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(54) **ULTRAVIOLET DETECTOR AND DOSIMETER**

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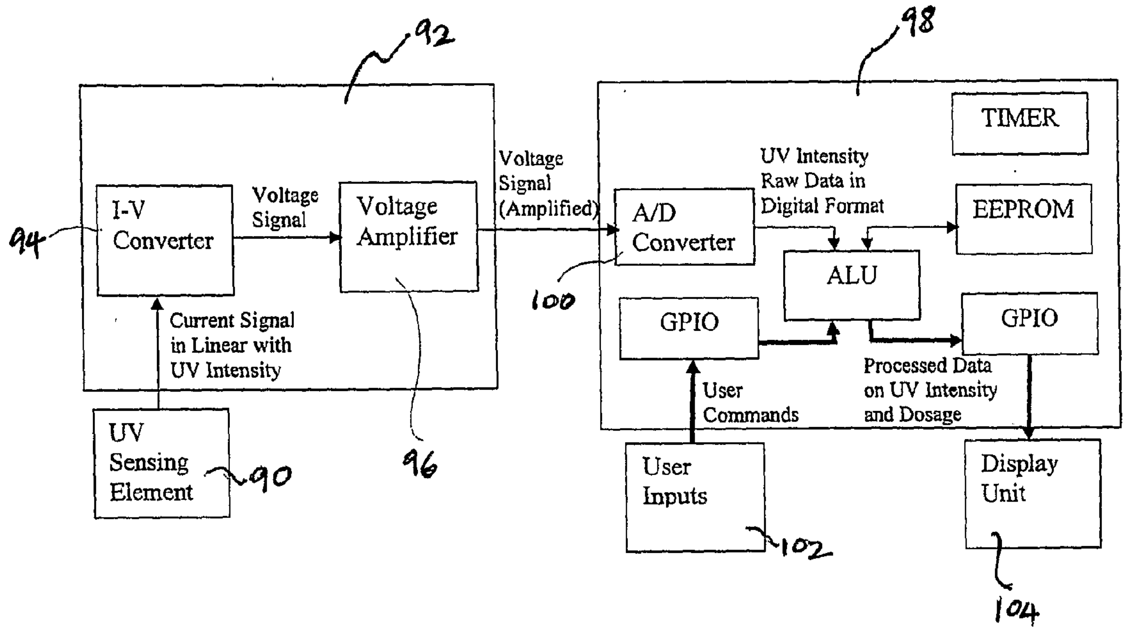
(57) **ABSTRACT**

A UV light detector is disclosed that has a UV sensing element comprising a substrate and a thin film layer formed on the substrate. The thin film layer is for receiving and converting UV light into electricity for a photovoltaic output. First and second electrodes are formed on one surface of the thin film layer and are configured to form an electric polarization in the thin film layer between the first and second electrodes and to collect the photovoltaic output. There is also an amplifier and an output display. The UV sensing element is configured to collect the photovoltaic output, the amplifier being configured to receive the photovoltaic output from the UV sensing element, the output display being configured to provide a display when UV light is received at the one surface, the display being derived from the photovoltaic output. A UV dosimeter is also disclosed.



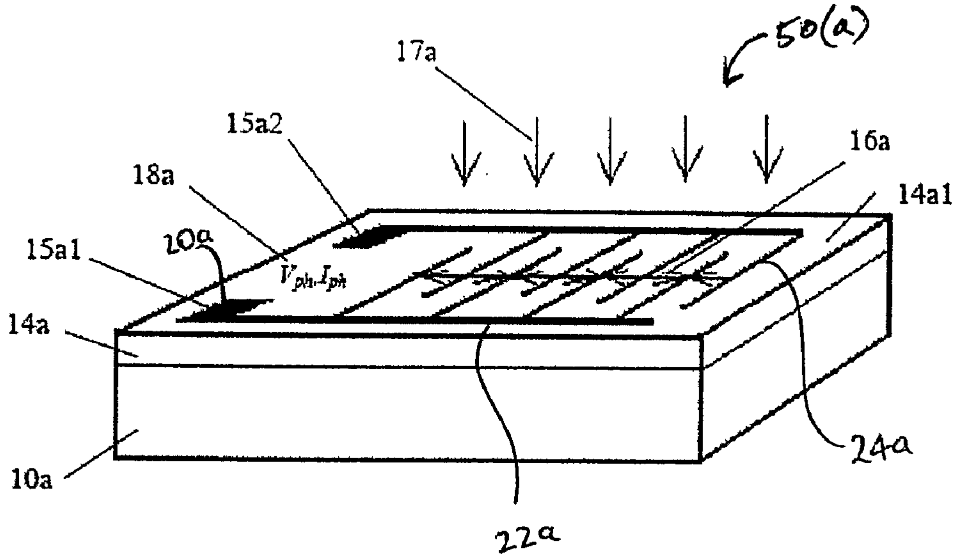


Figure 1(a)

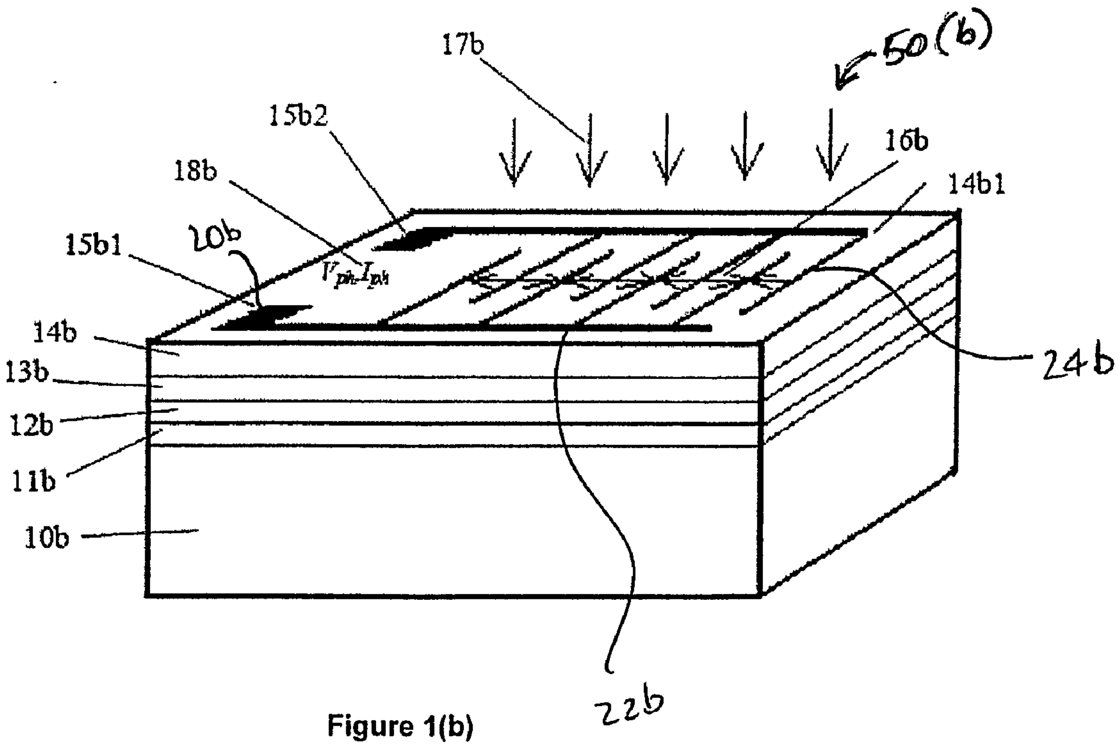


Figure 1(b)

