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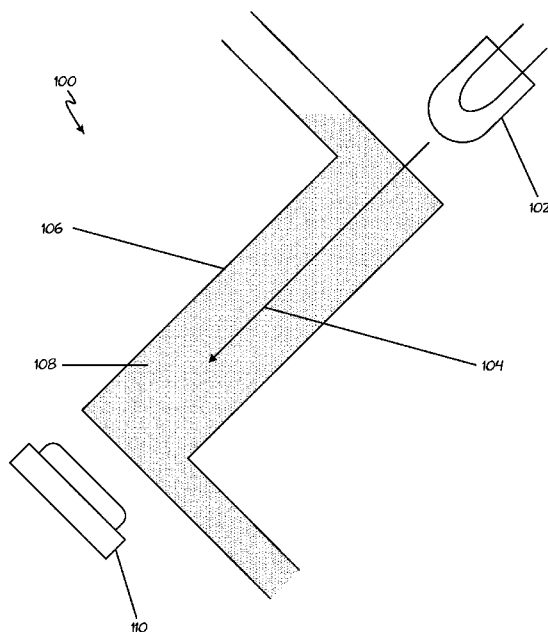


FIG. 1

(57) Abstract: A temperature-stabilized LED irradiance system (300) is provided. The system (300) includes an LED (302). A temperature sensor (306) is disposed to sense a temperature proximate the LED (302). Circuitry (308, 304) coupled to the temperature sensor (306) and the LED (302), is configured to adjust power to the LED (302) based on the sensed temperature.

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LED CONTINUOUS CONSTANT IRRADIANCE WITH TEMPERATURE VARIATION

BACKGROUND

[0001] Online wet chemistry analyzers are used in a variety of industries to provide a continuous indication of an analyte in a process sample. This continuous indication can be provided locally by the analyzer and/or remotely to one or more suitable devices in order to provide control and/or monitoring of a chemical process.

[0002] One particular type of online wet chemistry analyzer is an online silica analyzer. These devices are configured to generate a reaction in the process sample that allows an indication of silica in the sample to be determined. Such analyzers are useful in determining silica content in boiler water, boiler feedwater, demineralized water, and steam condensate. While such analyzers are useful in a variety of industries, they are of particular use in power plant boilers. In such systems, silica can form silicate deposits that can damage turbines and other generation equipment that is used in the water-steam turbine cycle. Accordingly, power plants with high pressure turbines generally monitor silica carefully in order to ensure effective detection and removal/remediation. One particular example of an online silica analyzer is sold under the trade designation Model CFA3030 Silica Analyzer from Rosemount Analytical, an Emerson Automation Solutions company.

[0003] An online silica analyzer will generally employ a known reaction to render the silica in the process sample readily detectable. One example of such a reaction is known as the molybdenum blue method. In the molybdenum blue method, molybdate (usually in the form of potassium molybdate) is used to react with silica in the process sample/solution in order to generate a compound suitable for colorimetric detection. In accordance with the molybdenum blue method, the silica content in water is measured based on the color of the silicomolybdic acid formed through the wet chemistry process.

SUMMARY

[0004] A temperature-stabilized LED irradiance system is provided. The system includes an LED. A temperature sensor is disposed to sense a temperature proximate the LED. Circuitry coupled to the temperature sensor and the LED, is configured to adjust power to the LED based on the sensed temperature.

[0005] These and various other features and advantages that characterize the claimed embodiments will become apparent upon reading the following detailed description and upon reviewing the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 illustrates a portion of a colorimetric analyzer in accordance with an embodiment of the present invention.

[0007] FIG. 2A is a chart illustrating irradiance versus temperature in accordance with an embodiment of the present invention.

[0008] FIG. 2B is a chart illustrating irradiance versus current in accordance with an embodiment of the present invention.

[0009] FIGS. 3A-B illustrate a LED circuits in accordance with an embodiment of the present invention.

