guide 205, and can absorb light that passes through the outer diffusion film 8, the spacer 7, and the inner diffusion film 6, and the light guide 205. The solar panel 207 can provide electric power to the other components of the solar sign described herein. Light emitted from an external light source (e.g., the sun, etc.) can pass through the layers of the diffusion film, the spacer, and the light guide 205, and contact the surface of the solar panel 207. Photons in the light can be absorbed by the solar panel 207 and converted into an electron flow that is stored in the battery 206 (e.g., via power circuitry on the PCB 4, etc.). The battery 2 can store a charge over the course of a day (e.g., via the solar panel 207 absorbing energy from an external light source, etc.). Then, in circumstances of low light (e.g., each evening if the solar sign is positioned outside, etc.), the solar panel 207 can generate a decreased electron flow (e.g., a decreased voltage from what was produced during periods of high external light, etc.). The solar panel 207 can be any sort of photovoltaic cell or photovoltaic film having a thin form factor. The solar panel 207 can be constructed from semiconducting materials, such as doped silicon.

**[0060]** The PCB 209 can be similar to and include any of the structure and functionality of the PCB 209 described herein in connection with FIGS. 4 and 5. The PCB 209 can include electronics, such as power electronics that can control the flow of electrons output by the solar panel 207. As described herein above, the PCB 209 can be electrically coupled to the solar panel 207 via one or more electrical connections (not shown). The PCB 209 can include one or more voltage sensors that can monitor voltage signals produced by the solar panel 207. In some implementations, the PCB 209 can include one or more voltage sensors that monitor the voltage level of the battery 206. For example, each of the voltage sensors can output a signal (e.g., an electrical signal, etc.) that indicates an amount of voltage generated by the solar panel 207 or the battery 206. The signals can be received, for example, by a controller on the PCB 209.

**[0061]** The PCB 209 can include one or more light sources that can illuminate the solar sign via the light guide 205 (described in further detail herein). In some implementations, the one or more light sources can be physically separate from but still electrically coupled to the

PCB 209, and any components thereof (e.g., the processor, power electronics, switches, etc.). The light sources can be any sort of light source that can emit light in response to receiving electric energy. The light sources can be electrically coupled to and receive electric power from the battery, for example, via power circuitry (e.g., voltage converters, etc.) on the PCB 209. The light sources can emit light with an intensity that is proportional to the amount of electric power received from the power circuitry. Thus, the power circuitry can control the amount of electric power provided to the light sources, and thus the amount of light emitted by the light sources. The light sources can have a thickness that corresponds (e.g., about equal to, less than, etc.) to a thickness of the light guide 205. The light sources can be, for example, one or more LEDs or any other type of light source. The light source can be a bright source of light that uses a low amount of power.

**[0062]** In some implementations, the PCB 209 can include one or more magnetic sensors. The magnetic sensors can be electrically coupled to one or more components of the PCB 209 (e.g., the processor, the power circuitry, etc.). The magnetic sensors can provide a signal to the components of the PCB 209 in response to sensing a magnetic field, for example, from a magnet positioned on a frame configured to hold the solar sign. The signal from the magnetic sensor can enable the use of the solar sign. Said another way, the solar sign can be used in connection with authorized frames that have magnets appropriately positioned to activate the magnetic sensors of the PCB 209. Once activated, the magnetic sensors can provide a signal that allows the sign to operate as intended (e.g., absorb light from the sun to charge the battery 206, and illuminate the sign in low-light environments, etc.). In some implementations, an electromagnetic sensor can be electrically coupled to the PCB 209. The electromagnetic radiation sensor can detect electromagnetic radiation emitted, for example, by an overlay film (e.g., similar to the top diffusion film 201, etc.) having an electromagnetic radiation source positioned thereon. Similar to the operation of the magnetic sensor, the electromagnetic radiation sensor can detect electromagnetic radiation from authorized overlay films. The electromagnetic radiation sensor can produce a signal that activates the other components of the PCB 209, allowing the solar sign to operate as intended, in response to detecting an electromagnetic radiation signal from an authorized solar sign. Such electromagnetic radiation signals can include, for example, a near-field communication (NFC) signal, a Bluetooth signal, or any other type of electromagnetic radiation signal. The overlay

film can be an optically clear sheet of film, and can include a printed surface. The overlay film can be positioned over the external surface of the top diffusion film 201.

**[0063]** The PCB 209 can include a controller that can monitor voltage signals produced by the voltage sensors and provide power controls to the electronic components (e.g., the light sources, the solar panel 207, etc.) of the solar sign. The controller (e.g., the computing system 400 of FIG. 10) can include at least one processor and a memory (e.g., a processing circuit, etc.). The memory can store processor-executable instructions that, when executed by processor, cause the processor to perform one or more of the operations described herein. The processor can include a microprocessor, a microcontroller, an ASIC, an FPGA, a GPU, etc., or combinations thereof. The memory can include, but is not limited to, electronic, optical, magnetic, or any other storage or transmission device capable of providing the processor with program instructions. The memory can further include a memory chip, ASIC, FPGA, ROM, RAM, EEPROM, EPROM, flash memory, optical media, or any other suitable memory from which the processor can read instructions. The instructions can include code from any suitable computer programming language.

**[0064]** The processor of the PCB 209 can receive signals (e.g., via an interconnect or other communications bus, etc.) from the voltage sensors on the PCB 209 that correspond to the amount of light being received by the solar panel 207. Based on the amount of light received from the solar panel 207, the processor can provide signals to one or more switches (e.g., transistors, integrated circuits, etc.) that cause the battery 206 to provide electric power to the light sources connected to the PCB 209. For example, if the processor detects that the amount of voltage produced by the solar panel 207 has fallen below a predetermined threshold, the processor can determine that the solar sign is not properly or completely illuminated. Based on the signals from the voltage sensors, the processor can determine whether the amount of light striking the solar panel 207 represents a temporary blockage (e.g., an external light source is obscured temporarily, etc.), of the amount of light striking the solar panel 207 represents that the solar sign is now in a dark environment (e.g., it is now night time, or the solar sign has been moved to a dark room, etc.). The PCB 209 can include or may be in communication with the computing system 400 described in connection with FIG. 10 (e.g., which may be included in the solar sign). For example, the processor of the PCB may be included as the processor 404

of the computing system 400 of FIG. 10. The processor(s) of the PCB can perform any of the functionalities described in connection with FIGS. 1-9.

**[0065]** The processor can compensate for the low light levels by transitioning from an unilluminated (e.g., the light source is not receiving power, etc.) state to an illuminated (e.g., the light source is receiving power, etc.) state. The processor can provide (e.g., via the power circuitry, transistors, switches, etc.) an amount of power that is proportional to the amount of light required to illuminate the solar sign. In some implementations, the processor can store information about the amount and the color of one or more graphical designs or printed images printed on the outer surface of the outer diffusion film 8. For darker images with more ink, the processor can provide more electric power to the light sources, thus providing more light to illuminate the darker graphic. Likewise, if a graphic on the solar sign is absent, or has light or small amounts of ink, the processor can provide slightly less electric power to the light sources, thus providing uniform illumination for the solar sign.

**[0066]** The filler 208 can fill the empty space between the other components in the layer formed by the battery 206, the solar panel 207, and the PCB 209. As shown, each of the battery 206, the solar panel 207, and the PCB 209 can be sized such that each has a similar thickness, and fit together on a single layer or plane. However, in some cases, additional space between the battery 206, the solar panel 207, the PCB 209, and the edges of the sheet (e.g., defined by the rails 212 or other edge pieces (not pictured), etc.). The filler 208 can be sized to fill in the gaps formed between the battery 206, the solar panel 207, and the PCB 209 to complete a flat structural layer on top of the back plate 210. The filler 208 can be formed from any suitable non-conductive material, such as plastic, foam, or any other type of filler material. The filler 208 can have substantially similar (e.g., plus or minus 10%) thickness to the battery 206, the solar panel 207, and the PCB 209. Thus, the filler 208 can be used to form a complete layer with the battery 206, the solar panel 207, and the PCB 209 across the entire back plate 210. In some implementations, in addition or as a part of the filler 208, a board with cutouts to hold components, including the PCB 209 (e.g., and any electronics forming a part of the PCB 209, etc.). The board can be manufactured from any suitable material, such as a corrugated plastic material. The board can have a surface color that is similar to the surface color of the solar panel 207. In some implementations, an additional colored film can be

positioned on this layer above the PCB 209, the battery 206, or the filler 208, or any combination thereof. The colored film can have a similar color to that of the solar panel 207.

**[0067]** The next layer in the stack can be formed from the light guide 205. The light guide 205 can be similar to and include any of the functional or structural features of the light guide 205 described herein in connection with FIGS. 4 and 5. The light guide 205 can be positioned adjacent to the solar panel 207, such that light passing through the light guide 205 can strike the solar panel 207 and generate electric power. The light guide 205 can be a transparent plate of material that can both receive and guide light from one or more light sources, such as the light sources on the PCB 209 or an external light source, such as the sun. As described herein, the surface of the light guide 205 (e.g., the surface coupled to the inner diffusion film 204, etc.) can include one or more light extraction features, such as lenses or lenslets. In some implementations, the surface of the light guide 205 opposite the surface coupled to the inner diffusion film 204 can include one or more light exaction features. The light extraction features can extract a portion of the light injected into the light guide 205, such as the light emitted by the light sources on the PCB 209. The light guide 205 can guide another portion of the light injected into the light guide towards an opposite edge of the light guide 205. The light extraction features can be precisely placed across the surface of the light guide 205 in a predetermined pattern, such that light is uniformly extracted, and thus emitted, across the entire surface of the light guide 205. Thus, the light guide 205 can uniformly illuminate the other layers of the solar sign (e.g., the inner diffusion film 204, the top diffusion film 201, etc.), including any graphical designed printed on the outer diffusion film.

**[0068]** The light guide 205 can be optically coupled to the light sources in the solar sign. In some implementations, the light sources can be positioned within a cavity formed in the light guide 205. In some implementations, the cavity can be a hole in the light guide 205 into which the one or more light sources are inserted. The light source can have a thickness that is similar to or less than the thickness of the light guide 205. The light source can emit light through the cavity and into the body of the light guide 205, thereby injecting light into the light guide 205. In some implementations, the light guide 205 does not include a cavity, and instead is a uniform rectangular plate that can receive light emitted from the light source via an

edge of the light guide 205. In such implementations, the light sources can be positioned external to the light guide 205 and inject light into the light guide plate via the edge.

