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Inventor(s)	CHANG; CHUNG-YI et al.

SELF-POWERED DISPLAY DEVICE

Abstract

A self-powered display device includes a display module and a power module. The display module is a cholesteric liquid crystal display module, and the power module is a solar cell module. The display module allows light to enter the power module from the front side, and the power module generates electricity upon receiving the light to provide the necessary energy for the display module to show images. The power module has multiple active areas and multiple inactive areas between the active areas. When the width of the inactive area is less than or equal to 50 μm, the human eye will have difficulty discerning the width of the inactive area. Additionally, a shielding layer can be placed on the inactive area to ensure that the visual color difference (ΔE) between the inactive area and the active area does not exceed 10 color difference units, thereby improving the image quality.

Inventors: **CHANG; CHUNG-YI (Tainan City, TW), CHEN; CHIH-WEI (Hsinchu County, TW), LIAO; CHI-CHANG (Tainan City, TW)**

Applicant: **Iris Optronics Co., Ltd.** (Tainan City, TW)

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Background/Summary

RELATED APPLICATIONS [0001] This application is a Continuation of application Ser. No. 18/496,838, filed on Oct. 27, 2023, which claims priority to Taiwan Application Serial Number 112130801, filed Aug. 16, 2023, all of which are herein incorporated by references.

BACKGROUND
Technical Field
[0002] The present invention relates to a self-powered display device, and in particular to a self-powered display device that improves color difference of the image or forms a confined visual area through a shielding layer.
Description of Related Art
[0003] A self-powered display typically consists of a cholesteric liquid crystal display and a solar cell. The material used for the solar cell can be categorized into two types: opaque and light-transmitting, as illustrated in FIG. **1** in the prior art. A display, denoted as display **0**, is using solar cells composed of the opaque material and comprises a cholesteric liquid crystal layer and a solar cell layer. Examples of the solar cell layer **2** may be single-crystalline silicon solar cell or polycrystalline silicon solar cell. When the solar cell layer **2** is opaque, high-efficiency power generation can be performed at a lower cost. When ambient light enters the display **0** from the environment, a portion of the light beams will be reflected by the cholesteric liquid crystal layer **1**, as perceived by the human eye. The remaining portion of the light beams will pass through the cholesteric liquid crystal layer **1** and ultimately be absorbed by the solar cell layer **2**. As a result, the solar cell layer **2** typically consists of two types of structures: busbars and fingers. These two structures are commonly made of metal materials such as materials like silver and other similar metals. However, this structure can significantly degrade the image quality of the display **0**. That is to say, when displaying a black image, the cholesteric liquid crystal layer **1** is driven into the focal conic state, i.e., the transparent state, wherein the black image is essentially provided by the solar cell layer **2**. In the region of the busbars and fingers, in addition to being unable to provide a black image, the stray light beams reflected by the metal material will also affect the display image. Besides, significant color discrepancies also arise between the region encompassing the busbars and fingers and the adjacent region lacking these elements. Consequently, the overall image quality of the display **0** is substantially diminished.
[0004] Furthermore, as shown in FIG. **2**, it illustrates the display **0** with light-transmitting solar cells in the prior art, including a cholesteric liquid crystal layer **1**, a solar cell layer **2**, and a light-absorbing layer **3**. The solar cell layer **2** can be, for example, an organic solar cell, dye-sensitized solar cell or perovskite solar cell, etc. When the solar cell layer **2** is in a transparent state, the ambient light enters the display **0** from the environment. A portion of the light beams will be reflected by the cholesteric liquid crystal layer **1** and be visible to the human eye, and another portion of the incident light beams traverses the cholesteric liquid crystal layer **1** and is absorbed by the solar cell layer **2**. Stray light beams that penetrate the solar cell layer **2** are subsequently absorbed by the light-absorbing layer **3**, wherein the light-absorbing layer **3** is usually made of