[0010] FIG. 4 illustrates a flow diagram of a method for LED control in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0011] The present disclosure relates to a light emitting diode (LED) that maintains a constant irradiance during temperature variations. A variety of colorimetric wet chemistry analyzers employ LEDs in order to generate the light required for colorimetric measurements. LED's utilize electron flow across a p-n junction to generate light. When driven at a constant current, the irradiance of an LED is a function of the temperature of the environment of the LED, i.e., the temperature of the LED substrate (die). This is especially so as the LED emits light closer to the infra-red light (IR) spectrum. In many situations, these temperature-based variations in the irradiance may be acceptable to a user of the LED. However, in some applications, such as colorimetric analyzers, such variations can cause measurement errors.

[0012] When an LED is used as the light source for a colorimetric analyzer, the light intensity of the light source changes with the temperature of the environment where the analyzer is placed. The light absorbance A, is set forth in Equation 1, below:

$$A = -\log_{10}(I/I^0) \quad \text{Equation 1}$$

[0013] Where I is the measured light intensity when color has been developed after reactions, and I^0 is the measured light intensity before the color is developed. During operation of the wet chemistry analyzer, these two measurements of light intensity occur at different

times. If the ambient temperature changes during the process and if the LED is driven at a constant electric current, the calculation of the measured (I/I^0) will include an error caused by the irradiance dependency on temperature.

[0014] FIG. 1 illustrates a portion of a colorimetric analyzer in accordance with an embodiment of the present invention. Colorimeter analyzer 100 may be useful to analyze a liquid 108 located in photometric cell 106 by passing an illumination 104 through liquid 108. LED 102 generates illumination 104 which passes through liquid 108 and is detected by a photo sensor 110. Photo sensor 110 may be any sensor that detects a characteristic of light, including, but not limited to, a colorimeter, spectroradiometer, spectrophotometer, or densitometer.

[0015] In order for multiple measurements taken by colorimeter analyzer 100 to be compared, illumination 104 must be consistent. If there is variation in illumination 104 between measurements, the variation must be adjusted for or the comparison between measurements will be inaccurate. A problem with LED's is illustrated in FIG. 2A. Chart 200 has an X-axis 202 representing temperature and Y-axis 204 representing irradiance. Trend line 206 illustrates how as temperature of an LED increases, the irradiance of the LED decreases.

[0016] One solution to this problem would be to, if temperature changes, drain liquid 108 from photometric cell 106 and measure un-obstructed illumination 104, as a control value. Then, while maintaining the temperature, refill photometric cell 106 with liquid 108 and project illumination 104 through liquid 108 and measure an experimental value. The experimental value can then be adjusted by the control value. This is a viable solution but comes with the cost of draining-refilling and also increased likelihood of errors during adjusting measured values based on varying illumination 104 values.

[0017] A better solution is to, as temperature changes, ensure that the illumination 104 generated by LED 102 stays constant. Irradiance of an LED is determined by more than just temperature. FIG. 2B is a chart illustrating irradiance versus current in accordance with an embodiment of the present invention. Chart 250 has an X-axis 252 representing current and a Y-axis 254 representing irradiance. Trend line 256 illustrates how as current supplied to an LED increase, the irradiance of the LED increases. In order for an LED to maintain a constant irradiance in a varying temperature environment, it is possible to vary the current supplied to the LED. For example, as temperature increases, current will also have to increase to maintain a constant irradiance.

[0018] FIG. 3A illustrates an LED circuit in accordance with an embodiment of the present invention. LED circuit 300 comprises an LED 302, LED driver circuitry 304, feedback

circuitry 308 and temperature sensor 306. Temperature sensor 306 is disposed to sense the temperature proximate LED 302. Temperature sensor 306 can be any suitable structure that has an electrical characteristic that varies with temperature. Examples, include a resistance temperature detector (RTD), a thermocouple, a thermistor, etc. Temperature sensor 306, in one embodiment, may be coupled to the LED 302 die/substrate utilizing a heatsink.