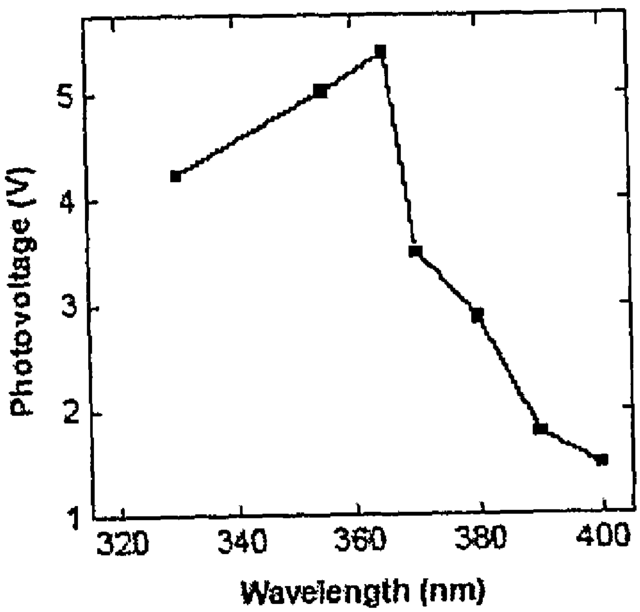


Figure 2

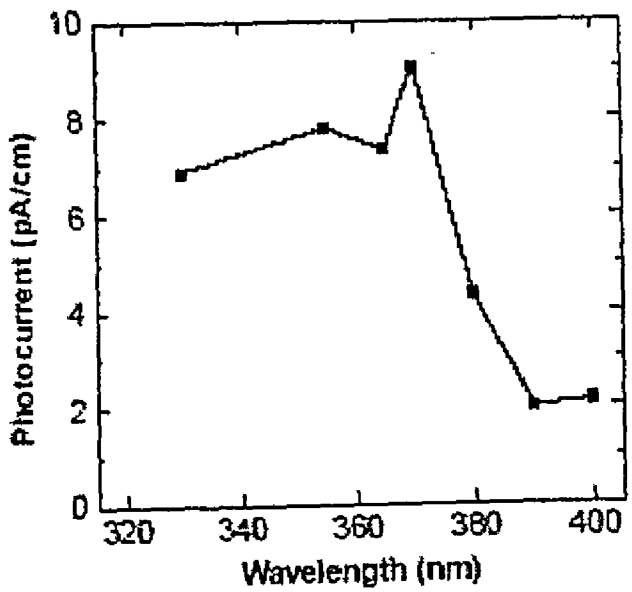


Figure 3

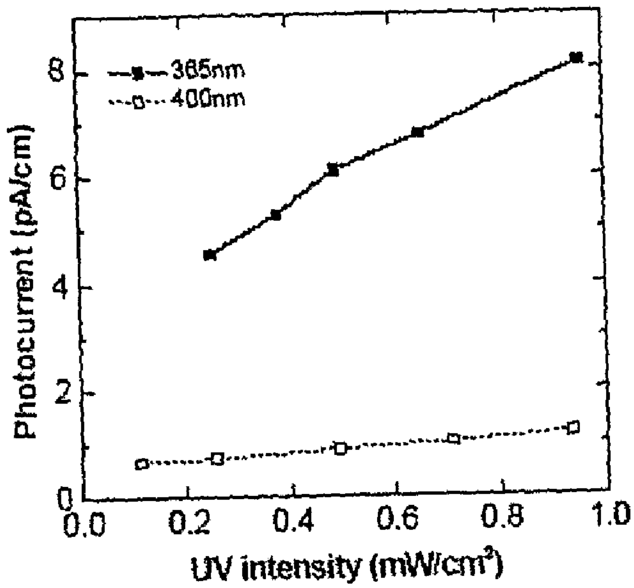


Figure 4

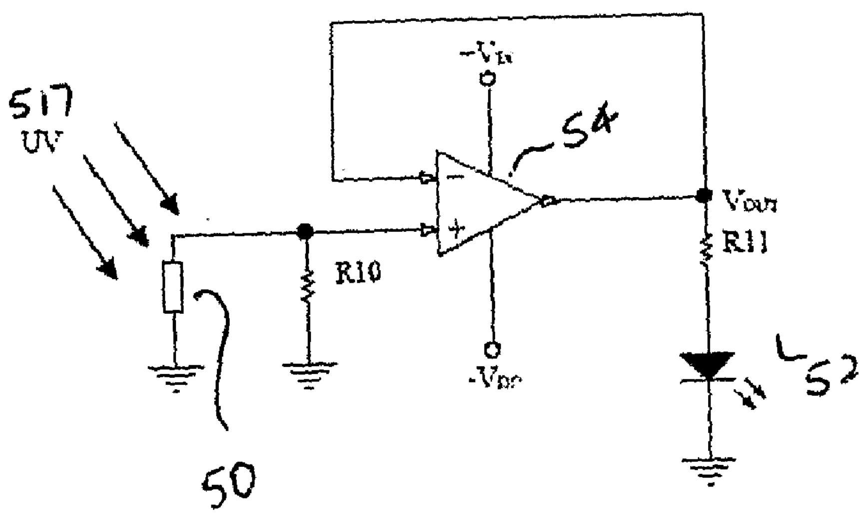


Figure 5

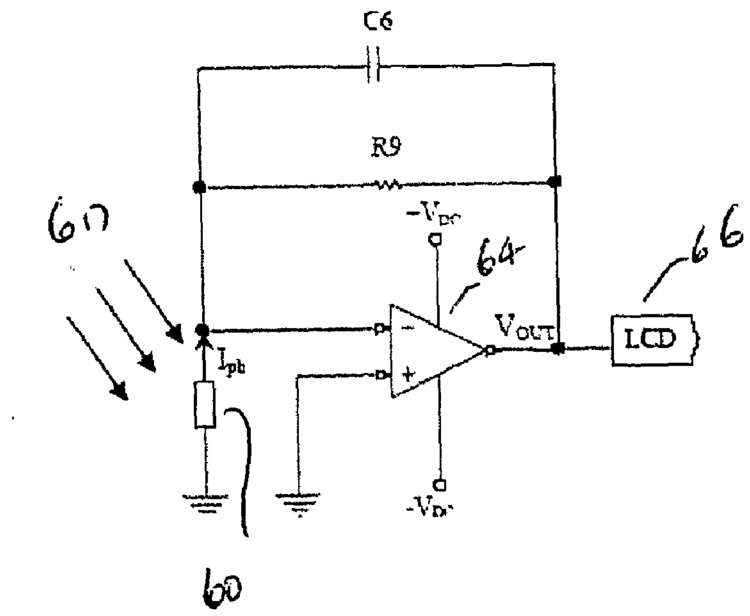


Figure 6

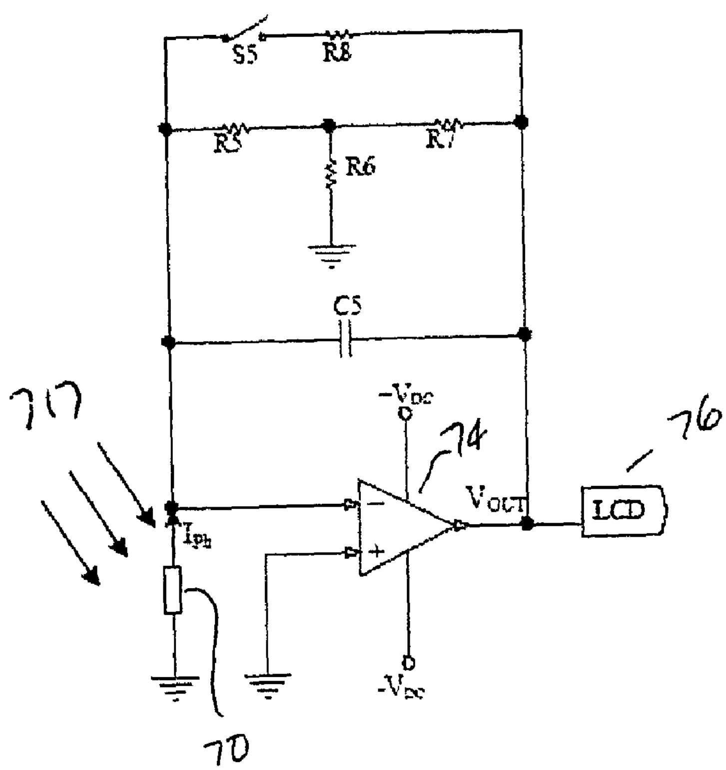


Figure 7

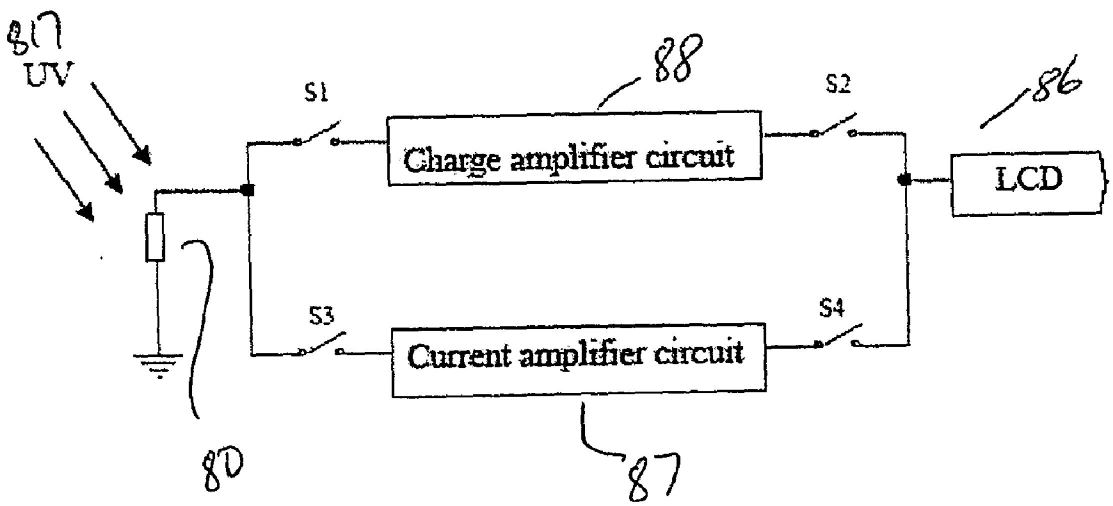

817
UV
S1
88
S2
86
Charge amplifier circuit
LCD
S3
S4
Current amplifier circuit
80
87

Figure 8

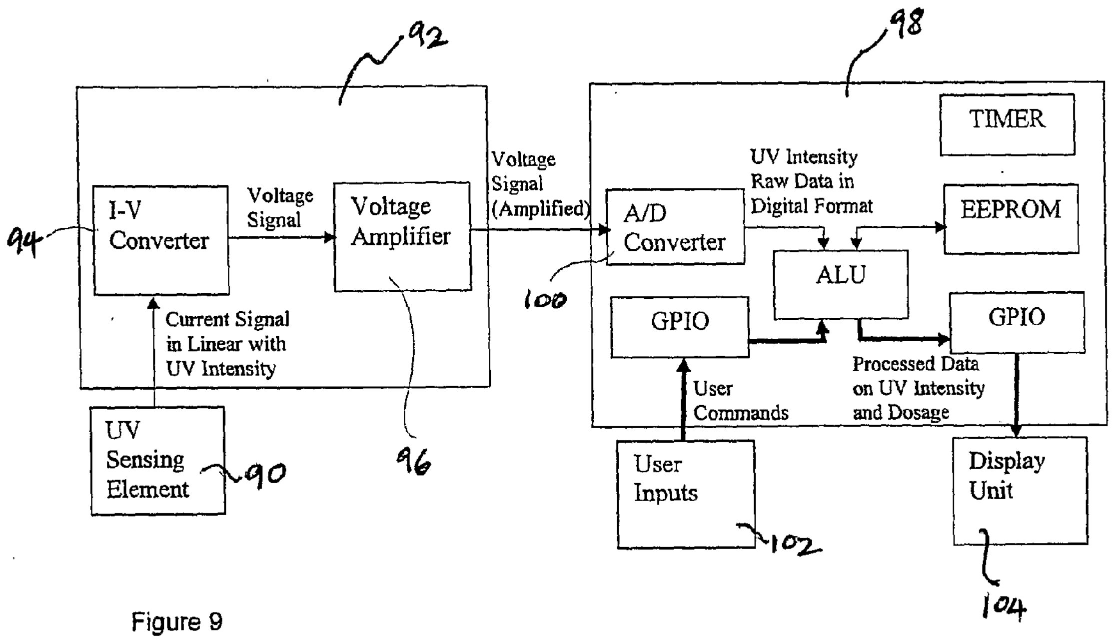