black material.
[0005] To illustrate further, when the solar cell layer **2** is in a transparent state, and a black image is displayed, in this specific situation, the cholesteric liquid crystal layer **1** undergoes a transition to the focal conic state, leading to the manifestation of the black image. The black image is in fact provided by the solar cell layer **2** to which a light-absorbing layer **3** is attached so that the black image present in the area of the busbars and fingers of the transparent conductive material is presented by the light-absorbing layer **3**, while the black image in other areas is provided by the solar cell layer **2**. The human eye can easily perceive the color differences in the above two areas, i.e., the busbars and fingers constituted from transparent conductive materials, tend to be prominently noticeable when a black image is displayed. Unfortunately, this color difference significantly leads to a reduction in the image quality of the display **0**.
[0006] Therefore, to ensure that the self-powered display accomplishes not only the goals of energy conservation and carbon emission reduction but also offers improved display quality when integrated with transparent or opaque solar cells, it's imperative to develop an optimal technical solution to address the aforementioned problems.

SUMMARY

[0007] The objective of the present invention is to provide a self-powered display device capable of enhancing the image quality of said device.
[0008] The present invention relates to a self-powered display device, which comprises a display module and a power module.
[0009] The display module of the present invention comprises a front side and a rear side. The front side is a display surface, while the power module is positioned on the rear side of the display module, and comprises multiple active and inactive surfaces distributed alternately. The visual color difference (ΔE) between the inactive surfaces and the active surfaces is limited to a maximum of 10 color difference units. The visual color difference (ΔE) is defined within the framework of the CIELAB color space, as established by the International Commission on Illumination (CIE) in 1976. The calculation formula for determining the visual color difference (ΔE) is as follows: ΔE= [(ΔL*).sup.2+(Δa*).sup.2+(Δb*).sup.2].sup.1/2),where L signifies color brightness, “a” represents the green-red value, and “b” represents the blue-yellow value. In this context, L spans in a range from 0 to 100, “a” is in a range between −128 and 127, and “b” is defined in a range within −128 to 127.
[0010] The display module is a cholesteric liquid crystal display module, while the power module is a solar cell module. Within this setup, the cholesteric liquid crystal display module enables the light beams enter to the solar cell module through its front side. Subsequently, the solar cell module receives the light beams, converting them into electricity and thus supplying the necessary energy for the cholesteric liquid crystal display module to exhibit a minimum of one image.
[0011] Furthermore, each active surface is a solar cell sheet, while each inactive surface features a busbar. The surface of the busbar can be provided with a shielding layer. The visual color difference between the shielding layer and the solar cell sheet as viewed from the direction towards the display module does not exceed a maximum of 10 color difference units, that is, when the shielding layer overlays the busbar, the visual color difference between the solar cell sheet and the busbar overlaid by the shielding layer remains within the range of 10 color difference units.
[0012] The shielding layer may include, but is not limited to, dark ink or adhesive tape.
[0013] The width of each of the inactive surfaces is less than or equal to 50 μm, and this range is narrower than the width recognizable by human eyes.
[0014] Furthermore, the present invention can also be a self-powered display device, which comprises a cholesteric liquid crystal display module, a solar cell module, and a shielding layer.
[0015] The cholesteric liquid crystal display module of the present invention has a front side and a rear side. The front side is a display surface, while the solar cell module is positioned on the rear side of the cholesteric liquid crystal display module and is electrically connected to it. The solar

cell module comprises multiple solar cell sheets and several busbars positioned between these solar cell sheets. The shielding layer corresponds to and is disposed on the surface of each of the busbars. The visual color difference (ΔE) between the shielding layer and the solar cell sheets is limited to within 10 color difference units.

[0016] The cholesteric liquid crystal display module enables light beams to enter the solar cell module from its front side. The solar cell module then converts the received light beams into electricity, which is used to provide electrical energy to the cholesteric liquid crystal display module so as to power the display to show at least one image.

[0017] The shielding layer may include, but is not limited to, dark-colored inks or adhesive tapes. For instance, the shielding layer could be opaque or composed of a low-transmittance dark material, such as black or dark blue tape.

[0018] The end surface of the solar cell module, which is away from the cholesteric liquid crystal display module, is provided with a light-absorbing layer. The light-absorbing layer serves to absorb any stray light that enters the solar cell module.

[0019] Furthermore, the present invention can also be a self-powered display device, which at least comprises a display module, a power module, and a shielding layer.