**[0069]** The next layer in the solar sign can be formed from the inner diffusion film 204. The inner diffusion film 204 can be similar to and include any of the functional and structural features of the inner diffusion film 6 described herein in connection with FIGS. 4 and 5. The inner diffusion film 204 can be a sheet of partially transparent film that has a first surface coupled to a border 203 and the spacer 202 (e.g., which can be a transparent plastic spacer, for example, to achieve a desired structural thickness, etc.), and a second surface that is coupled to the light guide 205. The inner diffusion film 204 can be a partially transparent film that appears white, or another solid color, while still allowing an amount of light to pass through the diffusion film and into the light guide 205. For example, light emitted by an external light source (e.g., the sun, etc.) can pass through both the top diffusion film 201, the spacer 202, and the inner diffusion film 204, striking the solar panel 207 where it is absorbed. The inner diffusion film 204 can be uniformly illuminated by the light extracted by the light extraction features of light guide 205, such that the solar sign and any graphical designs printed thereon can be illuminated in low-light environments (e.g., at night time, etc.). In some implementations, the inner diffusion film 204 can have greater than 70% angular diffusion. In some implementations, the inner diffusion film 204 can have a light transmission rate that exceeds 80%. The inner diffusion film can aid in the operation of the light guide 205, which in some implementations can provide a more uniformly distributed light pattern when exposed to air. The inner diffusion film 204 can have a rough surface, and thus when coupled to the light guide 205, the majority of the surface of the light guide 205 is exposed directly to air, because the rough surface of the inner diffusion film 204 is not uniform or perfectly flat.

**[0070]** The next layer in the solar sign can be formed from the border 203 and the spacer 202. The border 203 can provide a weatherproof border for the exposed edges of the solar sign, while surrounding the spacer 202. The spacer 202 can be positioned in the large opening of the border 203, and the spacer 202 and the border 203 can each be coupled to the inner diffusion film 204, described herein above. The border 203 can be manufactured from any suitable material, such as a plastic, rubber, metal, or composite material. In some implementations, the border 203 can be opaque. The spacer 202 can be a thin, flat portion of

plastic that acts as a buffer between the inner diffusion film 204 and the top diffusion film 201. The spacer 202 can be manufactured from a transparent material, such as glass, a transparent acrylic, or another type of transparent plastic. The spacer 202 can have dimensions smaller than the inner diffusion film 204, such that the spacer 202 can fit snugly in the large opening of the border 203. Together, the spacer 202 and the border 203 can form a single layer having similar dimensions to the light guide 205. The spacer 202 can have a thickness similar to the thickness of the border 203. The spacer 202 can have high transmissivity, such that light easily passes through the spacer 202. The spacer 202 can allow light diffused from the inner diffusion film 204 to pass largely uninterrupted to the top diffusion film 201, thereby illuminating the solar sign. Likewise, the spacer 202 can receive light from an external light source (e.g., the sun, etc.) via the top diffusion film 201, and allow the light to pass largely uninterrupted through the inner diffusion film 204, striking the solar panel 207.

**[0071]** The top layer of the printable solar sheet can be formed from the top diffusion film 201. The top diffusion film 201 can include any of the functional or structural features of the outer diffusion film 8 described herein in connection with FIGS. 4 and 5. The top diffusion film 201 can be a sheet of partially transparent film that has a first surface exposed to an external environment and a second surface that is coupled to the spacer 202 and the border 203. The top diffusion film 201 can include a light-turning imprinted surface (e.g., the surface facing the external environment, etc.). The top diffusion film 201 can include a partially transparent surface that appears white, or another solid color, while still allowing an amount of light to pass through the diffusion film and into the light guide 205. Light from an external light source (e.g., the sun, etc.) can pass through the top diffusion film 201, the spacer 202, the inner diffusion film 204, and the light guide 205, striking the solar panel 207 where it is absorbed. The top diffusion film 201 can be a printable film. The top diffusion film 201 can be made from a material to which printer ink can be directly applied. Thus, in some implementations, the solar sign (e.g., including the stack of one or more of the layers shown in FIG. 6, etc.) can be passed through a printer, such as a wide format inkjet printer, which can print ink directly onto the top diffusion film 201 of the solar sign. The solar sign can be placed on or coupled to a template that guides the solar sign through the printer to facilitate the printing process.

**[0072]** The top diffusion film 201 can be printed on using a latex ink, a colored latex ink, a black ink, a white ink, or any other semi-transparent ink. The top diffusion film 201 can be uniformly illuminated by the light extracted by the light extraction features of light guide 205, such that the solar sign and any graphical designs printed thereon can be illuminated in low-light environments (e.g., at night time, etc.). In some implementations, and as described herein above, the top diffusion film 201 can be coupled to an overlay film such that the illuminated top diffusion film 201 provides uniform illumination through the overlay film. In some implementations, the top diffusion film 201 can be easily removable and replaceable. Thus, different designs for the solar sign can easily be changed by exchanging the top diffusion films 201 having different designs printed thereon.

**[0073]** Referring now to FIG. 7, illustrated is a cross-sectional view of the example printable solar sign sheet of FIG. 6, in accordance with one or more implementations. As shown in the cross-sectional view, each of the layers in the solar sign can be pressed against one another firmly, such that they are fixed in place in the frame 1 of the solar sign. Also as shown, each of the components can fit within a housing or sheet structure, formed from the rails 212 (e.g., defining the edges of the sheet, etc.), the corner pieces 213 (e.g., defining the corners of the sheet, etc.), and the back plate 210 (e.g., forming the back of the sheet). To enhance weatherproofing and aesthetic appearance, a sheet of the vinyl 211 can cover any gaps formed between the corner pieces 213, the rails 212, and the back plate 210.

**[0074]** The components forming the layers of the solar sign can sit within the base formed from the back plate 210, the rails 212, and the corner pieces 213. In some implementations, an adhesive can be disposed between one or more of the layers of the solar sign. In some implementations, the adhesive can be an optically transparent adhesive with a similar index of refraction to other components of the solar sign (e.g., the light guide 205, etc.). Each of the components of the solar sign can be placed in the base in a particular order. As shown, the base can form a housing for the sign. In some implementations, the base can include one or more attachment or guiding features (e.g., grooves, slots, etc.) into which the other components of the solar sign can fit or connect.

**[0075]** The battery 206, the solar panel 207, the PCB 209, and the filler 208 (not pictured) can first be positioned near the bottom of the base, and can form the first layer of the

printable solar sign. In some implementations, the battery 206 can fit into one or more slots, grooves, or recessed portions of the solar sign. The solar panel 207 and the PCB 209 can be positioned adjacent to the battery 206 such that the battery 206, the solar panel 207, the PCB 209, and the filler 208 (not pictured) form a single layer having a relatively uniform thickness across the entire surface of the back plate 210. The PCB 209 can be positioned such that any light sources present on the PCB 209 will be aligned with the light guide 205 when the light guide 205 is positioned in the solar sign. The light guide 205 can be positioned on top of the first layer formed from the battery 206, the solar panel 207, the PCB 209, and the filler 208 in the solar sign. Light passing through the light guide 205 from an external light source can be passed to the surface of the solar panel 207. Further, the light guide 205 can be positioned in the solar sign such that a portion of the light guide 205 can receive light from a light source, such as a light source positioned on or electrically coupled to the PCB 209. In some implementations, the light source can be electrically coupled to but physically separate from the PCB 209 (e.g., on a separate circuit board module, etc.).

**[0076]** The inner diffusion film 204 can be positioned on top of the light guide 205, such that the light emitted from the light sources and extracted by the light extraction features on the surface of the light guide 205 is diffused through the inner diffusion film 204, thereby evenly illuminating the solar sign. The spacer 202 and the border 203 form another internal layer on top of the inner diffusion film 204. As shown, the spacer 202 can have a similar thickness to the border 203 and provide a buffer through which light from the top diffusion film 201 can pass before reaching the inner diffusion film 204. The final layer formed from the top diffusion film 201 can be positioned on top of the layer formed from the spacer 202 and the border 203. As described herein above, the top diffusion film 201 can include a printable surface exposed to the external environment. Inks such as latex inks, or other types of inks, can be printed directly onto the printable surface of the top diffusion film 201. In some implementations, the top diffusion film 201 can create weatherproof seal between the border 203 and the top diffusion film 201, thereby creating a weatherproof, printable sign. It should be understood that the various signs described herein can be scaled to any appropriate dimension, and the entire sign as pictured in FIGS. 6 and 7 can have a profile passable through a printer such that the printer can print on the top diffusion film 201.

[0077] Referring briefly now to FIG. 8A, illustrated is a front view of the example printable solar sign sheet shown in FIGS. 6 and 7, in accordance with one or more implementations. As shown, when fully assembled, the solar sign can resemble a regular sign. Graphical designs can be printed directly onto the surface of the top diffusion film 201, and the area in the center portion (e.g., within the region defined by the opening in the border, etc.) can be illuminated in low-light conditions. The solar sign can be thin enough to be used directly as a print media. FIG. 8B illustrates a side view of the example printable solar sign, showing that the sign itself, when assembled, can be thin enough to be fed directly into a printer. Thus, the solar signs here can be used directly as an opto-electronic print media that is self-contained, weatherproof, and includes automatic control circuitry that controls sign illumination and charging. In some implementations, one or more brackets (not pictured) can be coupled to or form a part of the back plate 210, the rails 212, or the corner pieces 213. The brackets can allow the sign to be mounted to one or more frames, such as an A-frame, that allows the sign to be positioned at an angle that appears upright but is at a slight angle to absorb optimal amounts of light from external light sources.

[0078] FIGS. 9A and 9B illustrate front view and cross-sectional side view block diagrams of an example system for controlling and operating the various solar-powered signs described herein. Controlling and operating the solar-powered signs may include activating, deactivating, or otherwise controlling one or more display portions 315 formed as part of, or coupled to, an overlay 310 of the solar powered sign 305. Controlling and operating the solar-powered signs described herein may include dynamically changing imagery, text, or other information presented via the display portions 315, as well as controlling the brightness of various illumination components of the solar-powered sign 305.

[0079] The solar-powered sign 305 may be similar to and include any of the structure or functionality of the solar signs described in connection with FIGS. 4-8. The solar-powered sign 305 can include one or more processors, which can determine an ambient brightness of an area in which the solar-powered sign is located, and automatically adjust an intensity of a light source based on the ambient brightness. For example, each solar sign may include a photo-sensor, such as a camera or a lux meter. In some implementations, the photo-sensor may be

internal to the solar-powered sign 305. In some implementations, the photo-sensor may be external to the solar-powered sign 305.