Figure 9

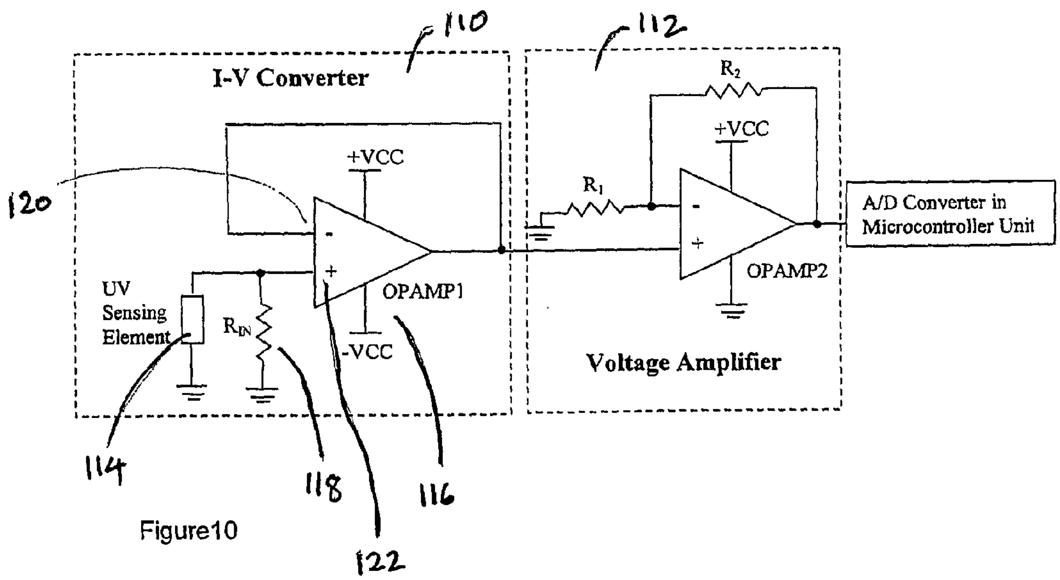


Figure10

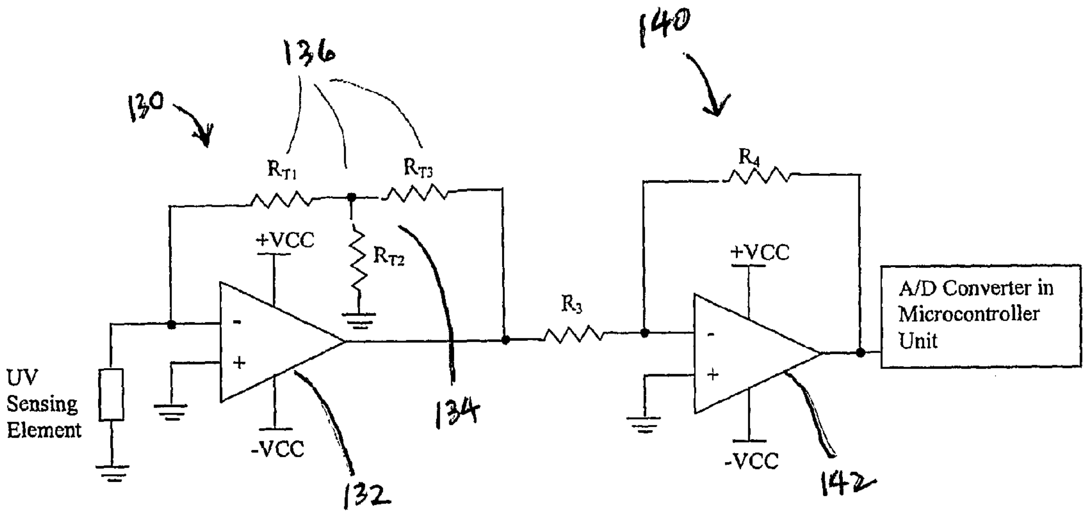


Figure 11

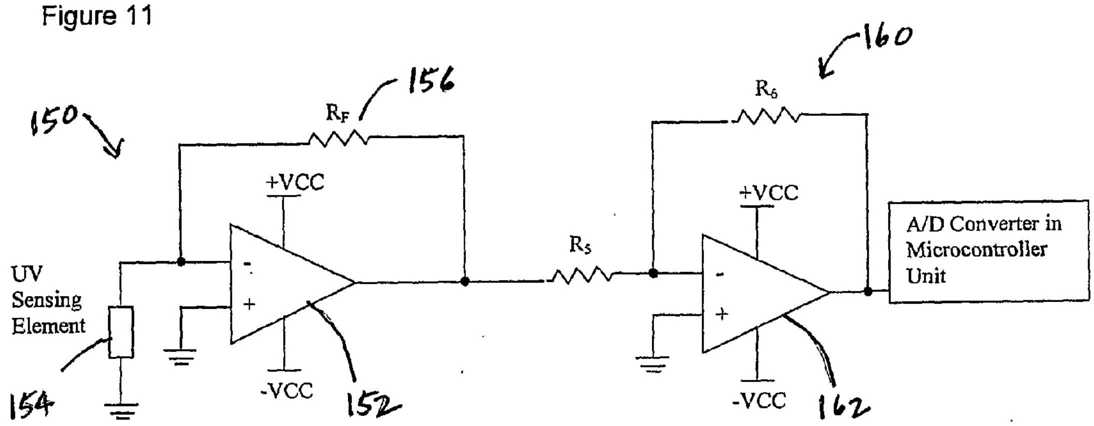


Figure 12

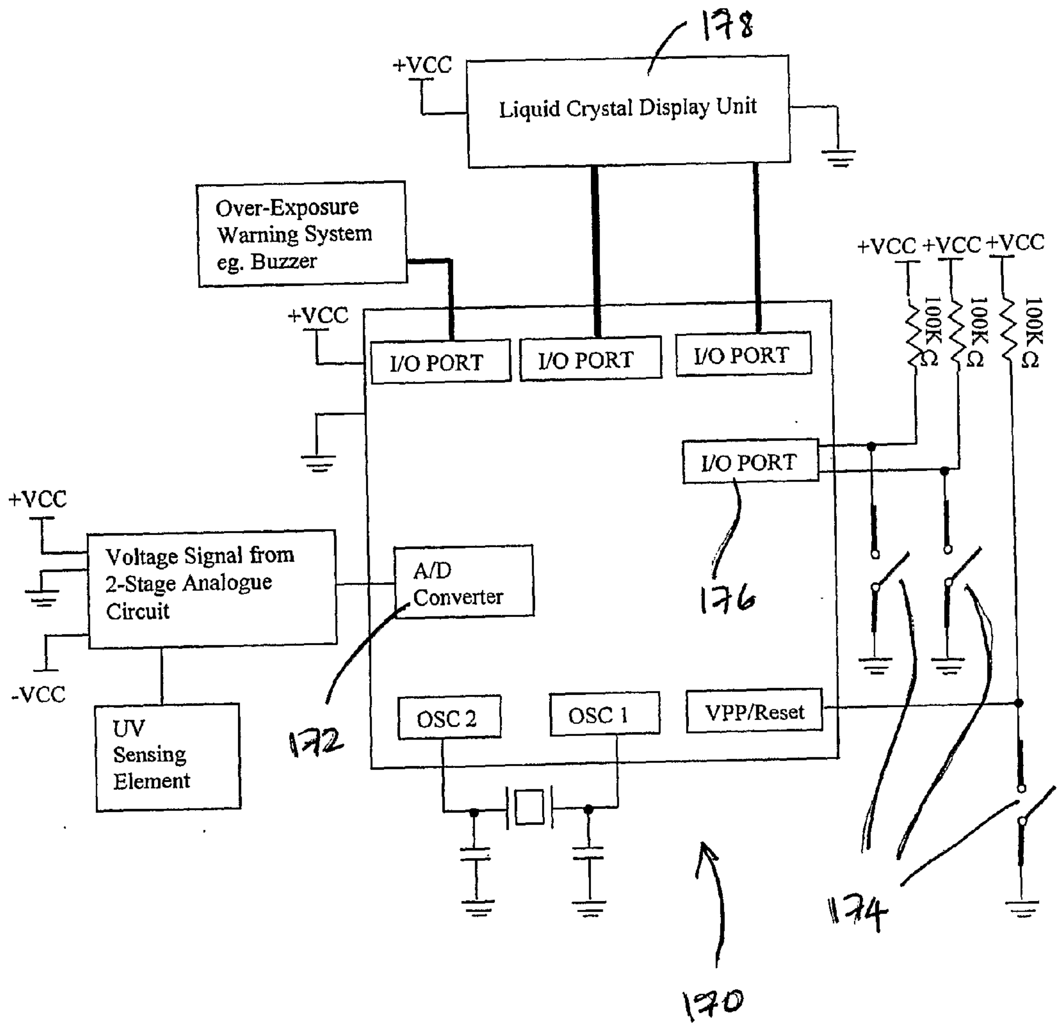

178
+VCC
Liquid Crystal Display Unit
Over-Exposure Warning System eg. Buzzer
+VCC +VCC +VCC
+VCC
I/O PORT
I/O PORT
I/O PORT
100K Ω
100K Ω
100K Ω
I/O PORT
+VCC
Voltage Signal from 2-Stage Analogue Circuit
A/D Converter
176
-VCC
172
UV Sensing Element
OSC 2
OSC 1