[0020] The display module comprises a front side and a rear side. The front side is a display surface, while the power module is positioned on the rear side of the display module and is electrically connected to the display module. The power module is provided with multiple active surfaces and multiple inactive surfaces located between these active surfaces. Each active surface is furnished with and corresponds to an electrode layer, while the shielding layer is situated on the inactive surface. The visual color difference (ΔE) between the shielding layer and the active surface does not exceed 10 color difference units.

[0021] The display module is a cholesteric liquid crystal display module, and the power module is a solar cell module. The cholesteric liquid crystal display module permits light beams to enter the solar cell module from its front side. The solar cell module generates electricity upon receiving these light beams, thereby supplying the necessary energy for the cholesteric liquid crystal display module to display at least one image.

[0022] Each of the active surfaces is a solar cell, and each of the inactive surfaces is a busbar. The shielding layer covers the busbar, and visual color difference between the shielding layer and the solar cell as viewed from the direction towards the display module does not exceed 10 color difference units.

[0023] The shielding layer may include, but is not limited to, dark ink or adhesive tape.

[0024] A protective layer, positioned away from the shielding layer, is applied to cover the busbars. Additionally, it may come into contact with the solar cells.

[0025] The power module system may further comprise a transparent substrate positioned between the electrode layer and the display module.

[0026] Therefore, the present invention provides a self-powered display device primarily achieved by implementing a narrower inactive surface on the solar cell module beneath the cholesteric liquid crystal display module. The inactive surface, for instance, with a width of 50 μm or less imperceptible to the human eye or through the physical implementation of covering the inactive surface with a dark-colored shielding layer, can effectively minimize the visual color difference (ΔE) between the inactive surface and the adjoining area. The visual chromatic aberration method ensures that a difference of the visual color difference (ΔE) does not more than 10 color difference units. As a result, the method can significantly enhance and improve the viewing experience for users when observing images displayed by the cholesteric display module.

[0027] The foregoing features of the present invention may be combined with the following drawings in various combinations without exclusivity, unless expressly indicated otherwise. Apparently, descriptions of drawings in the following may be some of embodiments of the present invention, those of ordinary skill in the art may derive other drawings based on the following drawings without unduly experiments.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. **1** is a diagram of a self-powered display in the prior art;

[0029] FIG. **2** is another diagram of a self-powered display in the prior art;

[0030] FIG. **3** is a cross-sectional view of the first embodiment of a self-powered display device of the present invention;

[0031] FIG. **4** is a top perspective view of the first embodiment of a solar cell of self-powered display device according to the present invention;

[0032] FIG. **5** is a cross-sectional view of the second embodiment of a self-powered display device of the present invention;

[0033] FIG. **6** is a top perspective view of the second embodiment of a solar cell of self-powered display device according to the present invention; and

[0034] FIG. **7** is a cross-sectional view of the third embodiment of a self-powered display device of the present invention.

DETAILED DESCRIPTION

[0035] The aforementioned constructions and associated functions and following detailed descriptions are exemplary for the purpose of further explaining the scope of the present invention. Other objectives and advantages related to the present invention will be illustrated in the subsequent descriptions and appended drawings. Furthermore, the present invention may be embodied in various modifications, and descriptions and illustrations are not-limiting.

[0036] The objective of the present invention is to introduce a self-powered display device. This self-powered display apparatus can incorporate solar cells in either a transparent or opaque manner. In addition to its capacity to generate power for image display, it also has the capability to minimize visual chromatic aberrations, thereby enhancing image quality.

[0037] Please refer to FIG. **3** in conjunction with FIG. **4**. FIG. **3** illustrates a cross-sectional view of the first embodiment of the self-powered display device of the present invention, while FIG. **4** is a top perspective view of a solar cell of the first embodiment for the self-powered display device according to the present invention. The present invention pertains to a self-powered display device **10**, and comprises a display module and a power module. The display module takes the form of a cholesteric liquid crystal display module **20**, while the power module adopts the configuration of a solar cell module **40**. Furthermore, the solar cell module **40** is constructed using either an opaque monocrystalline silicon solar cell or a polycrystalline silicon solar cell.