**[0080]** Additionally, the processor of the solar-powered sign 305 may activate, deactivate, or otherwise control the display portion 315 formed on, or coupled to, the overlay 310 of the solar-powered sign 305. Although one display portion 315 is shown on the overlay 310, it should be understood that the solar-powered signs 305 described herein may be coupled to or otherwise include multiple overlays 310 or multiple display portions 315 on one or more overlays 310. In some implementations, each of the multiple display portions 315 may be controlled according to the techniques described herein individually, or collectively. In some implementations, the processor of the solar-powered sign 305 can control a brightness of one or more of the display portions 315 (or a backlight or another light source providing illumination for the one or more display portions 315) based on an ambient brightness of an external environment.

**[0081]** Brightness of the external environment can be detected according to a variety of approaches. In some implementations, a voltage sensor can be utilized to detect an output voltage of a solar panel (e.g., the solar panel 3, the solar panel 207, etc.), which may be proportional to an amount of light detected by the solar panel of the solar-powered sign 305. The voltage produced by the voltage sensor can be utilized to automatically adjust the intensity of the light source(s) (e.g., the LEDs of the PCB 209, etc.) of the solar-powered sign 305, as described herein. The sensors of the solar-powered sign 305 can be any device that generates sensor data about the environment (e.g., temperature, ambient light, etc.) and provides that sensor data to the processor(s) or memory of the solar-powered sign 305. One or more of the sensor(s) may be internal or external to the solar-powered sign 305. The sensors may be included, for example, as part of the PCB 209 described in connection with FIGS. 6-8, or in the circuitry 320 described in connection with FIG. 9B.

**[0082]** The solar-powered sign 305 can include one or more communications interface(s) (e.g., the communications interface 416 of FIG. 10, etc.). The communications interface(s) can include one or more of a wireless fidelity (Wi-Fi) interface, a Bluetooth interface, a Zigbee interface, a near-field communications (NFC) interface, a wired interface, or a cellular communications interface (e.g., 3G, 4G, LTE, 5G etc.), among others. The

communications interface can include any type of electronic device that can transmit and receive data to and from other devices, such may include other solar signs 305 (e.g., the solar sign 305 may transmit or receive data from other solar-powered signs and/or other external data sources or sensors, etc.), mobile communications devices (e.g., smartphones, tablets, laptops, etc.), or remote computing systems (e.g., servers, cloud computing systems, etc.).

**[0083]** In some implementations, the solar-powered sign 305 can communicate with one or more other devices via a network. Such networks can include computer networks such as the Internet, local networks, wide networks, metro networks, or other area networks, intranets, satellite networks, other computer networks such as voice or data mobile phone communication networks, or combinations thereof. The network may be any form of computer network that can relay information between the solar-powered signs 305, one or more mobile communications devices, and one or more information sources, such as web servers or external databases, amongst others. In some implementations, the network may include the Internet and/or other types of data networks, such as a local area network (LAN), a wide area network (WAN), a cellular network, a satellite network, or other types of data networks. The network may also include any number of computing devices (e.g., computers, servers, routers, network switches, etc.) that are configured to receive or transmit data within the network.

**[0084]** The one or more processors of the solar-powered sign 305 can control of the light output of the light source within the solar-powered sign 305 in response to different external conditions. For example, the solar-powered sign 305 can execute software (e.g., computer-executable instructions, an operating system, etc.) that implements illumination according to pre-programmed cycles (e.g., as stored or specified in the memory of the solar-powered sign 305), dynamic responses to perceived weather (e.g., based on ambient lighting conditions, temperature conditions, or weather information received via the communications interface), or actions triggered by specific outside input (e.g., a Bluetooth signal, one or more messages received from another device, or being electrically coupled to a charging cradle, etc.). In some implementations, the processor(s) of the solar-powered sign 305 can monitor current or projected battery life and utilize the remaining battery life to determine adjustments to the intensity of the light source in the solar-powered sign 305. Monitoring the projected battery life may include monitoring a power consumption of the one or more display portions 315.

**[0085]** The processor(s) of the solar-powered sign 305 can execute software, a script, instructions, or an operating system that can maintain an internal clock. The internal clock may provide a time of day. The processor(s) of the solar-powered sign 305 can store, in the memory of the solar-powered sign 305, a predicted sunrise and sunset for the location in which the solar-powered sign 305 is located. This is sometimes referred to herein as a “day/night cycle,” which can be utilized to determine when to activate, deactivate, or adjust the intensity of the light sources within the solar-powered sign 305 (or external light sources, in some implementations). The day/night cycle can be established or adjusted to conform to the local time zone and coordinates (e.g., latitude, longitude, etc.) of the location of the solar-powered sign 305. This enables the solar-powered sign 305 to conserve battery more effectively and maintain brightness during longer nights in more extreme latitudes, for example.

**[0086]** In some implementations, the processor(s) of the solar-powered sign 305 can determine the day/night cycle automatically, based on sensor data captured by the sensor(s) of the solar-powered sign 305. For example, the processor of the solar-powered sign 305 continuously (or periodically) store sensor data from one or more of the sensors in or in communication with the solar-powered sign 305, such as ambient light sensors, temperature sensors, or other sensors. Using the information from the sensors, the processor of the solar-powered sign 305 can determine a pattern of ambient illumination using a rolling average for different time periods. This process can be performed using sensor data from various different periods of time, for example, over a period of two or more days, one or more weeks, one or more months, or a year or more.

**[0087]** The day/night cycle may also be established based on other types of information, such as information received from other devices. In such implementations, the processor of the solar-powered sign 305 include a global positioning system (GPS), and can query or request day/night cycle information for the determined GPS location of the solar-powered sign 305 from an external computing device (e.g., a mobile computing device, a remote server, etc.). The processor of the solar-powered sign 305 can utilize the internal clock to determine the time until sunrise or sunset and adjust the light source(s) accordingly to uniformly illuminate the solar-powered sign 305.

**[0088]** The processor of the solar-powered sign 305 can determine the ambient brightness of the environment surrounding the solar-powered sign 305 using a variety of approaches. For example, the internal solar panel of the solar-powered sign 305 can be utilized as a sensor, where the recordings of the amount of power produced by the solar panel correlate over time with to approximate the ambient brightness. In some implementations, sensor data from an external sensor, such as a camera or lux meter can be polled or accessed by the processor of the solar-powered sign 305 to determine the ambient brightness. In some implementations, the camera or lux meter may be internal to the solar sign (e.g., coupled to or in communication with the PCB of the solar-powered sign 305, etc.). The day/night cycle can be computed based on a signal from an outside source (e.g., from satellites through a GPS receiver or via the communications interface), which can provide an exact location of the solar-powered sign 305 and time of year information, from which the expected sunrise/sunset can be calculated.

**[0089]** The processor of the solar-powered sign 305 can execute software to determine the day/night cycle based on information in addition to the ambient brightness of the environment surrounding the solar-powered sign 305. The processor of the solar-powered sign 305 may utilize sensor data captured over a period of time (e.g., multiple days), or may utilize an independent timekeeping source (e.g., an external computing system), to reconstruct the correct timing for the day/night cycle. For example, the time keeping source could be utilized to determine a particular time frame for which the sign will remain on (e.g. 8 hours) to conserve energy.

**[0090]** Various other conditions besides nightfall may cause the solar-powered sign 305 to experience lower levels of ambient brightness, including but not limited to cloudy weather, precipitation (e.g., rain, snow, hail, etc.), external obstructions like an overhead bird or plane, or the sign being put into a box or brought indoors, among other environmental conditions. In some implementations, a single method of determining the day/night cycle may be used. In some implementations, a combination of methods can be utilized and averaged to determine an average day/night cycle, which may be more accurate than using a single method.

**[0091]** The power generation data may be captured from the solar panel using a rolling average over 2 to 10 minutes, for example. The day/night cycle can include time data as well

as consistent ambient brightness thresholds for dawn, dusk, day, and night. Seasonality may also affect the ambient brightness of the environment, and may be utilized a factor in determining the brightness of the solar-powered sign 305. In some implementations, the processor of the solar-powered sign 305 can determine the current season of the region in which the solar-powered sign 305 is located based on GPS location data.

**[0092]** The processor of the solar-powered sign 305 can monitor and maintain the battery life of the system to provide consistent overnight lighting by varying the intensity of the light source(s) of the solar-powered sign 305. For example, the processor of the solar-powered sign 305 can alter the power-draw of the solar-powered sign 305 by varying the intensity of the light source to maintain a charge in the battery that capable of illuminating the solar-powered sign 305 for at least two days. The processor of the solar-powered sign 305 can maintain one or more curves that predict the remaining charge in the battery. As the charge in the battery falls below a predetermined threshold, processor of the solar-powered sign 305 can dim the intensity of the light source to reduce the power draw of the battery, thus extending the life of the battery. The processor of the solar-powered sign 305 may also adjust the brightness or illumination intensity of the one or more display portions 315 defined on the one or more overlays 310 coupled to or integrated with the solar-powered sign 305.

**[0093]** In some implementations, the communications interface of the solar-powered sign 305 can receive signals to control and re-programming of the one or more processors of the solar-powered sign 305. For example, a mobile computing device may execute an application (e.g. a smartphone app) that transmits a message to the solar-powered sign 305 via the communications interface that instructs the processor to perform one or more actions, such as adjust the brightness of the sign, or activate or deactivate the solar-powered sign 305. In some implementations, the behavior of the solar-powered sign 305 can be changed via external signals from other devices. For example, a sign that was previously used for automatic behavior (e.g., following a day/night cycle) could be converted to only allow a manual on/off switch to manage the lighting behavior via instructions from an external device.

**[0094]** The communications interface can enable peer-to-peer (P2P) communication among the solar-powered signs 305. For example, multiple proximate (e.g., determined based on location information, wireless signal strength, or associations defined in the memory of the

solar-powered signs 305) solar-powered signs 305 can share day/night cycle information. This enables signs to correct their neighbors about the relative day/night cycle through a consensus-building algorithm, or even to allow the tracking of weather patterns through the collection of signals across a wider area. Ambient brightness information may also be shared between the solar-powered signs 305 and determined using a consensus building algorithm or function. The consensus-building algorithm may cause one of the solar-powered signs 305 to be a “master” sign, which coordinates the consensus communications and any resulting output of the consensus algorithm to the other solar-powered signs 305. Coordination across groups of solar-powered signs 305 allows for the groups to pre-emptively brighten in response to changing conditions, such as predicted weather conditions.