VPP/Reset
174
170

Figure 13

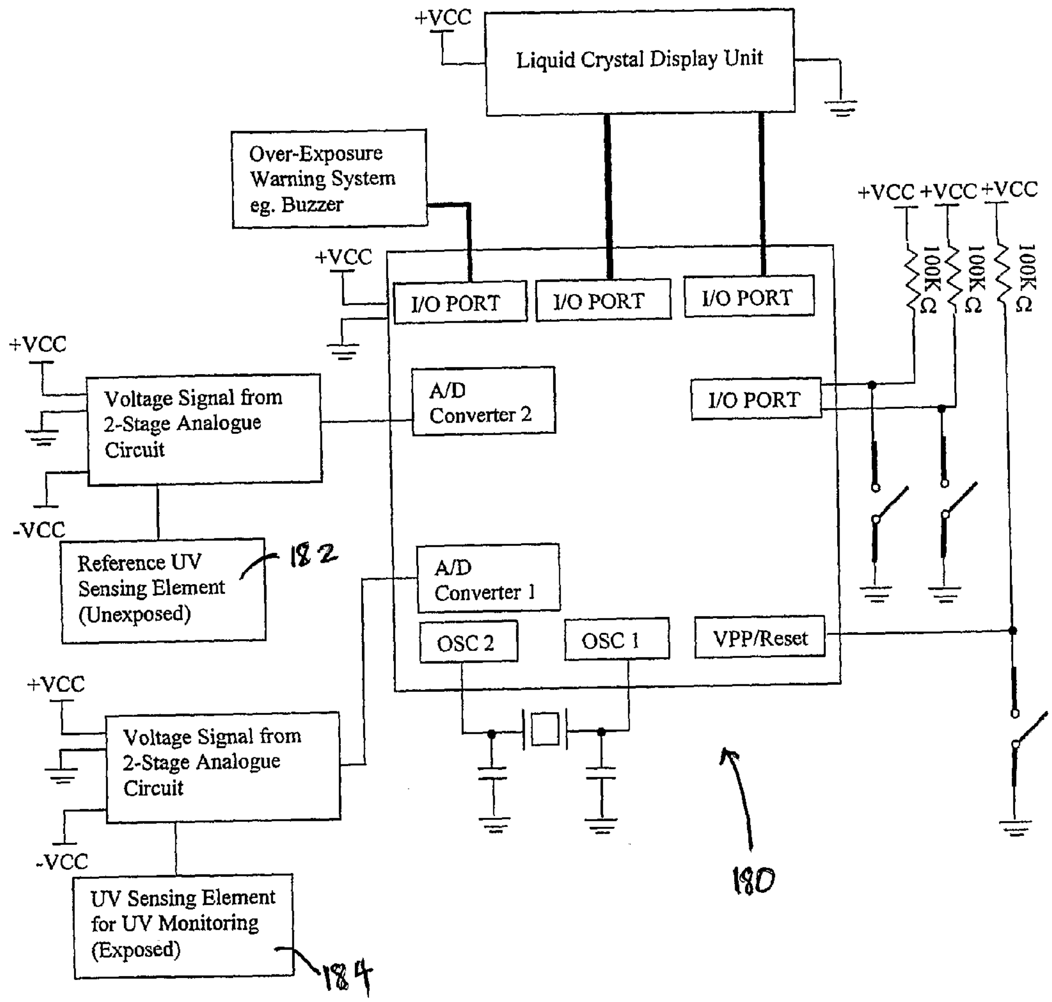

+VCC
Liquid Crystal Display Unit
Over-Exposure Warning System eg. Buzzer
+VCC
+VCC +VCC +VCC
100K Ω
100K Ω
100K Ω
I/O PORT
I/O PORT
I/O PORT
+VCC
Voltage Signal from 2-Stage Analogue Circuit
A/D Converter 2
I/O PORT
-VCC
Reference UV Sensing Element (Unexposed)
182
A/D Converter 1
OSC 2
OSC 1
VPP/Reset
+VCC
Voltage Signal from 2-Stage Analogue Circuit
-VCC
UV Sensing Element for UV Monitoring (Exposed)
184
180