[0038] The cholesteric liquid crystal display module **20** comprises a front side **26** and a rear side **27** positioned opposite to the front side **26**. The front side **26** is a display surface to display at least one image. Additionally, the solar cell module **40** is implemented on the rear side **27** of the cholesteric liquid crystal display module **20**, and electrically coupled to the cholesteric liquid crystal display module **20**. The cholesteric liquid crystal display module **20** allows external light beams to enter into the solar cell module **40** from its front side **26**. Subsequently, the solar cell module **40** converts these received light beams to generate electricity, thereby supplying the necessary energy for the cholesteric liquid crystal display module **20** to display the image.

[0039] The solar cell module **40** comprises multiple active surfaces and multiple inactive surfaces implemented among these active surfaces. The active surfaces, referred to as solar cell sheets **46** are light-receiving active surfaces. The inactive surfaces are also light-receiving inactive surfaces, and in the form of the busbars **48** positioned between the solar cell sheets **46**. The solar cell sheets **46** is responsible for receiving external light beams (sunlight or ambient light sources), and converting them into electricity to power the cholesteric liquid crystal display module **20**. The busbars **48** function as metal electrodes within the solar cell module **40** and facilitate external circuit connections. Thus, the visual color difference (ΔE) between the inactive surfaces of the busbars **48** and the active surfaces of the solar cell sheets **46** does not exceed a limit of 10 color difference units.

[0040] Moreover, a shielding layer **60** can be applied to the surface of each of the busbars **48**. The visual color difference (ΔE) between the shielding layers **60** and the solar cell sheets **46**, as viewed from the direction toward the cholesteric liquid crystal display module **20**, does not exceed 10 color difference units. In other words, the shielding layer **60** is used to cover each of the busbars **48**, ensuring that the visual color difference (ΔE) between the solar cell sheets **46** and the busbars **48**, now covered by the shielding layer **60**, remains within 10 color difference units. Preferably, when the visual color difference (ΔE) between the solar cell sheets **46** and the busbars **48** remains within 5 color difference units, more pixel enhancement can be achieved. Additionally, the shielding layer **60** is implemented using materials like dark ink or tape. In a preferred embodiment of the present invention, the shielding layer **60** comprises a dark-colored ink that is applied and overlaid onto the busbars **48**.

[0041] In another embodiment of the present invention, the width W of each of the busbars **48** on the inactive surface may be equal to or less than 50 μm, and the range of the width W is falling within a range smaller than the perceptible width to the human eye. When it becomes challenging for the human eye to distinguish the separation between two adjacent solar cell sheets **46**, denoted by the width W of the busbar **48**, a noticeable visual color difference (ΔE) is almost absent. The preferred range for the width W of the busbar **48** is in a range between 30 and 50 μm. Moreover, if the structure of the shielding layer **60** that covers the busbar **48** is implemented, a distinguishable visual color difference (ΔE) would not be apparent.

[0042] Please refer to FIG. **5** together with FIG. **6**. FIG. **5** is a cross-sectional view of the second embodiment of a self-powered display device of the present invention, and FIG. **6** is a top view of the solar cell of the second embodiment of the self-powered display device of the present invention. The self-powered display device **10** of the present invention comprises a cholesteric liquid crystal display module **20**, a solar cell module **40**, a light-absorbing layer **4**, and a shielding layer **60**. The solar cell module **40** is manufactured using one of the following: a light-transmitting pattern organic solar cell, a dye-sensitized solar cell, or a perovskite solar cell, among others. That is, within the first and second embodiments of this present invention, the most prominent contrast in a self-powered display device **10** lies between these two embodiments: in the first embodiment, the solar cell module **40** consists of solar cells with an opaque pattern, while in the second embodiment, the solar cell module **40** is composed of solar cells featuring a light-transmitting pattern. As such, in the second preferred embodiment, the solar cell module **40** is supplemented with a light-absorbing layer **4** on the opposite surface of the cholesteric liquid crystal display module **20**, serving to absorb any stray light that may penetrate through the solar cell module **40**.

[0043] As depicted in the first embodiment, the shielding layer **60** overlays the busbars **48** of the solar cell module **40**. The visual color difference (ΔE) between this shielding layer **60** and the solar cell sheets **46**, as viewed from the direction toward the cholesteric liquid crystal display module **20**, is constrained to not surpass 10 color difference units. It implies that due to the presence of the shielding layer **60** on the busbars **48**, the visual color difference (ΔE) between the solar cell sheets **46** and the shielding layer **60** remains within 10 color difference units. Preferably, when the visual color difference (ΔE) between the solar cell sheets **46** and the shielding layer **60** is restricted to 5 color difference units or less, it yields a more enhancement in pixel quality.