**[0095]** In some implementations, the processor of the solar-powered sign 305 can pre-emptively brighten or dim the light source of the solar-powered sign 305 to compensate for future weather events. For example, if the solar-powered sign 305 receives (e.g., from an external computing system via the communications interface) an indication that a storm will pass through the location of the solar-powered sign 305 within a predetermined period of time, the solar-powered sign 305 can pre-emptively adjust the intensity of the light source to brighten the solar sign such that it is illuminated during the storm. Pre-emptively adjusting the intensity of various factors may include dynamically adjusting the brightness or illumination intensity of one or more display portions 315.

**[0096]** The processor of the solar-powered sign 305 may utilize readings from temperature sensors within or in communication with the circuitry of the solar-powered sign 305 to select a source of power for the solar-powered sign 305. In some implementations, the internal battery of the solar-powered sign 305 may be selected as a default source of power for the internal light source of the solar-powered sign 305 (as well as any other electronics of the solar-powered sign 305 that may utilize electric power). However, use the internal battery of the solar-powered sign 305 may be optimal in certain temperature conditions, which if not met, may make charging or discharging the internal battery inefficient. In some implementations (e.g., one or more of the implementations described in connection with FIGS. 9A and 9B), the processor of the solar-powered sign 305 can select from a secondary source of power that may be stored in a stand or post (e.g., battery 520 within the post 510, or the underground battery

525 electronically coupled to the post or the solar-powered sign 305 as shown in FIGS. 9A and 9B, respectively).

[0097] The external batteries may be optimized for different weather conditions and may be selected by the processor of the solar-powered sign 305 when the detected temperature of the internal battery exceeds a predetermined threshold or falls below a second predetermined threshold. Similar approaches may be utilized if the charge of the internal battery falls below a threshold, in order to keep the solar-powered sign illuminated using a source of external. Other sources of external power may also be used, such as from a power supply or from another voltage source electrically coupled to the solar-powered sign. Configuration of the power source from which the solar-powered sign 305 should draw power can be modified via communications from external computing devices or other solar-powered signs 305.

[0098] The processor of the solar-powered sign 305 can implement anti-counterfeiting techniques to prevent the solar-powered sign 305 from being utilized with unauthorized overlays 310. In some implementations, a particular magnet may be used in an overlay 310 that is detected by a Hall Effect sensor in communication with the processor. If the Hall Effect sensor detects the magnet (e.g., which may have a predetermined field strength corresponding to authorization of the overlay 310), the processor solar-powered sign 305 can activate the internal light source of the solar-powered sign 305 and operate according to the techniques described herein. If the overlay 310 is not authorized, the processor of the solar-powered sign 305 may deactivate the light source of the solar-powered sign 305, in order to prevent illumination of unauthorized overlays 310. In some implementations, an additional light source and light sensor, which emits and detects a predetermined wavelength (or range of wavelengths) of light may be utilized.

[0099] Authorized overlays 310 may include portions of ink or colored material that reflects the predetermined wavelength (or range of wavelengths). The processor can activate the additional light source (which may emit light within or outside of the visible spectrum), and if the wavelength (or range of wavelengths) of light is reflected from the portions of ink or colored material from the authorized overlay 310, those wavelength(s) can be detected via the additional light sensor, and the processor can determine that the overlay 310 is authorized. In some implementations, the ink or colored material of authorized overlays 310 may block

certain wavelength(s) of light. If those wavelength(s) are not detected by the additional light sensor in communication with the processor, the processor may determine that the overlay 310 is authorized. Otherwise, the overlay 310 can be considered unauthorized. The additional light source and light sensor may be internal or external to the solar-powered sign 305. In some implementations, an authorized overlay 310 may include a particular printed pattern or pattern of material, which can be detected by changes in power delivered by the solar panel or by the additional light sensor as described herein. When the overlay 310 on the solar-powered sign 305 is switched out, the processor can re-verify that the overlay 310 is authorized and may deactivate the light source of the solar-powered sign 305 if a non-authenticated visual media is installed.

**[0100]** In some implementations, an overlay 310 may be integrated within a housing of the solar-powered sign 305, as described herein. For example, the overlay 310 may take the place of or may be coupled to an outer layer of diffusion film (e.g., the top diffusion film 201) on the solar-powered sign 305. In some implementations, multiple overlays 310 may be provided as part of or coupled to the solar-powered sign 305. As shown, the overlay 310 may include one or more display regions 315. The display region 315 may be coupled to, formed on, or otherwise form a part of the overlay 310. If the overlay 310 is removable, the display region 315 can be removed from the solar-powered sign 305 with the overlay 310. In some implementations, the display region 315 may be coupled to electronic circuitry (e.g., the circuitry 320 shown in FIG. 9B) that forms a part of the overlay 310, or is otherwise electrically coupled to traces, wires, or other electronically conductive components present on the overlay 310. Although shown as separate from the overlay 310, it should be understood that in some implementations, the circuitry 320 may be included within a portion of the overlay, and may interface with the processor of the solar-powered sign 305 via a communications interface or bus. In some implementations, the circuitry 320 may be separate from the overlay, and may be included as part of an internal PCB of the solar-powered sign 305.

**[0101]** As described herein, the display region 315 can be any type of digital display device that can present information, text, graphics, or other types of content. In some implementations, the display region 315 can be a bistable display, such as an e-ink or e-paper display. Such displays may mimic the appearance of ink on paper, using tiny microcapsules

filled with white and black particles suspended in a clear fluid. One advantage of bistable displays is low power consumption, because the display only requires power to change the image presented on the display region 315. In some implementations, the display region 315 may include a partially transparent layer of material. In some implementations, the display region 315 may be opaque or partially opaque and partially transparent. In some implementations, the bistable display may be a printed display (e.g., printed via inkjet printing or another printing technique). In such implementations, the bistable display may be printed at least partially in a half-tone pattern of bistable pixels, such that the bistable display is at least partially transparent.

**[0102]** The overlay 310 may be utilized, in some implementations, for a variety of signage applications. For example, the display region 315 may include graphics, text, or other information that may be changed dynamically to represent or indicate events, locations, or other information that may be conveyed via signage. For example, the overlay 310 may include graphics, text, or other dynamic content relating to real estate (e.g., forming a real-estate rider). Furthering this example, the graphics or text may be dynamically changed to read any of “Coming Soon”, “Sold”, “For Sale”, “Pending”, “Contingent”, “Now Showing”, or “Open House”, among others.

**[0103]** In some implementations, the processor of the solar-powered sign 305 may communicate with one or more remote servers to receive updates for the overlay 310, for example, to change the content of the display region 315. Furthering the example above, the processor of the solar-powered sign 305 may communicate with one or more real-estate servers corresponding to a location of the solar-powered sign (e.g., determined via GPS, determined via a stored configuration setting, determined via a setting provided via a mobile device or remote computing system, etc.) to retrieve up-to-date real-estate information relating to a status of a listing. The display region 315 may automatically be updated to represent up-to-date status information or other information relating to the listing or property. In some implementations, the solar-powered sign 305 may implement a schedule that updates the display region 315 to show whether a business location is open or closed.

**[0104]** As described herein, the solar panel (e.g., the solar panel 30) can be coupled to a battery within the solar sign 305, and can absorb light that passes through the overlay 310

and/or the outer diffusion film, the light guide, and the various components of the solar-powered signs described herein. The solar panel of the solar-powered sign 305 operates when enough light passes through layers of to charge the battery and power the internal electronics of the solar-powered sign 305. While semi-transparent layers (e.g., latex inks printed on the overlay film, outer diffusion films, etc.) are sufficiently transparent, any opaque components, including opaque components of bistable e-ink displays may block light from reaching some internal areas of the solar-powered sign 305.

**[0105]** To avoid instances where the display portion 315 blocks or obscures light from reaching the internal components of the sign, the display portion 315 may be arranged over portions of the sign that do not include light-sensitive components (e.g., areas on the surface that do not block the solar panel, etc.). In some implementations, the internal components of the solar-powered sign 305 may be arranged to accommodate the display portion 315 that would otherwise block light from striking the solar panel. In some implementations, the display portion 315 may block a portion of the solar panel, but let enough light through for the solar-powered sign 305 to operate properly. In some implementations, there may be an upper limit to the amount of surface area of the solar sign that may be covered with the display region 315 to avoid instances where the solar panel cannot receive enough light. For example, the upper limit may be 80% coverage, 70% coverage, 50% coverage, 40% coverage, or 30% coverage, among others.

**[0106]** In addition to the various display regions 315 described herein, the overlay 310 may include one or more printed regions. The printed regions may be printed on using a latex ink, a colored latex ink, a black ink, a white ink, or any other semi-transparent ink. The surface of the overlay 310 (e.g., the surface shown in the front view, surface of the solar sign assembly 805, other surfaces of the solar sign assembly 805, etc.) can be uniformly illuminated by the light extracted by the light extraction features of a light guide within the solar-powered sign 305, such that the solar sign and any graphical designs printed thereon can be illuminated in low-light environments (e.g., at night time, etc.). In some implementations, the overlay 310 can be easily removable and replaceable. Different designs, and different display regions 315 for the solar-powered sign 305, can easily be changed by exchanging the overlays having different designs printed thereon.

**[0107]** The overlay 310 may include wires, traces, or other electronic components that enable the display region 315 to be electrically coupled to internal components of the solar-powered sign 305. For example, the display region 315 may be coupled to an internal battery of the solar-powered sign 305. In some implementations, the overlay 310 may include wires, traces, or other electronic components that electrically couple the display region 315 to one or more external sources of power, such as an external battery. The display region 315 may receive control signals from the processor of the solar-powered sign. The control signals may change what is displayed by the display region 315, activate the display region 315, deactivate the display region 315, or modify a brightness of the display region 315.

**[0108]** As shown in the cross-sectional side view of 9B, the solar-powered sign 305 may include circuitry 320, which may be electrically coupled to or form a part of a PCB of the solar-powered sign (e.g., the PCB 4, the PCB 209, etc.). In some implementations, the circuitry 320 may form a part of the overlay 310. The circuitry 320 can include any traces, wires, electronics (e.g., power converters, display driving circuits, etc.) that facilitate communication between the processor of the solar-powered sign 305 and the one or more display regions 315. For example, the circuitry 320 may include one or more connectors, DC-DC power converters, display driver circuits, or other types of circuitry 320 that support the functionality of the display region 315.

**[0109]** The circuitry 320 may be electrically coupled to, and can receive power from, one or more power sources of the solar-powered sign 305. The circuitry 320 can receive power from an internal battery of the solar-powered sign 305. In some implementations, the circuitry 320 can receive power from one or more external power sources that provide power to the solar-powered sign, such as an external battery (e.g., a weatherproof battery) or an external voltage source. The circuitry 320 may include a hardware display driver that can translate commands received from the processor of the solar-powered sign 305 to low-level inputs to control the display region 315. For example, in implementations where the display region 315 is an e-ink or bistable display, the circuitry 320 can include circuitry that causes the display region 315 to render one or more images, text, or graphics, manage the power consumption for writing to the display region 315, manage updating portions of the display region 315 to reduce

power consumption, and implementing ghosting reduction by refreshing portions of the display region 315 to prevent artefacts.