Figure 14

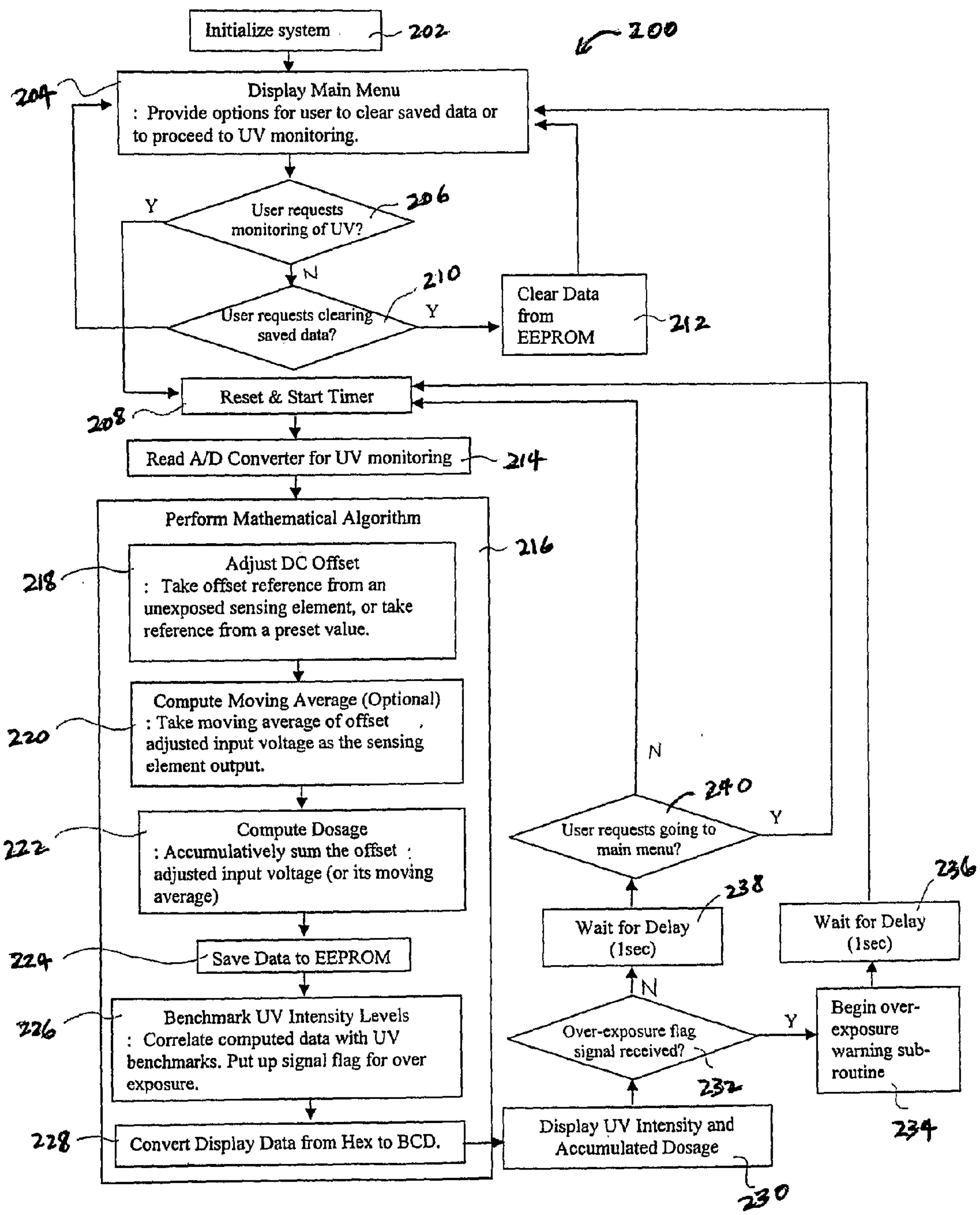

Initialize system
202
200
Display Main Menu
: Provide options for user to clear saved data or to proceed to UV monitoring.
204
User requests monitoring of UV?
206
Y
N
User requests clearing saved data?
210
Y
Clear Data from EEPROM
212
Reset & Start Timer
208
Read A/D Converter for UV monitoring
214
Perform Mathematical Algorithm
216
Adjust DC Offset
: Take offset reference from an unexposed sensing element, or take reference from a preset value.
218
Compute Moving Average (Optional)
: Take moving average of offset adjusted input voltage as the sensing element output.
220
Compute Dosage
: Accumulatively sum the offset adjusted input voltage (or its moving average)
222
Save Data to EEPROM
224
Benchmark UV Intensity Levels
: Correlate computed data with UV benchmarks. Put up signal flag for over exposure.
226
Convert Display Data from Hex to BCD.
228
Display UV Intensity and Accumulated Dosage
230
Over-exposure flag signal received?
232
N
Y
Wait for Delay (1sec)
238
User requests going to main menu?
240
N
Y
Begin over-exposure warning sub-routine
234
Wait for Delay (1sec)
236

Figure 15

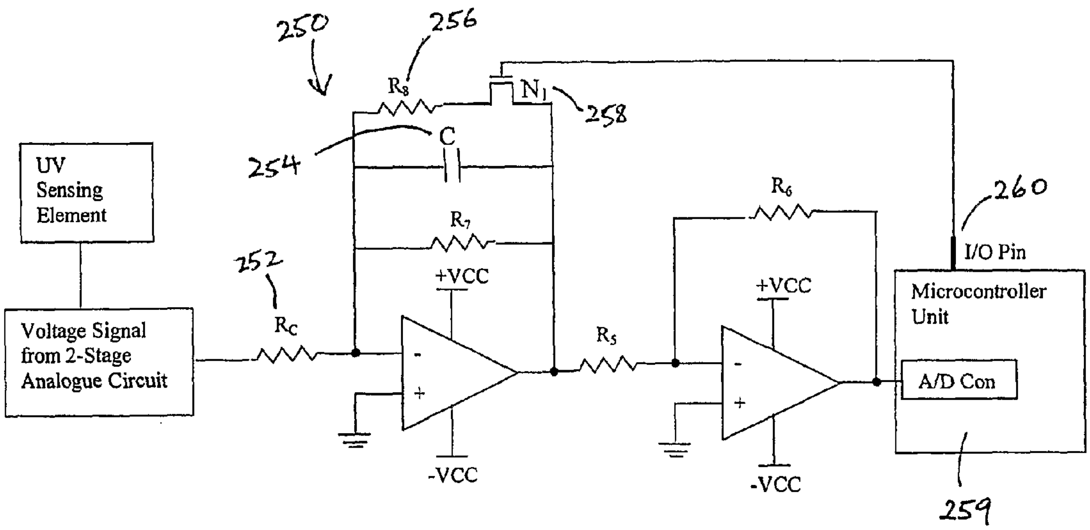


Figure 16

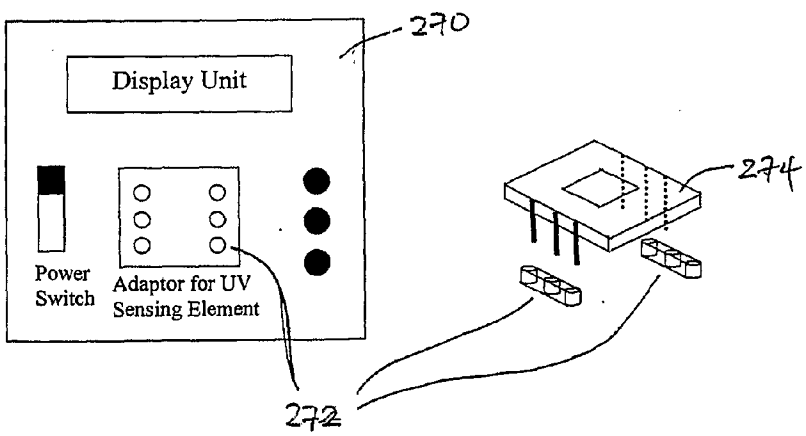


Figure 17

ULTRAVIOLET DETECTOR AND DOSIMETER

REFERENCE TO RELATED APPLICATION

[0001] Reference is made to our earlier U.S. patent application Ser. No. 11/386,295 filed 21 Mar. 2006 for an invention titled "Thin Film Photovoltaic Device" published on 28 Sep. 2006 as US2006/0213549 (our "earlier application"), the contents of which are hereby incorporated by reference as if disclosed herein in their entirety.

TECHNICAL FIELD

[0002] This invention relates to an ultraviolet (UV) detector and dosimeter and refers particularly, though not exclusively, to an ultraviolet detector and dosimeter using a photovoltaic thin film as a sensing element.

BACKGROUND

[0003] Ultraviolet ("UV") light in solar radiation has pronounced effects on human health. UV radiation is subdivided according to wavelength into UV-A (320 to 400 nm), UV-B (290 to 320 nm), and UV-C (200 to 290 nm). Usually, only UV-A and UV-B can penetrate the atmosphere and reach the surface of the earth. UV-A is responsible for tanning, and plays a role in skin cancer. It is also the cause of eye cataracts, solar retinitis and corneal dystrophies. UV-B is considered to be the cause of skin cancer in humans. In addition, the interaction between UV-A and UV-B radiation may have a synergistic skin-cancer causing-effect. This combination is a cause of skin aging and wrinkling.

[0004] According to information provided by the World Health Organization, about 2 to 3 million non-melanoma skin cancers and approximately 130,000 malignant melanomas occur globally each year. This substantially contributes to the mortality rate in the fair-skinned population. About 12 to 15 million people worldwide become blind from cataracts annually, of which up to 20% may be caused or enhanced by sun exposure.

[0005] With reduction of the stratospheric ozone layer through anthropogenic influence, the problems of UV effects on human health may become even more severe. Nevertheless, small amount of UV is beneficial, and is essential in the production of Vitamin D. In addition, because skin type and health condition vary between individuals, UV exposure levels that may cause significant damage to one person may be benign and even beneficial to another. Therefore, it is necessary to monitor and manage UV exposure for individuals. In view of this, the use of personal portable UV detectors is of advantage, particularly for those whose skin or eyes are more liable to damage under UV light.

[0006] Among existing UV detectors, photon detectors are commonly utilized at UV wavelengths due to their greater sensitivity. UV photon detectors have traditionally been divided into two distinct classes: photographic and photoelectric. Due to the quantitative measurement capability, semiconductor photoelectric detectors are competitive for personal healthcare applications. Semiconductors with a large band-gap, such as GaN, AlN, and SiC, have been explored for UV detection. However, detectors made out of these materials, or combinations of them, are usually obtained via expensive deposition methods in a vacuum chamber. Methods such as, for example, metal organic chemical vapor deposition (MOCVD) or molecular beam epitaxy (MBE) may be used. As semiconductors with a relatively small band-gap, such as Si, are also sensitive to longer wavelength light than UV, a low pass filter that only allows UV light to pass is needed, which is costly and makes the device structure more complicated. In addition, such filters usually have a poor transparency for UV light wavelengths that are dangerous to human health.

[0007] Semiconductor photovoltaic effects, which are based on a p-n junction or Schottky barrier, can only produce a photo-voltage typically below one volt. UV sensors using the photovoltaic effect in a ferroelectric thin film cannot generate a larger voltage due to the small thickness of the ferroelectric thin film and its constraint on the voltage. The small voltage limits the ability of the photovoltaic element to drive the circuit.