[0019] Temperature sensor 306 is coupled to feedback circuitry 308, which provides a signal to LED driver circuitry 304. Feedback circuitry 308 and/or driver circuitry 304 can be embodied in any combination of digital or analog circuitry. For example, feedback circuitry 308 could be embodied using a microcontroller having an analog to digital converter that receives a signal from temperature sensor 306 and provides a digital indication of temperature. This digital indication can then be used by LED driver circuitry 304 to compute and adjust the power provided to LED 302, thereby controlling irradiance based on the measured temperature. In one embodiment, LED driver circuitry 304 and feedback circuitry 308 are components of a single circuitry.

[0020] While the embodiment shown in FIG. 3A illustrates temperature sensor 306 separate from LED 302, it is expressly contemplated that embodiments can be practiced where the temperature sensor is a part of LED 302 or disposed within the LED package. FIG. 3B illustrates an embodiment, wherein LED driver circuitry 304, feedback circuitry 308 and temperature sensor 306 are disposed within LED 302. However, any of these components may be separate from LED 302.

[0021] FIG. 4 illustrates a flow diagram of a method for LED control in accordance with an embodiment of the present invention. Irradiance stabilization 400 comprises three steps. At block 402, a temperature is measured proximate the LED. In one embodiment, the temperature measurement is taken within the LED.

[0022] At block 404, a power adjustment is calculated. The calculation of power adjustment uses the temperature measured in block 402 as an input. The calculation, in one embodiment, includes temperature vs irradiance data from the manufacturer. In another embodiment, the calculation comprises a temp-radiance constant multiplied by the measured temperature.

[0023] At block 406, the power to the LED is adjusted utilizing the calculation from block 404. The adjustment may be made can be by circuitry, embodied in any combination of digital and/or analog circuitry. After the power supplied to the LED is adjusted, the cycle may

repeat and the power supplied constantly adjusted to compensate for any change in temperature.

WHAT IS CLAIMED IS:

1. A temperature-stabilized LED irradiance system comprising:
an LED;
a temperature sensor disposed to sense a temperature proximate the LED; and
circuitry coupled to the temperature sensor and the LED, wherein the circuitry is configured to adjust power to the LED based on the sensed temperature.
2. The temperature-stabilized LED irradiance system of claim 1, wherein the LED is an illumination source in a colorimetric analyzer.
3. The temperature-stabilized LED irradiance system of claim 1, wherein the irradiance of the LED is kept constant by continuously controlling the LED power.
4. The temperature-stabilized LED irradiance system of claim 1, wherein power is adjusted by controlling current to the LED.
5. The temperature-stabilized LED irradiance system of claim 1, wherein the temperature sensor is heatsinked to the LED.
6. The temperature-stabilized LED irradiance system of claim 1, wherein the temperature sensor is disposed within the LED.
7. The temperature-stabilized LED irradiance system of claim 1, wherein the circuitry comprises: a digital circuitry component and an analog circuitry component.
8. A light emitting diode (LED), the LED comprising:
a temperature sensor configured to sense a temperature within the LED; and
circuitry coupled to the temperature sensor and a power supply, wherein the circuitry is configured to adjust a power provided to the LED based on the sensed temperature.
9. The LED of claim 8, wherein the temperature sensor is heatsinked to a p-n junction of the LED.
10. The LED of claim 8, wherein the temperature sensor comprises a thermocouple.
11. The LED of claim 8, wherein the temperature sensor comprises a resistance temperature detector.
12. The LED of claim 8, wherein the circuitry comprises: a digital circuitry component and an analog circuitry component.
13. The LED of claim 8, wherein an irradiance of the LED is kept constant by continuously adjusting the power provided to the LED.

14. The LED of claim 8, wherein the LED is configured for providing illumination in a wet chemistry analyzer.
15. A method of operating an LED, the method comprising:
 - monitoring a temperature signal of a temperature sensor disposed to sense a temperature proximate the LED;
 - calculating a power adjustment for an LED based on the temperature signal; and
 - adjusting a power provided to the LED based on the calculated power adjustment.
16. The method of claim 15, wherein adjusting comprises adjusting a current provided to the LED.
17. The method of claim 15, wherein the temperature sensor is heatsinked to the LED.
18. The method of claim 15, wherein the calculating comprises an input indicative of a temperature-irradiance constant specific to the LED.
19. The method of claim 15, wherein the calculating and adjusting are completed by controller circuitry.
20. The method of claim 15, wherein the calculating comprises determining a target power to maintain a given irradiance at the sensed temperature.