**[0110]** In some implementations, the circuitry 320 can receive power from one or more external power sources, such as an external DC power source, an external AC power source, an external battery, or another type of external power source. The circuitry 320 may utilize the power received via the external power source, for example, to charge the battery or to power one or more components of the solar-powered sign 305. The circuitry 320 may include power conversion components, such as DC-DC converters, AC-DC converters, or voltage regulators that generate and maintain proper voltage and current for the various components of the solar-powered sign 305.

**[0111]** In some implementations, the circuitry 320 may implement hybrid charging of the internal battery of the solar-powered sign 305, in which the circuitry 320 may charge the internal battery via one or more power sources (e.g., the internal solar panel, an external power source, etc.). In some implementations, hybrid charging may include charging the internal battery according to expected or received external light (e.g., utilizing external power to charge the battery when the internal solar panel is not generating suitable power, etc.). In some implementations, the circuitry 320 may implement hybrid charging for one or more external batteries that are electrically coupled to one or more components of the solar-powered sign 305. External power may be received via any suitable connector.

**[0112]** The circuitry 320 may be electrically coupled to a single display region 315 in a one-to-one configuration, or the circuitry 320 may be electrically coupled to and control multiple display regions 315, in some implementations. The processor of the solar-powered sign 305 can provide commands to control one or more display regions 315 of the solar-powered sign 305. The commands may be display commands that change what is displayed on the display region 315. For example, the commands may cause the display region(s) 315 to display one or more images, videos, graphics, text, or other content.

**[0113]** In some implementations, the processor may transmit the display commands based on an internal display schedule stored in memory (e.g., the main memory 406, the read-only memory 408, etc.) of the solar-powered sign. The display schedule may include a time-

indexed sequence of content to display via the display region 315. To implement the display schedule, the processor may transmit commands to change the display content of the display region 315 according to content associated with the current time (e.g., based on a real-time clock maintained by the processor, etc.) in the display schedule. In some implementations, the processor may transmit commands to cycle through display content stored in the memory of the solar-powered sign 305 in response to expiration of a timer. For example, the processor may change the content displayed by the display region 315 periodically (e.g., every 30 seconds, every 5 minutes, etc.).

**[0114]** Any suitable content may be displayed by the display region 315. Content displayed by the display region may be stored or generated by the processor of the solar-powered sign 305. In some implementations, the processor may cause the display region 315 to display dynamic or changing content, such as videos. In some implementations, the processor of the solar-powered sign 305 may cause the display region 315 to display dynamic content that changes over time, such as a timer, a clock, an animation, or another type of moving graphic. In some implementations, the processor of the solar-powered sign 305 can update content that is to be displayed by the display region 315. For example, the processor of the solar-powered sign 305 may cause the display region 315 to display an updated real-time clock. The processor can update the text or graphic representing the current time, and cause the display region 315 to update the display accordingly.

**[0115]** In some implementations, the processor of the solar-powered sign 305 can display content that is received from one or more external sources. For example, a mobile device or another external computing device may transmit content to the processor via one or more communication interfaces of the solar-powered sign. The processor may then transmit commands that cause the display region 315 to display the received content. The processor may also modify, create, or delete display schedules or sequences or in response to receiving corresponding commands from an external computing device. Such commands may provide additional or alternative content to display, or may provide time periods, schedule information (e.g., times of day to present certain content, etc.); among other information to change what content is displayed by the display region. In implementations where the solar-powered sign communicates with the Internet via the communications adapter, the solar-powered sign 305

may download or otherwise retrieve display content from a predetermined or specified (e.g., via commands from an external computing system) network location (e.g., a uniform resource locator (URL), etc.).

**[0116]** The solar-powered sign 305 may illuminate the display region 315 using a variety of techniques. In some implementations, the display region 315 may be partially transparent, such that it may be illuminated by a back light. In such implementations, light extracted by the light extraction features of the light guide (e.g., the light guide 5, the light guide 205, etc.) of the solar-powered sign 305 can illuminate the display region 315. In some implementations, an additional light source may be provided to illuminate the display region of the solar-powered sign 305. In one implementation, the display region 315 may include a dedicated backlight that can be controlled by the processor of the solar-powered sign 305 via the circuitry 320. In some implementations, an external lamp or light source may be positioned to emit light on the outer surface of the display region. The external lamp or light source may be electrically coupled to and controlled by the processor of the solar-powered sign, as described herein. In some implementations, no illumination may be provided for the display region 315.

**[0117]** In some implementations, the display region 315 may be a self-illuminating display, such as an LED display or an OLED display. Such displays may receive power via the circuitry as described herein, but emit their own light and therefore may not utilize a backlight or additional light source. In such implementations, the display region 315 may include additional circuitry to provide power to the OLED or LED display. In some implementations, the display portion 315 may be a printed OLED display, with printed conductive traces or circuits that can electrically couple the display portion 315 to the circuitry 320 and/or the processor of solar-powered sign 305.

**[0118]** The processor of the solar-powered sign 305 can provide commands to control the brightness of the illumination for one or more display regions 315. Controlling the illumination may include controlling the internal light sources of the solar-powered sign 305 that illuminate the overlay 310 via a light guide, as described herein (e.g., in implementations where the display portion 315 is transparent or at least partially transparent). In implementations where the display region has a dedicated backlight or internal illumination

source, the processor may provide commands to the circuitry 320 to control the backlight or internal illumination source according to a desired brightness. In implementations where an external light source or lamp is used to illuminate the surface of the display region, the processor may control the external light source or lamp via the circuitry 320 or a suitable communications bus or communications interface.

**[0119]** The processor can control the brightness to optimize for visibility of the display portion(s) 315, as described herein. This can include performing similar techniques to control the display portions 315 according to a day/night cycle, such that the battery life is optimized while ensuring that content can still be dynamically displayed via the display portion(s) 315 of the solar-powered sign. For example, the processor of the solar-powered sign 305 can increase the brightness of the illumination for one or more display portions 315 when ambient lighting conditions become dark or dim, or if a time of day indicates that it is nighttime. The processor may perform any of the techniques described herein with respect to controlling the internal light sources of the solar-powered sign 305 to control the illumination of one or more display regions 315 of the solar-powered sign 305.

**[0120]** Although FIG. 9A is shown as including a single display region 315, it should be understood that the overlay 310 may include any number of display regions 315, each of which may be controlled independently by the processor(s) of the solar-powered sign. In some implementations, multiple display regions 315 on an overlay 310 may have a different type (e.g., one being an e-ink display, another an OLED display). Further, although it is shown that the display region 315 occupies a portion of the overlay 315, it should be understood that in some implementations, the display region 315 may occupy the entirety, or about the entirety, of the overlay 315. The display region 315 may be partially transparent and enable light to propagate through the layers of the solar-powered sign 305 to strike the internal solar panel of the solar-powered sign 305, as described herein.

**[0121]** FIG. 10 illustrates a block diagram of an example computing system suitable for use in the various arrangements described herein, in accordance with one or more example implementations. FIG. 4 is a component diagram of an example computing system suitable for use in the various implementations described herein, according to an example implementation. For example, the computing system 400 may be implemented on the PCB 209 of the solar signs

described herein, or may otherwise be included in the solar signs described herein or in communication with the various components of the solar signs described herein, or various other example systems and devices described in the present disclosure.

**[0122]** The computing system 400 includes a bus 402 or other communication component for communicating information and a processor 404 coupled to the bus 402 for processing information. The computing system 400 also includes main memory 406, such as a RAM or other dynamic storage device, coupled to the bus 402 for storing information, and instructions to be executed by the processor 404. Main memory 406 can also be used for storing position information, temporary variables, or other intermediate information during execution of instructions by the processor 404. The computing system 400 may further include a ROM 408 or other static storage device coupled to the bus 402 for storing static information and instructions for the processor 404. A storage device 410, such as a solid-state device, magnetic disk, or optical disk, is coupled to the bus 402 for persistently storing information and instructions. The computing system 400 may be coupled via the bus 402 to a display 414, such as a bistable display (e.g., an e-ink display, a multicolor e-ink display, etc.), an LED display, an OLED display, a liquid crystal display, for displaying information to a user. The display 414 may be, or may include, one or more of the display portions 315 of FIG. 9A.

**[0123]** In some implementations, the computing system 400 may include a communications interface 416, such as a networking adapter. Communications interface 416 may be coupled to bus 402 and may be configured to enable communications with a computing or communications network or other computing systems. In various illustrative implementations, any type of networking configuration may be achieved using communications interface 416, which may be wired (e.g., via Ethernet), wireless (e.g., via Wi-Fi, Bluetooth, NFC, 3G, 4G, LTE, 5G, etc.), satellite (e.g., via GPS) pre-configured, ad-hoc, LAN, WAN, and the like.

**[0124]** According to various implementations, the processes of the illustrative implementations that are described herein can be achieved by the computing system 400 in response to the processor 404 executing an implementation of instructions contained in main memory 406. Such instructions can be read into main memory 406 from another computer-readable medium, such as the storage device 410. Execution of the implementation of

instructions contained in main memory 406 causes the computing system 400 to perform the illustrative processes described herein. One or more processors in a multi-processing implementation may also be employed to execute the instructions contained in main memory 406. In alternative implementations, hard-wired circuitry may be used in place of or in combination with software instructions to implement illustrative implementations. Thus, implementations are not limited to any specific combination of hardware circuitry and software.

**[0125]** In the present disclosure, the methods disclosed may be implemented as sets of instructions or software readable by a device. Further, it is understood that the specific order or hierarchy of steps in the methods disclosed are instances of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the method can be rearranged while remaining within the disclosed subject matter. The accompanying method claims present elements of the various steps in a sample order and are not necessarily meant to be limited to the specific order or hierarchy presented.

**[0126]** The described disclosure may be provided as a computer program product, or software, that may include a non-transitory machine-readable medium having stored thereon instructions, which may be used to program a computer system (or other electronic devices) to perform a process according to the present disclosure. A machine-readable medium includes any mechanism for storing information in a form (e.g., software, processing application) readable by a machine (e.g., a computer). The machine-readable medium may include, but is not limited to, magnetic storage medium, optical storage medium; magneto-optical storage medium, read only memory (ROM); random access memory (RAM); erasable programmable memory (e.g., EPROM and EEPROM); flash memory; or other types of medium suitable for storing electronic instructions.