[0008] In UV sensors, UV light must penetrate at least one metal layer or a semiconductor layer. For example, UV light needs to pass through the top electrode layer in a ferroelectric thin film with sandwiched top and bottom electrodes; or the metal layer in a Schottky barrier; or one of the semiconductor layers in a p-n junction. As metal electrodes, including so-called transparent electrodes, do not have a satisfactory transparency for UV light in the wavelengths that are dangerous to human health, UV energy loss is significant due to the penetration of the top electrode layers. The dependence of the transparency on the UV wavelength, and incidence angle for any layers at the top of the photovoltaic region, also cause the spectrum as received to be changed. Also, the acceptance angle is narrow.

SUMMARY

[0009] According to an exemplary aspect, there is provided a UV light detector comprising a UV sensing element comprising a substrate and a thin film layer formed on the substrate. The thin film layer is for receiving and converting UV light into electricity for a photovoltaic output. First and second electrodes are formed on one surface of the thin film layer and are configured to form an electric polarization in the thin film layer between the first and second electrodes and to collect the photovoltaic output. There is also an amplifier and an output display. The UV sensing element is configured to collect the photovoltaic output, the amplifier being configured to receive the photovoltaic output from the UV sensing element, the output display being configured to provide a display when UV light is received at the one surface, the display being derived from the photovoltaic output.

[0010] According to another exemplary aspect there is provided a UV light dosimeter comprising a UV sensing element comprising a substrate and a thin film layer formed on the substrate. The thin film layer is for receiving and converting UV light into electricity for a photovoltaic output. First and second electrodes are formed on one surface of the thin film layer and are configured to form an electric polarization in the thin film layer between the first and second electrodes and to collect the photovoltaic output. There is also an amplifier, a capacitor for storing the photovoltaic output, a memory, and an output display. The output display is configured to provide a display representing the stored photovoltaic output in the capacitor and the information in the memory.

[0011] For both aspects, the first electrode and the second electrode form a pair of interdigital electrodes. The thin film layer may be a ferroelectric thin film. The output display may be one of: an LED and an LCD.

[0012] The UV detector may further comprise a first resistor in parallel with the UV sensing element. The UV detector may further comprise a second resistor in series with the output display and being configured to control a voltage magnitude to activate the output display.

[0013] The output display may be controlled by at least one of: photo-current magnitude and photo-voltage magnitude. The amplifier may be configured to convert the photo-current to an output voltage. The amplifier may be configured to convert the photo-voltage to an output voltage. The amplifier may be a voltage measurement unit without resistive gain in the output voltage.

[0014] The UV light detector may be a UV dosimeter for showing an accumulated dosage of UV light received at the one surface. The UV light detector may further comprise a capacitor configured to store photo-current. The output voltage of the amplifier may be an accumulated voltage of the capacitor during UV light radiation on the thin film. The amplifier may be a current integrator. A plurality of resistors may be in parallel with the capacitor for regulating a charging response speed of the capacitor. The UV light detector may further comprise a further resistor and a switch.

[0015] Voltage or current output from the UV sensor can be input to a microcontroller for computation of the actual UV radiation and the results may be shown in the display unit. The microcontroller is used to digitize analog voltage output from UV sensor. Computed parameters include a moving average of the input in real times, accumulative summing of the input over a period of times and making adjustments to eliminate any DC offset on the input voltage that may arise due to ambient disturbances. In addition, the microcontroller may store the gathered data on UV exposure in an internal or external memory storage device for future reference.

[0016] To obtain a highly accurate measurement of the actual UV exposure level, the microcontroller may also compensate for effects of temperature and other ambient disturbances by using output from an identical but unexposed UV sensing element as a baseline reference in the computation.

[0017] The UV detector may provide a user with flexibility by allowing changing of the sensing elements in applications where the UV sensor elements are to be used in a disposable manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments, the description being with reference to the accompanying illustrative drawings.

[0019] In the drawings:

[0020] FIG. **1**(*a*) is an illustration of a photovoltaic device according to our earlier application for use as a UV sensing element;

[0021] FIG. **1**(*b*) is an illustration of another photovoltaic device according to our earlier application for use as a UV sensing element;

[0022] FIG. **2** is a graph showing photo-voltage vs. UV wavelength of light for the sensing element of FIG. **1**(*b*);

[0023] FIG. **3** is a graph of photocurrent vs. UV wavelength of light for the sensing element of FIG. **1**(*b*);

[0024] FIG. **4** is a graph of photocurrent vs. UV intensity at wavelengths of light of 365 nm and 400 nm for the sensing element of FIG. **1**(*b*);

[0025] FIG. **5** is an illustration of an exemplary circuit design using the sensing element of FIG. **1**(*a*) or FIG. **1**(*b*) with an LED as a output display;

[0026] FIG. **6** is an illustration of another exemplary circuit design using the sensing element of FIG. **1**(*a*) or FIG. **1**(*b*) with an LCD as the output display;

[0027] FIG. **7** is an illustration of a further exemplary circuit design using the sensing element of FIG. **1**(*a*) or FIG. **1**(*b*) to display accumulated UV radiation and therefore that functions as a UV dosimeter;

[0028] FIG. **8** is an illustration of a block diagram illustrating switching between UV sensor and dosimeter functionality;

[0029] FIG. **9** is an exemplary embodiment of a UV detector with a two-stage analogue signal processing circuit and microcontroller;

[0030] FIG. **10** is a preferred embodiment of the two-stage analog circuit of FIG. **9** for detection and amplification of UV sensor signal prior to microcontroller processing;

[0031] FIG. **11** is an alternative embodiment of the two-stage analogue circuit comprising an I-V converter circuit adopting a T-Network configuration at the negative feedback loop and a voltage amplifier with negative configuration;

[0032] FIG. **12** is an alternative embodiment of the two-stage analog circuit comprising an I-V converter with a single feedback resistor and a voltage amplifier with negative configuration;

[0033] FIG. **13** is an exemplary embodiment of a microcontroller in the UV detector;

[0034] FIG. **14** is an exemplary embodiment of a microcontroller system in the UV detector designed to take a reading of an unexposed UV sensing element as a baseline reference;

[0035] FIG. **15** is a process flowchart illustrating the operation of the microcontroller;

[0036] FIG. **16** is an exemplary embodiment of an analogue integrator circuit that accumulates the charge supplied by a two-stage analogue circuit prior to microcontroller processing; and

[0037] FIG. **17** is an exemplary embodiment of a UV detector featuring a detachable UV sensing element.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0038] The UV detectors in the exemplary embodiments have a thin film sensor as described in our earlier application as the sensing element. The thin film is preferably a ferroelectric thin film.

[0039] To first refer to FIGS. **1**(*a*) and **1**(*b*) there is shown two photovoltaic devices **50**(*a*) and **50**(*b*) respectively, both being according to our earlier application and both being for use as UV light sensing elements. Each sensing element **50**(*a*) and (*b*) has a thin film layer **14***a* and **14***b* of a ferroelectric material formed on a substrate **10***a* and **10***b* respectively. In the exemplary embodiment of FIG. **1**(*a*), one pair of electrodes, comprising first electrode **15***a***1** and second electrode **15***a***2**, is formed on the ferroelectric thin film **14***a* and disposed apart from each other on the top surface **14***a***1** of the ferroelectric thin film layer **14***a*. In this embodiment, electrodes **15***a***1** and **15***a***2** form a pair of interdigital electrodes.

[0040] As such, the total current output between electrodes **15***a***1** and **15***a***2** is the collective value of the current between each pair of electrode fingers **24***a*. An electric field is applied at the terminals **20***a* and thus between electrodes **15***a***1** and **15***a***2** to polarize the ferroelectric thin film layer **14***a* between the electrodes **15**a**1** and **15**a**2**. Preferably, polarization of the ferroelectric thin film layer **14**a is parallel to a surface of the thin film layer between the electrodes **15**a**1** and **15**a**2**. Alternately, the thin film layer **14**a could be made of a polar material such as ZnO, ZnS, AlN, GaN, with electrical polarization existing between the electrodes **15**a**1** and **15**a**2** without poling by applying an electric field.

[0041] According to this embodiment, when a beam of UV light **17**a illuminates the top surface **14**a**1** of the ferroelectric thin film layer **14**a, a photo induced electric signal **18**a (i.e. V_{ph} and I_{ph}) is generated between electrodes **15**a**1** and **15**a**2**. The photovoltage able to be produced by this exemplary embodiment is not limited by one or more of: an energy barrier height of a p-n junction, and a Schottky barrier, as happens in semiconductor UV sensing elements. In this exemplary embodiment, the ferroelectric thin film layer **14**a of the UV sensing element is exposed directly to light. This prevents light loss due to the light having to penetrate a top electrode layer.

[0042] The photovoltaic properties of the UV sensing element according to the exemplary embodiment were investigated under UV illumination with a mercury xenon lamp. The UV intensity was determined with a power meter calibrated at different wavelengths.

[0043] The dependences of photo-voltage and photocurrent on wavelength of light for the UV sensing element in FIG. **1**(*b*) are shown in FIGS. **2** and **3**, respectively. The light intensity was **0**.**38** mW/cm^2. FIG. **2** shows a photovoltage greater than 5 V, which is significantly large than that of a semiconductor photovoltaic element which is typically less than 1 V. The photo-current as shown in FIG. **3** is the current generated per unit length of the electrode fingers **24**b in the interdigital electrodes **15**b**1** and **15**b**2**. The results show that the UV sensing element has a photovoltaic response to UV light at a wavelength below 400 nm. The maximum photo-voltage and photo-current are observed at a wavelength of 365 nm, which corresponds to the energy bandgap of PLWZT.