[0044] In another preferred embodiment, if the width (W) of each of the busbars **48** is less than or equal to 50 μm, it falls within a range that is smaller than the width distinguishable by the human eye. In other words, it becomes challenging for the human eye to discern the precise width of the busbars **48**, leading to an almost imperceptible visual color difference (ΔE). The preferred width

(W) of the busbars **48** lies in a range of 30 to 50 μm. When the shielding layer **60** is used to cover the busbars **48**, it's even more challenging for human eyes to visually identify any visual color difference (ΔE) between the shielding layer **60** and the solar cell sheets **46**.

[0045] Please refer to FIG. **7**, illustrating a cross-sectional view of the third embodiment of a self-powered display device according to the present invention. The self-powered display device **10** comprises at least a cholesteric liquid crystal display module **20**, a solar cell module **40**, and a shielding layer **60**. In this embodiment, the cholesteric liquid crystal display module **20** is designed to allow external light beams to penetrate from its front side **26**. These light beams subsequently enter the solar cell module **40**. As a result of this interaction, the solar cell module **40** is capable of converting the received light beams into electricity. This generated electric energy is then supplied to the cholesteric liquid crystal display module **20** to effectively display images.

[0046] The cholesteric liquid crystal display module **20** comprises a front side **26** and a rear side **27** situated opposite to the front side **26**. The front side **26** is a display surface, intended for displaying at least one image.

[0047] Moreover, the solar cell module **40** is implemented onto the rear side **27** of the cholesteric liquid crystal display module **20**, and establishes an electrical connection with the cholesteric liquid crystal display module **20**. The solar cell module **40** comprises at least a plurality of active surfaces, a plurality of inactive surfaces situated between these active surfaces, a transparent substrate **80**, an electrode layer **84**, and a protective layer **86**. Each of the active surface is a solar cell sheet **46**, while each of the inactive surfaces corresponds to the busbar **48**, which is implemented between the solar cell sheets **46** and is constructed using a metallic element. The transparent substrate **80** is implemented in a transparent manner and is positioned between the solar cell sheet **46** and the cholesteric liquid crystal display module **20**. That is, it signifies that the transparent substrate **80** concurrently covers both the solar cell sheet **46** and the busbars **48**. Besides, the electrode layer **84** is implemented in a transparent manner and corresponds to the solar cell sheet **46** and is in contact with the transparent substrate **80**. Due to the intermittent arrangement of the solar cell sheets **46**, and the busbars **48** are arranged between the solar cell sheets **46**, the electrode layer **84** also exhibits a discontinuous pattern. Both the transparent substrate **80** and the electrode layer **84** are transparent and can allow the external light beams from the front side **26** of the cholesteric liquid crystal display module **20** to penetrate to the solar cell sheet **46**. In addition, the protective layer **86** is employed to envelop the busbar **48**, starting away from one end of the cholesteric liquid crystal display module **20** so as to protect the solar cell module **40**. Due to the intermittent nature of the busbars **48**, the protective layer **86** fills the gaps existing between the busbars **48** and comes into contact with the solar cell sheets **46**. As a result, the protective layer **86** becomes securely positioned on the shielding layer **60** of the busbars **48** so that the overall stability of the solar cell module **40** is enhanced.

[0048] In addition, the shielding layer **60** is disposed between the busbar **48** and the transparent substrate **80**. That is, the visual color difference (ΔE) between the shielding layer **60** and the solar cell sheet **46** as viewed from the direction toward the cholesteric liquid crystal display module **20** is not more than 10 color difference units. Preferably, when the visual color difference (ΔE) between the above two is within 5 color difference units, more enhancement in pixel quality can be achieved.