**[0127]** While the present disclosure has been described with reference to various implementations, it will be understood that these implementations are illustrative and that the scope of the present disclosure is not limited to them. Many variations, modifications, additions, and improvements are possible. More generally, embodiments in accordance with the present disclosure have been described in the context of particular implementations. Functionality may be separated or combined in blocks differently in various embodiments of

the disclosure or described with different terminology. These and other variations, modifications, additions, and improvements may fall within the scope of the disclosure as defined in the claims that follow.

**WHAT IS CLAIMED IS:**

1. A system comprising:  
an outer diffusion film of a solar-powered sign;  
an internal light guide;  
a light source;  
a solar panel;  
one or more processors configured to receive power generated via the solar panel; and  
a display region configured to display content provided via the one or more processors while the light source illuminates at least a portion of the outer diffusion film.
2. The system of claim 1, wherein the outer diffusion film is a removable overlay and the display region is coupled to the removable overlay.
3. The system of claim 1, further comprising circuitry that receives commands from the one or more processors to control the content displayed via the display region.
4. The system of claim 1, wherein the display region comprises a bistable display.
5. The system of claim 4, wherein the bistable display comprises a multi-color bistable display.
6. The system of claim 1, wherein the display region comprises an organic light-emitting diode (OLED) display.
7. The system of claim 1, wherein the one or more processors are further configured to modify the content displayed via the display region according to a display schedule.
8. The system of claim 1, wherein the one or more processors are further configured to:  
determine an ambient brightness of an area in which the solar-powered sign is located; and  
automatically adjust illumination of the display region based on the ambient brightness.

9. The system of claim 8, wherein the one or more processors are further configured to adjust the illumination of the display region by adjusting a brightness of a back light of the display region.
10. The system of claim 8, further comprising:  
an external light source configured to illuminate the display region, and wherein the one or more processors are further configured to adjust the illumination of the display region by adjusting a brightness of the external light source.
11. The system of claim 1, wherein the one or more processors are further configured to receive, from a computing device via a communications interface, additional content to display via the display region.
12. The system of claim 1, wherein the one or more processors are further configured to change the content displayed via the display region upon expiration of a timer.
13. The system of claim 1, further comprising an internal battery that stores the power generated via the solar panel, wherein the display region receives power from the internal battery.
14. A system comprising:  
an overlay including a display region configured to display content; and  
circuitry configured to:  
receive one or more commands from one or more processors of a solar-powered sign; and  
control the content displayed via the display region based on the one or more commands.
15. The system of claim 14, wherein the overlay is an outer diffusion film configured to couple a stack of materials to form the solar-powered sign.
16. The system of claim 14, wherein the overlay is configured to couple with an outer diffusion film of the solar-powered sign.

17. The system of claim 14, wherein the display region occupies a portion of a surface of the overlay.
18. The system of claim 14, wherein the display region is a bistable display.
19. The system of claim 18, wherein the bistable display is a multi-color bistable display.
20. The system of claim 14, wherein the display region is an organic light-emitting diode (OLED) display.

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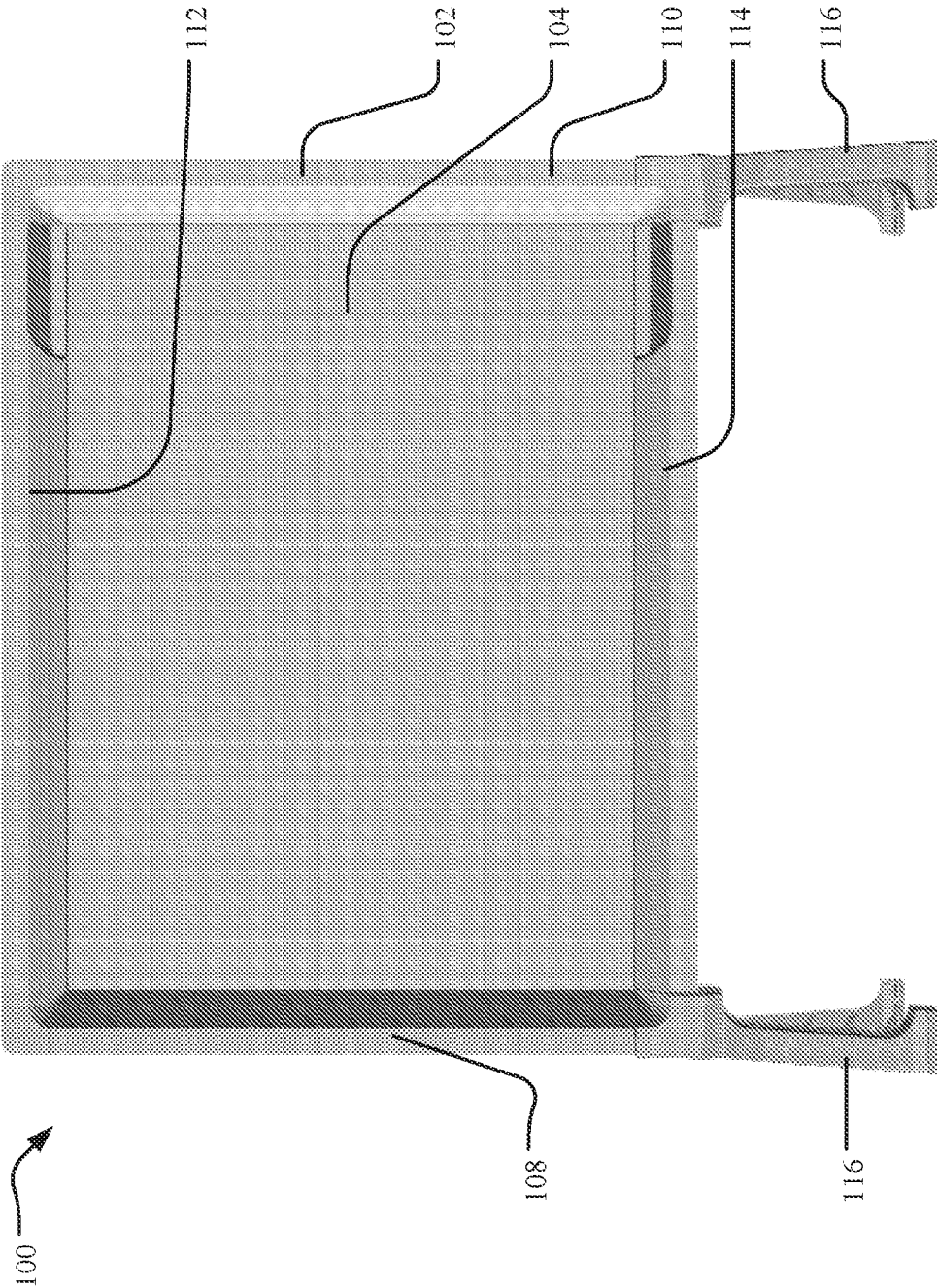


FIG. 1

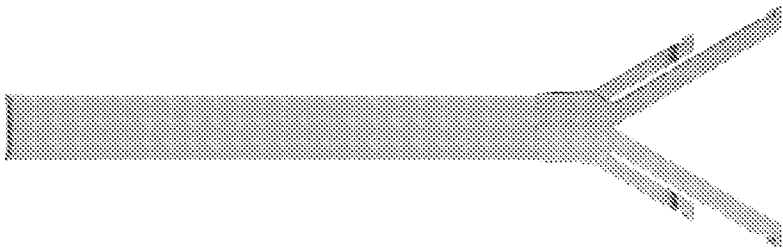


FIG. 2A

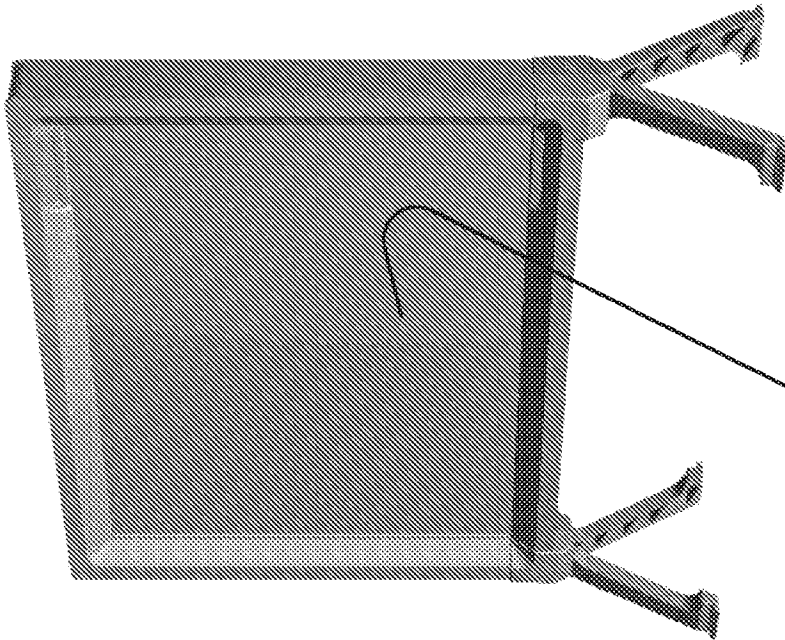
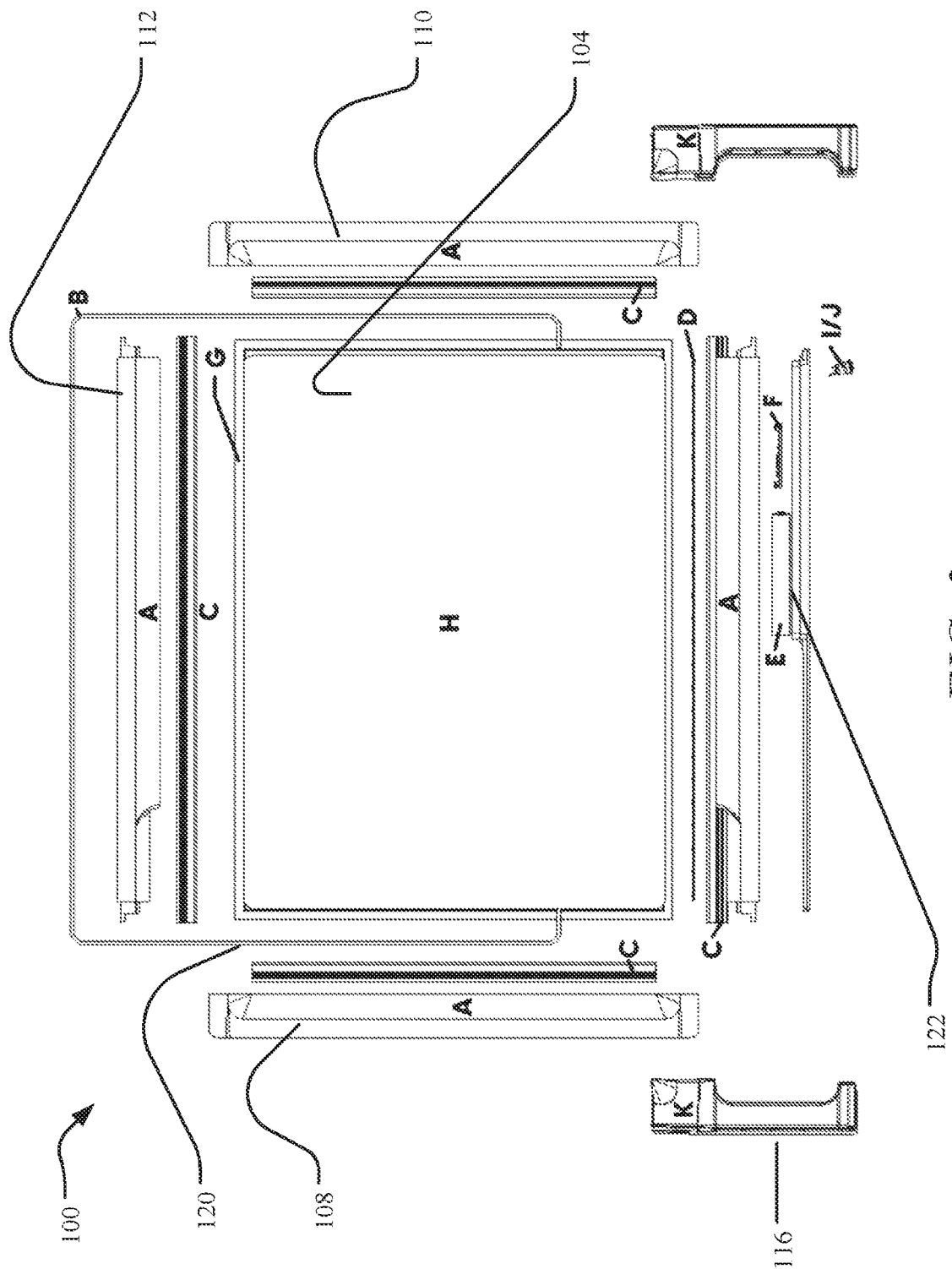