[0044] FIG. **4** shows the UV intensity dependence of photocurrent at wavelength of 365 nm and 400 nm. The photocurrent of the UV sensing element is substantially linearly proportional to UV intensity. The photocurrent as shown in FIG. **4** is the current generated per unit length of the electrode fingers **24**b in the interdigital electrodes **15**b**1** and **15**b**2**.

[0045] UV light radiation may be detected and displayed with UV detectors as disclosed below on the basis of the electrical output from the UV sensing element.

[0046] FIG. **5** shows a UV detector comprising the UV sensing element **50** and an LED **52** as the output display device to indicate the presence of UV radiation **517**. The amplifier **54** functions as a voltage measurement unit without resistive gain in the output voltage. A large resistor R**10** is in parallel with the UV sensor element **50** to improve the stability of the input voltage to the amplifier **54**. Another resistor R**11** in series with the LED **52** is chosen on the basis of the voltage magnitude required to activate the LED **52**. With UV light **517** illuminating the UV sensing element **50**, a voltage will be generated and thus the LED **52** is activated to indicate the presence of UV light **517**.

[0047] FIG. **6** shows another UV detector comprising the UV sensing element **60** and an LCD **66** as the output display device to indicate the intensity of UV light **617**. The amplifier **64** is preferably a sensitive and low input current operational amplifier. It serves as a high impedance electrometer by allowing the current to flow into the resistor R**9**. The output voltage V_{out} from the amplifier reflects the photocurrent I_{ph} in the UV sensing element **60** according to a simple relationship: $V_{out}=-I_{ph}\times R9$. As I_{ph} is proportional to the intensity of UV light **617** and the value displayed on the LCD **66** is proportional to V_{out}, the digits on the LCD **66** indicate the intensity of UV light **617**. The sensitivity of the photocurrent detector can be adjusted by the resistance value of R**9**. A capacitance C**6** is optionally connected in parallel with R**9** to stabilize the circuit characteristics.

[0048] FIG. **7** shows a further UV detector that can display the accumulated UV radiation, thereby functioning as a UV dosimeter. The amplifier **74** is preferably a sensitive and low input current operational amplifier. It serves as a current integrator with high input impedance by allowing the photocurrent I_{ph} to flow into the capacitor C**5**. The output voltage of the amplifier V_{out} reflects the cumulative charges at C**5**. In this case, the capacitor C**5** should be sufficiently large (e.g. 1 μF in the exemplary embodiment) to store the charge over a relatively long period. In parallel with C**5**, a combination of resistors R**5**, R**6** and R**7** is connected to regulate the charging response speed. As the effective resistance of the combination R**5**, R**6** and R**7** is high at approximately 1 GΩ and the discharge time is long, going into hours, a resistor R**8** of 1 kΩ together with a switch S**5** are optionally introduced as a discharge or reset for the UV dosimeter, whenever desired. Since the output voltage V_{out} of the amplifier is proportional to the charge stored in C**5**, and the charge in C**5** is proportional to the cumulative UV radiation, the digits displayed in the LCD **76** reflect the dosage of UV light **717** received by the UV sensing element **70**.

[0049] FIG. **8** is a general block diagram illustrating the switching between the sensor and dosimeter functions as shown in FIGS. **6** and **7**, respectively. As shown in FIG. **8**, the UV detector can detect both UV light **817** intensity and dosage with the one UV sensing element **80** and one output device, preferably an LCD **86**. The UV sensing element and LCD can be switched between the current amplifier **87** similar to that of FIG. **6**, and the charge amplifier **88** similar to that of FIG. **7**. As such the LCD **86** can alternately or simultaneously display UV light **817** intensity or dosage.

[0050] An exemplary embodiment of an improved UV detector is shown in FIG. **9**. The detector comprises a UV sensing element **90** connected to a two-stage operational amplifier circuit **92**. A current-to-voltage (I-V) converter **94** captures a current output in pico-nano amperes range from the UV sensing element **90** and translates the current output into a voltage output. The voltage output is channeled into a voltage amplifier **96** that amplified the output voltage, resulting in an amplified output. The amplified output is fed into a microcontroller **98** via an analog-to-digital converter **100** for signal processing. The microcontroller **98** can perform mathematical algorithms on the voltage input to compute an actual UV intensity and dosage. The microcontroller **98** is also configured to process commands input by a user via an input device **102**, and to display computed results on a display unit **104**. A preferred embodiment of the two-stage operational amplifier circuit (analogy circuit) in the UV detector is shown in FIG. **10**. The circuit comprises of an I-V converter **110** (similar to the circuit shown in FIG. **5**) as a primary stage and a voltage amplifier **112** as a secondary stage. In the I-V converter **110**, a UV sensing element **114** is connected at a positive input terminal of an operational amplifier **116** and in parallel with a high value resistor R_{IN} **118** with a preferred value of 100 mega-ohms. This provides current output from the UV sensing element **114** with a high impedance input for I-V conversion. Output voltage of the first stage operational amplifier **116** is directly connected to its negative input terminal **120** to form a negative feedback loop in order to achieve high stability for the output voltage. Upon exposure to UV light, the output current from the UV sensing element **114** is channeled into the resistor R_{IN} **118** and creates a voltage that linearly with the output current from the UV sensing element **114** at the positive input terminal **122** of the operational amplifier **116**. This voltage is reflected at the output of the operational amplifier **116** as $I_{ph} \cdot R_{IN}$. The operational amplifier **116** used for implementing the I-V converter **110** preferably has high precision and high input impedance characteristics. For the secondary stage, the operational amplifier adopts a positive configuration to boost the converted voltage output from the primary stage to a higher level.

[0051] FIG. **11** shows an alternative embodiment of the two-stage analog circuit in which the primary stage for I-V conversion **130** comprises an operational amplifier **132** adopting a T-network **134** at the negative feedback resistive loop to provide high gain for the UV sensing element output current. In the exemplary embodiment of FIG. **11**, values of the T-network resistors **136** can be 1 Giga-ohms, 100 K-ohms and 100 M-ohms for R_{T1}, R_{T2} and R_{T3} respectively. The operational amplifier **132** preferably has high precision and high impedance input characteristics. The secondary stage **140** operational amplifier **142** adopts a negative configuration so as to revert the negative voltage signal back to positive polarity before relaying to the microcontroller for processing.

[0052] FIG. **12** shows another alternative embodiment of a two-stage analog circuit in which the primary stage **150** operational amplifier **152** adopts a negative configuration for I-V conversion by receiving current output from a UV sensing element **154** at its negative input terminal. The output current from the UV sensing element **154** flows through a feedback resistor R_F **156** and produces a voltage of $-I_{ph}*R_F$ at the output of the operational amplifier **152**. In the exemplary embodiment in FIG. **12**, values of the feedback resistors R_F **156** can be 100 M-ohms and the operational amplifier **152** preferably has high precision and high impedance input characteristics. The secondary stage **160** operational amplifier **162** adopts a negative configuration so as to revert the voltage signal back to positive polarity before relaying to the microcontroller.

[0053] A preferred embodiment of the microcontroller **170** in the UV detector is shown in FIG. **13**. Voltage output from the two-stage analog circuit is input into the microcontroller via an analog to digital converter **172** which can be a built-in module in the microcontroller **170** or an external integrated circuit device. The analog to digital converter **172** translates input analog voltage into a digital format, based on which the microcontroller **170** computes the UV exposure. In the exemplary embodiment in FIG. **13**, the microcontroller **170** can also receive commands input by a user by means of switches **174** at an I/O port **176** of the microcontroller **170**. The microcontroller **170** can also send computed data to a display unit **178** such as an LCD to present the UV exposure information to the user.

[0054] An alternative embodiment of the microcontroller **180** is shown in FIG. **14**. The microcontroller **180** is configured to adjust for a DC offset level at the microcontroller input where exposure to UV light is being monitored. The DC offset level may arise from the two-stage analog circuits, temperature variations or other ambient noise. In order to cancel out the DC offset level, the microcontroller **180** takes a reading of an unexposed UV sensing element **182** as a baseline reference. The unexposed UV sensing element **182** should be identical to the UV sensing element **184** exposed for UV monitoring. Readings obtained from the exposed UV sensing element **184** for UV light monitoring are subtracted by the baseline reference level in order to yield a more accurate UV reading.

[0055] FIG. **15** is an exemplary process flowchart for the microcontroller. The process **200** comprises a series of events that may be executed by the microcontroller. Steps in the process are referenced with reference numerals in parentheses. To begin with, system initialization is performed (**202**). A main menu is then displayed (**204**) to provide a user with options to clear saved data from a previous session, or to proceed to UV monitoring. If the user decides to begin monitoring of UV (**206**), a timer is reset and started (**208**). If the user decides not to begin monitoring of UV, the user may request saved data to be cleared (**210**), whereupon data will be cleared from the EEPROM (**212**) and the process goes back to the step of displaying the main menu (**204**). When the timer has been reset and started at (**208**), an analog-to-digital converter is read (**214**) to obtain voltage readings from the output of the two-stage analog circuit.