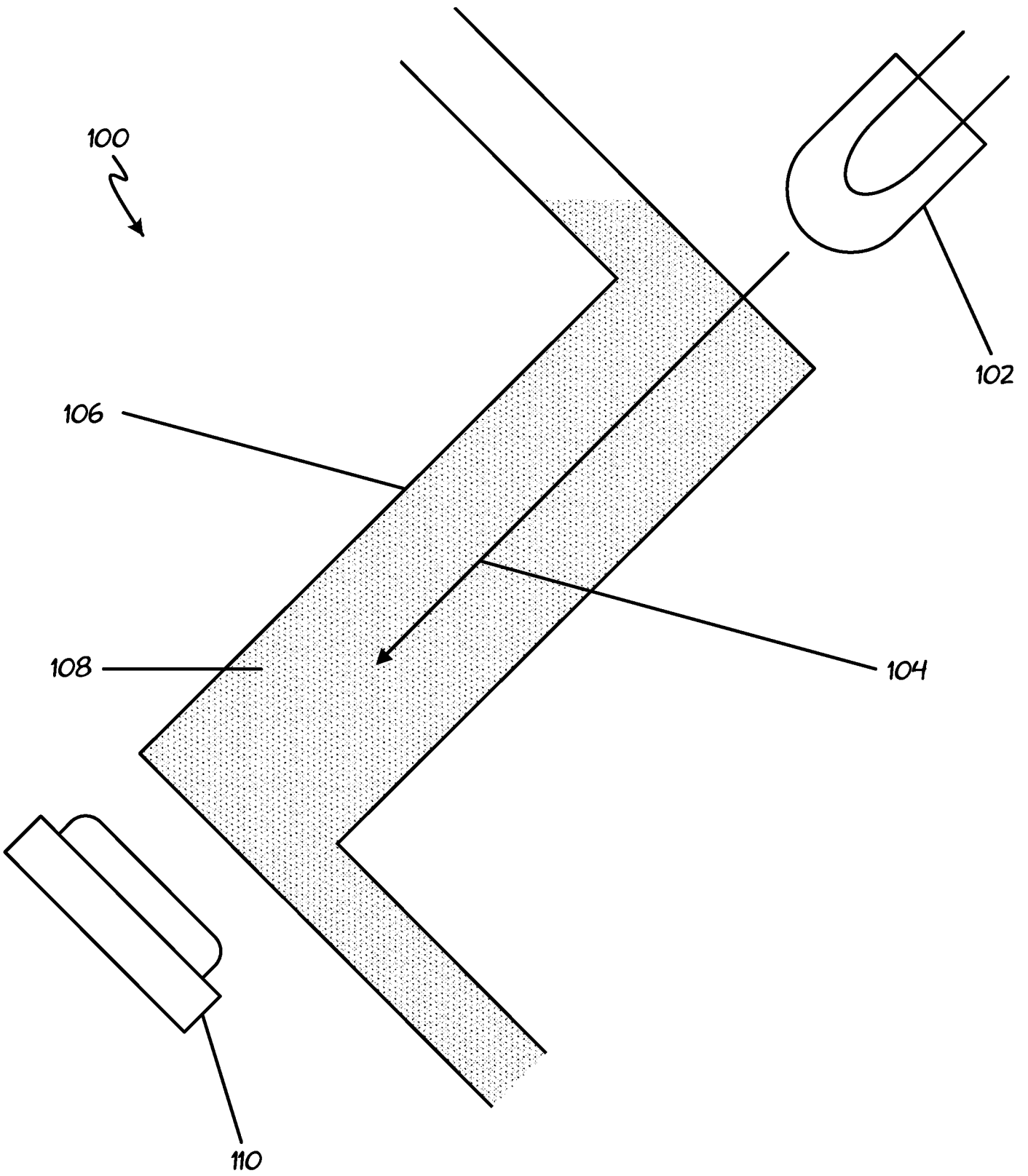


FIG. 1