FIG. 2A

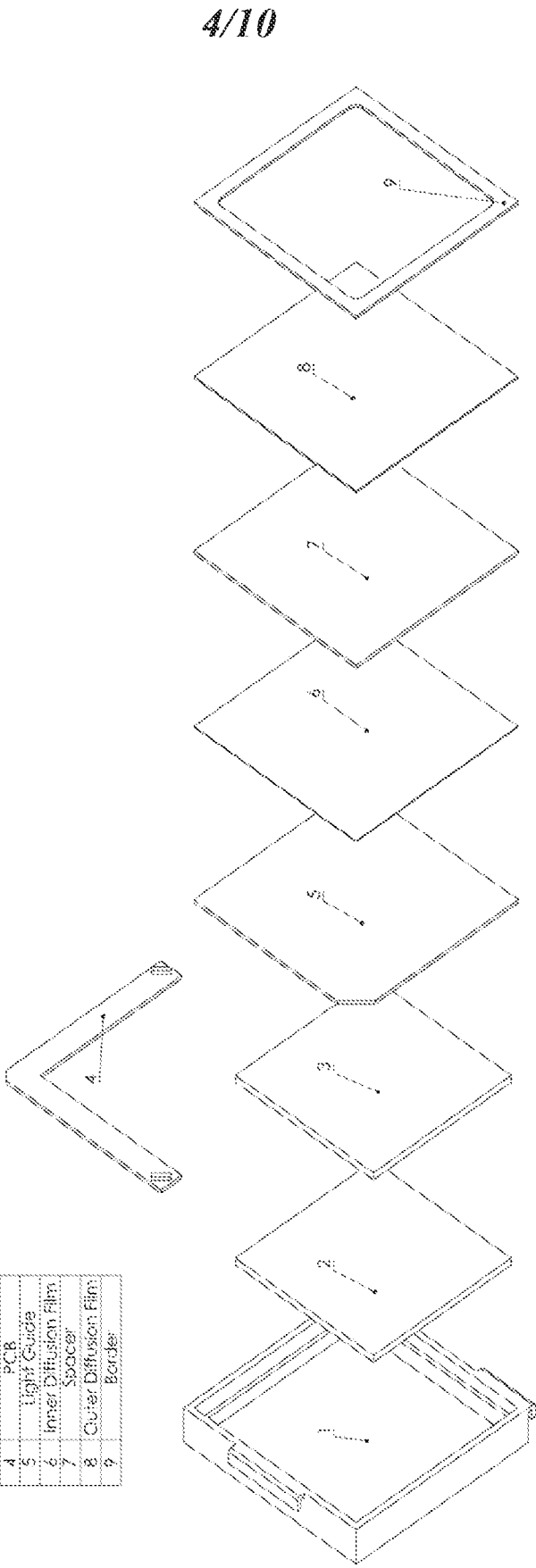
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200

|   |                      |
|---|----------------------|
| 1 | Base                 |
| 2 | Battery              |
| 3 | Solar Panel          |
| 4 | PCB                  |
| 5 | Light Guide          |
| 6 | Inner Diffusion Film |
| 7 | Spacer               |
| 8 | Outer Diffusion Film |
| 9 | Border               |



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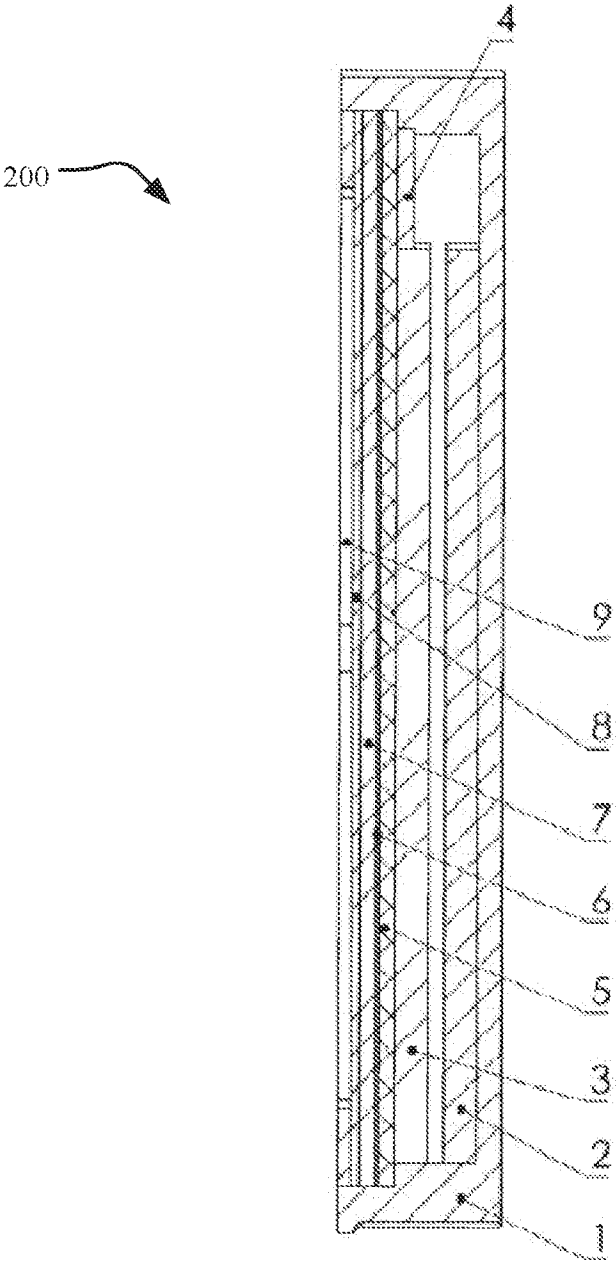


FIG. 5

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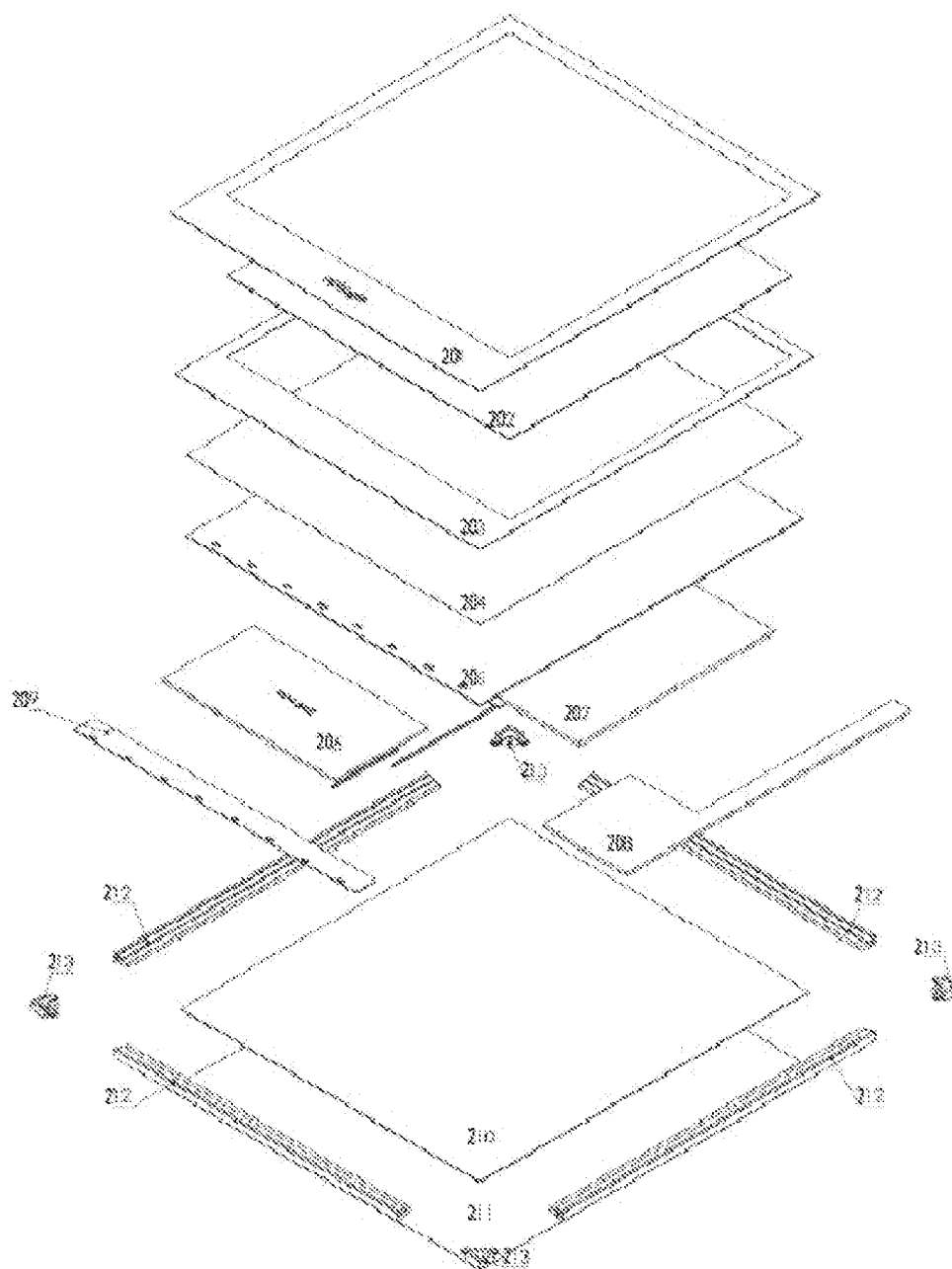