[0056] The voltage readings are processed by a mathematical algorithm (**216**). The algorithm includes adjusting the DC offset (**218**) by taking an offset reference from an unexposed UV sensing element or taking reference from a preset value to result in an offset-adjusted input voltage. Optionally, a moving average (**220**) may be computed from the offset-adjusted input voltage as the output of the UV sensing element. The UV dosage is then computed (**222**) by accumulatively summing the offset-adjusted input voltage or its moving average. The UV dosage data is saved to EEPROM (**224**). Benchmarking of UV intensity levels (**226**) is performed by correlating computed data with UV benchmarks. A signal flag may be put up in case of over exposure. Display data is converted from Hex to BCD (**228**) and UV intensity and accumulated dosage is then displayed (**230**).

[0057] If an over-exposure flag signal was received (**232**), an over-exposure warning sub-routine is begun (**234**) and waiting for a delay of one second (**236**) takes place before looping back to resetting and starting the timer at (**203**). If no over-exposure flag was put up, wait for a delay of one second (**238**) also takes place. If a user requests going to the main menu (**240**), the process loops back to displaying the main menu (**204**). If no such request is made, the process loops back to resetting and starting the timer at (**208**). The process thus coordinates user interaction by checking for input by the user input at the I/O port periodically and activating specific events such as clearing data from EEPROM (**212**) upon a user's request.

[0058] FIG. **16** shows an exemplary embodiment of an analog integrator circuit **250** that can be added to the UV detector so as to accumulate the charge supplied by the two-stage analog circuit over a time frame in order to provide an output voltage linearly with the dosage of UV exposure prior to the microcontroller processing. In the integrator circuit **250**, a resistor R_C **252** and capacitor C **254** form a charging circuit over which the output voltage from the two-stage analog circuit can be accumulated gradually. In the exemplary embodiment, values of R_C and C may be as high as 10 K ohms and 100 uF respectively, so as to cater for a long charging duration before the integrator circuit **250** reaches saturation point. A resistor R_8 **256** and MOSFET switch N**1** **258** serves as a discharge path for the charging capacitor C **254**. Upon reading the output voltage of the integrator circuit **250** at every interval, the microcontroller **259** can switch on the MOSFET switch N**1** **258** via an I/O pin **260** so that the accumulated voltage at the output of the integrator circuit **250** can be reset to zero. The integrator circuit **250** reduces required CPU times of the microcontroller **259** effectively as the microcontroller **259** can sense the input for UV monitoring at a longer interval while the integrator circuit **250** consolidates the accumulated UV exposure dosage.

[0059] The UV detectors, in accordance with the above-described embodiments, are reliable, user-friendly, compact and cost-effective. They can be miniaturized into handheld portable UV detectors powered by batteries or solar cells. They may even be further miniaturized into pendant size so that the UV detector can be worn by the user. As shown in FIG. **17**, the UV detector **270** may provide the user with the flexibility of changing the UV sensing **274** element by having an adaptor **272** to hold the UV sensing element **274** and electrically connecting it with the UV detector **270**. In this way, the UV sensing element **274** may be used in a disposable manner. Alternatively, the UV detector may also be integrated into any consumer electronics such as a mobile-phone or wrist-watch.

[0060] A ferroelectric material typically has a wide energy bandgap, and generally does not exhibit photovoltaic response to long wavelength light above UV range. Therefore, in principle, no expensive low-pass filter with UV transparency is required.

[0061] Whilst the foregoing description has described exemplary embodiments, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention.

1-41. (canceled)

42. An ultraviolet light detector comprising:

an ultraviolet sensing element comprising a substrate and a thin film layer formed on the substrate wherein the thin film layer is for receiving and converting ultraviolet light having a wavelength between 330 nm and 370 nm into electricity for a photovoltaic output, and first and second electrodes formed on one surface of the thin film layer and being configured to collect the photovoltaic output and the thin film layer having an electric polarization between the first and second electrodes;

an amplifier; and

an output display;

the ultraviolet sensing element being configured to generate and collect the photovoltaic output, the amplifier being configured to receive and amplify the photovoltaic output from the ultraviolet sensing element, the output display being configured to provide a display when ultraviolet light is received at the one surface, the display being derived from the photovoltaic output.

43. The ultraviolet light detector as claimed in claim **42**, wherein the first electrode and the second electrode form a pair of interdigital electrodes.

44. The ultraviolet detector as claimed in claim **42**, wherein the thin film layer is a ferroelectric thin film.

45. The ultraviolet detector as claimed in claim **42**, wherein the electric polarization is parallel to a surface of the thin film layer between the first and second electrodes.

46. The ultraviolet detector as claimed in claim **44**, wherein polarization in the ferroelectric thin film is produced by applying an electric field to pole the thin film through the first and the second electrodes.

47. The ultraviolet detector as claimed in claim **42**, further comprising a first resistor in parallel with the ultraviolet sensing element and a second resistor in series with the output display and being configured to control a voltage magnitude to activate the output display.

48. The ultraviolet light detector as claimed in claim **42**, wherein the output display is controlled by at least one selected from the group consisting of: photocurrent magnitude and photo-voltage magnitude; and the amplifier is configured to convert one of: the photo-current to an output voltage, and the photo-voltage to an output voltage.

49. The ultraviolet light detector as claimed in claim **48**, wherein the amplifier is a voltage measurement unit without resistive gain in the output voltage.

50. The ultraviolet light detector as claimed in claim **48**, wherein the ultraviolet light detector is an ultraviolet dosimeter for showing an accumulated dosage of ultraviolet light received at the one surface.

51. The ultraviolet light detector as claimed in claim **50**, further comprising a capacitor configured to store photocurrent, the output voltage of the amplifier being an accumulated voltage of the capacitor during ultraviolet light radiation on the thin film;

and the amplifier is a current integrator.

52. The ultraviolet light detector as claimed in claim **51**, further comprising a plurality of resistors in parallel with the capacitor for realizing the current integrator function with the amplifier, and a further resistor and a switch.

53. The ultraviolet light detector as claimed in claim **42**, further comprising a microcontroller configured to perform computations on output of the amplifier to produce computed output, the amplifier comprising a two-stage analog circuit and amplified voltage from the amplifier is able to be input into the microcontroller.

54. The ultraviolet light detector as claimed in claim **53**, wherein a first stage of the two-stage analog circuit comprises a current-to-voltage converter in which current from the ultraviolet sensing element is channeled into a resistor connected between a positive input terminal of an operational amplifier and ground and output of the operational amplifier is channeled directly to a negative input terminal of the operational amplifier.

55. The ultraviolet light detector as claimed in claim **53**, wherein a first stage of the two-stage analog circuit comprises a current-to-voltage converter having a T-network configuration at a resistive feedback loop.

56. The ultraviolet light detector as claimed in claim **53**, wherein a first stage of the two-stage analog circuit comprises a current-to-voltage converter having a negative configuration in which output of a first operational amplifier is channeled to a negative input terminal of the first operational amplifier via a first resistor and into a negative input terminal of a second operational amplifier, and output of the second operational amplifier is channeled to the negative input terminal of the second operational amplifier via a second resistor.

57. The ultraviolet light detector as claimed in claim **53**, wherein the microcontroller is configured to execute an algorithm for cancelling a DC offset level arising from an ambient disturbance, the algorithm comprising using an output of an unexposed ultraviolet sensing element as a baseline reference.

58. The ultraviolet light detector as claimed in claim **53**, wherein the microcontroller is configured to execute an algorithm for cancelling a DC offset level arising from an ambient disturbance, the algorithm comprising subtracting a predetermined value from the output of the amplifier.

59. An ultraviolet light dosimeter comprising:

an ultraviolet sensing element comprising a substrate and a thin film layer formed on the substrate wherein the thin film layer is for receiving and converting ultraviolet light having a wavelength between 330 nm and 370 nm into electricity for a photovoltaic output, and

first and second electrodes formed on one surface of the thin film layer and being configured to collect the photovoltaic output and the thin film layer having an electric polarization between the first and second electrodes;

an amplifier; a capacitor for storing and accumulating the photovoltaic output; and

an output display; the output display being configured to provide a display representing the stored accumulated photovoltaic output in the capacitor.

60. The ultraviolet light dosimeter as claimed in claim **59**, wherein the output display is controlled by at least one selected from the group consisting of: photo-current magnitude and photo-voltage magnitude; and the amplifier is configured to convert one of: the photo-current to an output voltage, and the photo-voltage to an output voltage.

61. The ultraviolet light dosimeter as claimed in claim **60**, wherein the output voltage of the amplifier is accumulated voltage of the capacitor during ultraviolet light radiation on the thin film, the amplifier being a current integrator.

62. The ultraviolet light dosimeter as claimed in claim **59**, wherein a plurality of resistors are in parallel with the capacitor for realizing the current integrator function with the amplifier, and further include a resistor and a switch.

63. The ultraviolet light dosimeter as claimed in claim **59**, further comprising a microcontroller configured to perform computations on output of the amplifier to produce computed output.

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