[0049] In another preferred embodiment of the present invention, if the width of the busbar **48** is equal to or less than 50 μm, then it is not necessary to dispose the shielding layer **60** on the busbar **48**. This is due to the difficulty in visually discerning busbar's widths narrower than 50 μm. As a result, the technical requirement that the visual color difference (ΔE) between the shielding layer **60** and the solar cell sheet **46**, as observed from the direction toward the cholesteric liquid crystal display module **20**, remains within 10 color difference units, will still be achieved. Of course, it should be noted that if the shielding layer **60** is implemented onto the narrower busbar **48** simultaneously, the advantage of reducing the overall color difference can still be realized.

[0050] Therefore, the present invention provides a self-powered display device **10**. The shielding layer **60** can be positioned either externally or internally, ensuring that the visual color difference (ΔE) between the region covered by the shielding layer **60** and the surrounding area, when observed from the direction towards the cholesteric liquid crystal display module **20**, remains within 10 color difference units, and potentially even below 5 color difference units. As a result, the pixel quality of the self-powered display device **10** is significantly enhanced.
[0051] The descriptions illustrated above set forth simply the preferred embodiments of the present invention; however, the characteristics of the present invention are by no means restricted thereto. All changes, alterations, or modifications conveniently considered by those skilled in the art are deemed to be encompassed within the scope of the present invention set forth by the following claims.

Claims

1. A self-powered display device, comprising: a cholesteric liquid crystal display module, comprising a front side and a rear side, wherein the front side is a display surface; a solar cell module, positioned on the rear side of the cholesteric liquid crystal display module and electrically connected to the cholesteric liquid crystal display module, and comprising a plurality of solar cell sheets and a plurality of busbars positioned between the solar cell sheets, wherein the busbars function as metal electrodes within the solar cell module and facilitate external circuit connections; and a shielding layer, corresponding to and disposed on a surface of the busbars, wherein a visual color difference (ΔE) between the shielding layer and the solar cell sheets remains within a range of 10 color difference units.
2. The self-powered display device according to claim 1, wherein the cholesteric liquid crystal display module enables light beams to enter the solar cell module from its front side, the solar cell module then converts the received light beams into electricity, which is used to provide electrical energy to the cholesteric liquid crystal display module so as to power the display to show at least one image.
3. The self-powered display device according to claim 1, wherein the shielding layer is made of dark ink or adhesive tape.
4. The self-powered display device according to claim 1, wherein a light-absorbing layer is further implemented on the solar cell module and positioned away from one end surface of the cholesteric liquid crystal display module.
5. The self-powered display device according to claim 1, wherein the visual color difference (ΔE) is defined within a framework of a CIELAB color space, as established by an International Commission on Illumination (CIE) in 1976.
6. A self-powered display device, comprising: a display module, comprising a front side and a rear side, wherein the front side is a display surface; a power module, positioned on the rear side of the display module and electrically connected to the display module, and comprising multiple active and inactive surfaces distributed alternately, wherein each active surface comprises and corresponds to an electrode layer; and a shielding layer, disposed on the inactive surface, wherein a visual color difference (ΔE) between the shielding layer and the active surface is within a maximum of 10 color difference units; wherein each of the active surfaces is a solar cell sheet, each of the inactive surfaces is a busbar, the busbars function as metal electrodes within the power module and facilitate external circuit connections, and the visual color difference (ΔE) between the shielding layer and the solar cell sheet as viewed from a direction towards the display module does not exceed a maximum of 10 color difference units.
7. The self-powered display device according to claim 6, wherein the display module is a cholesteric liquid crystal display module, the power module is a solar cell module, the cholesteric liquid crystal display module enables light beams to enter the solar cell module from its front side,

the solar cell module then converts the received light beams into electricity, which is used to provide electrical energy to the cholesteric liquid crystal display module so as to power the display to show at least one image.

8. The self-powered display device according to claim 6, wherein a protective layer positioned away from the shielding layer is applied to cover the busbar, and comes into contact with the solar cell sheet.

9. The self-powered display device according to claim 6, wherein the shielding layer is made of dark ink or adhesive tape.

10. The self-powered display device according to claim 6, wherein the power module further comprises a transparent substrate positioned between the electrode layer and the display module.

11. The self-powered display device according to claim 6, wherein the visual color difference (ΔE) is defined within a framework of a CIELAB color space, as established by an International Commission on Illumination (CIE) in 1976.