FIG. 6

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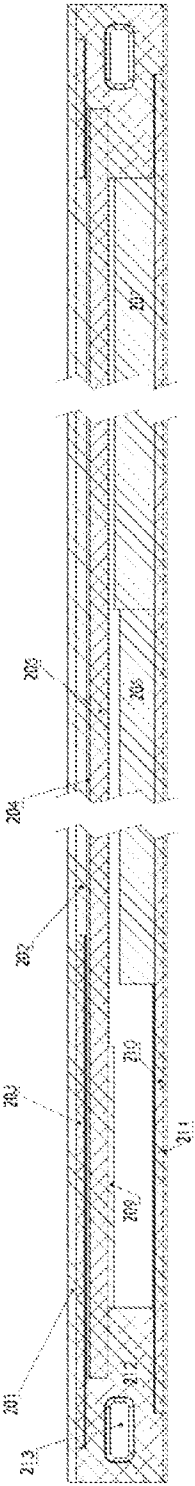


FIG. 7

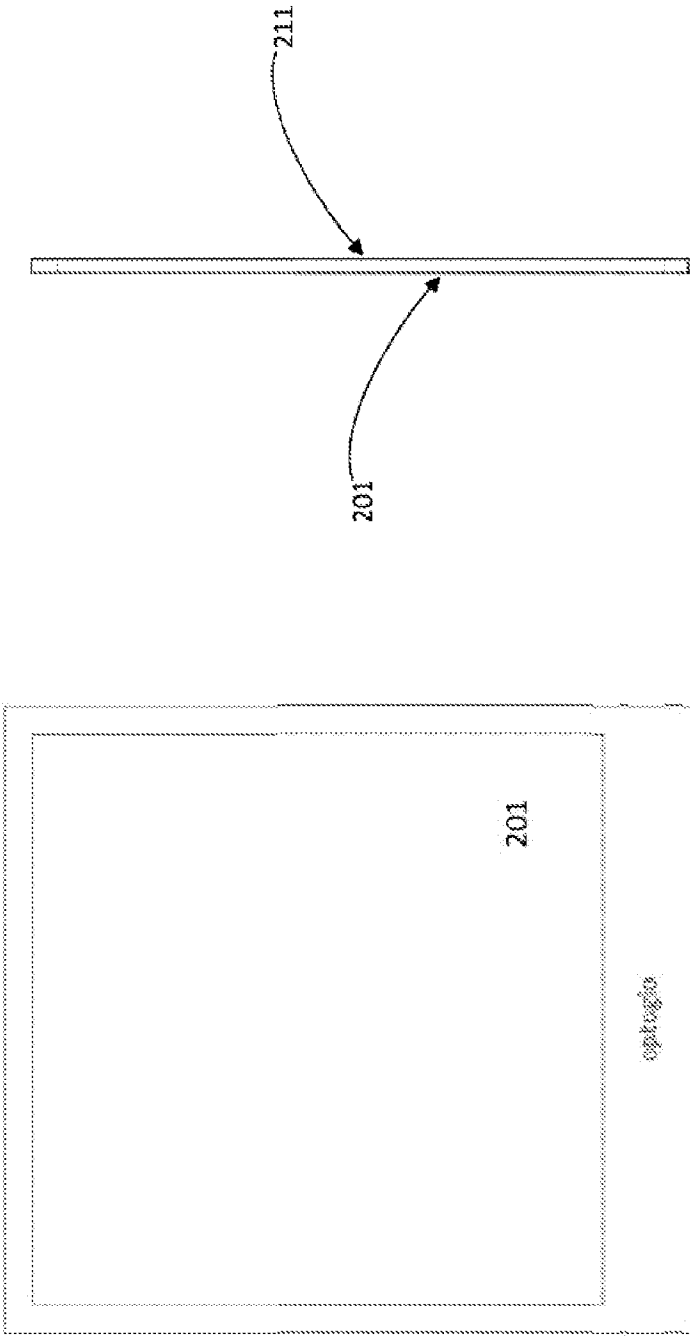


FIG. 8B

FIG. 8A

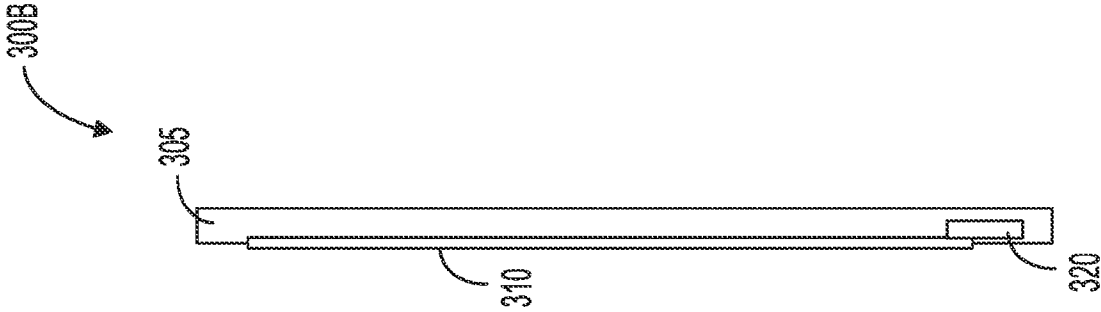


FIG. 9B

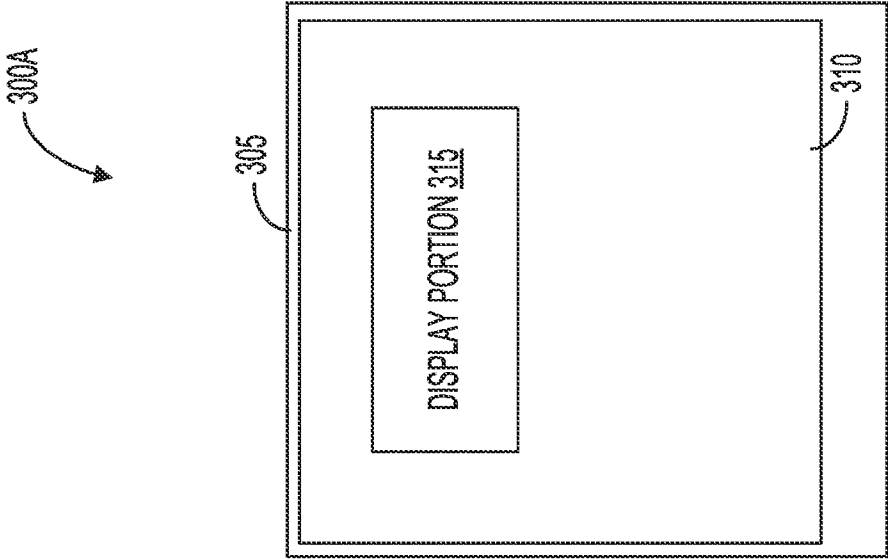


FIG. 9A

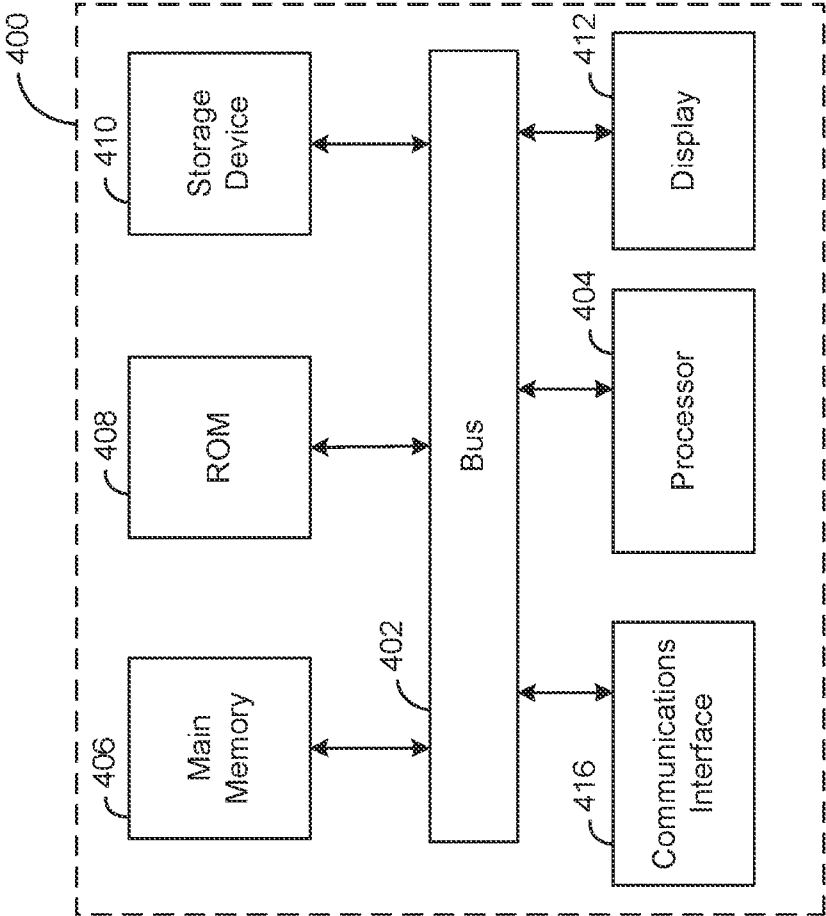


FIG. 10