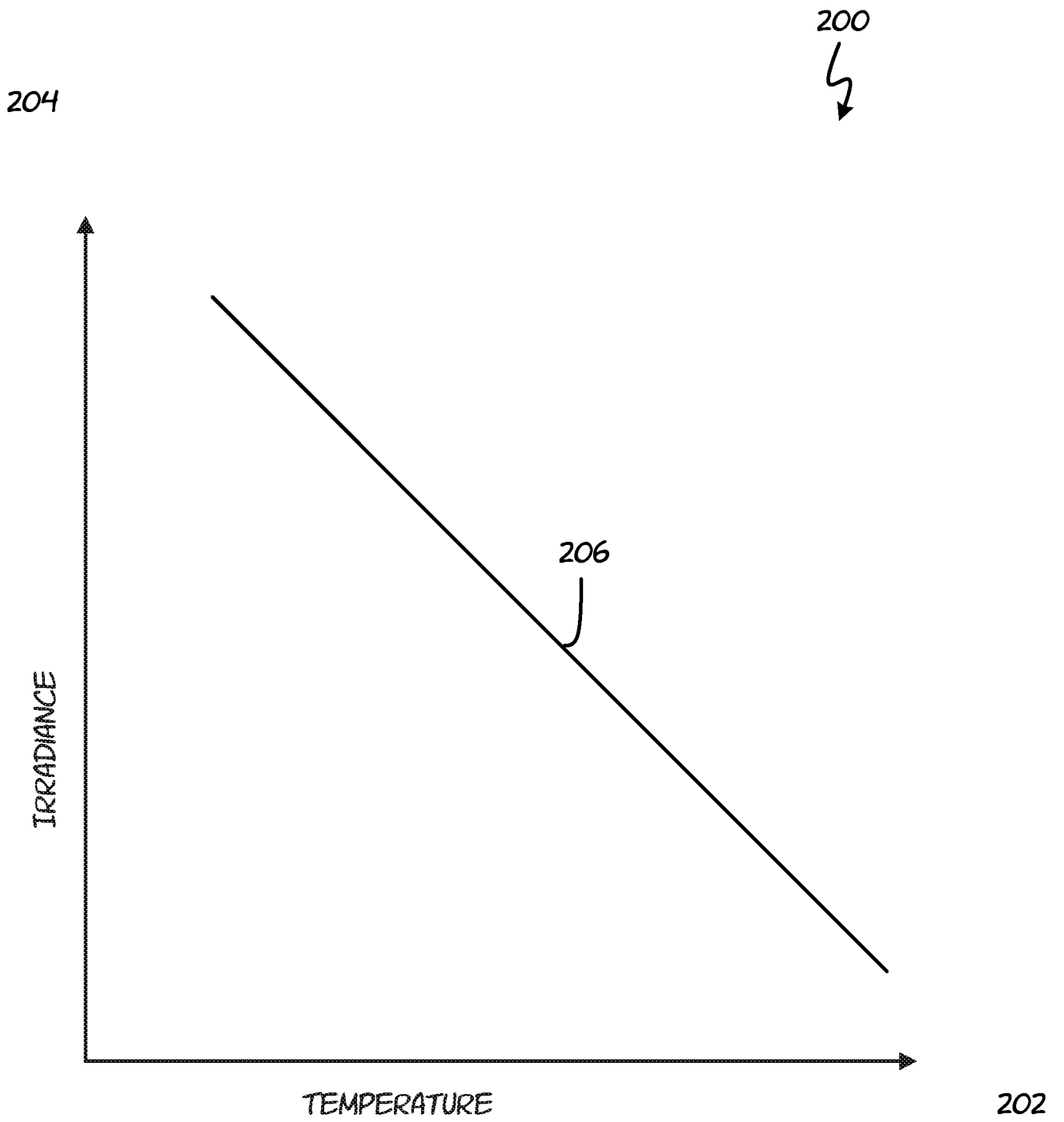


FIG. 2A

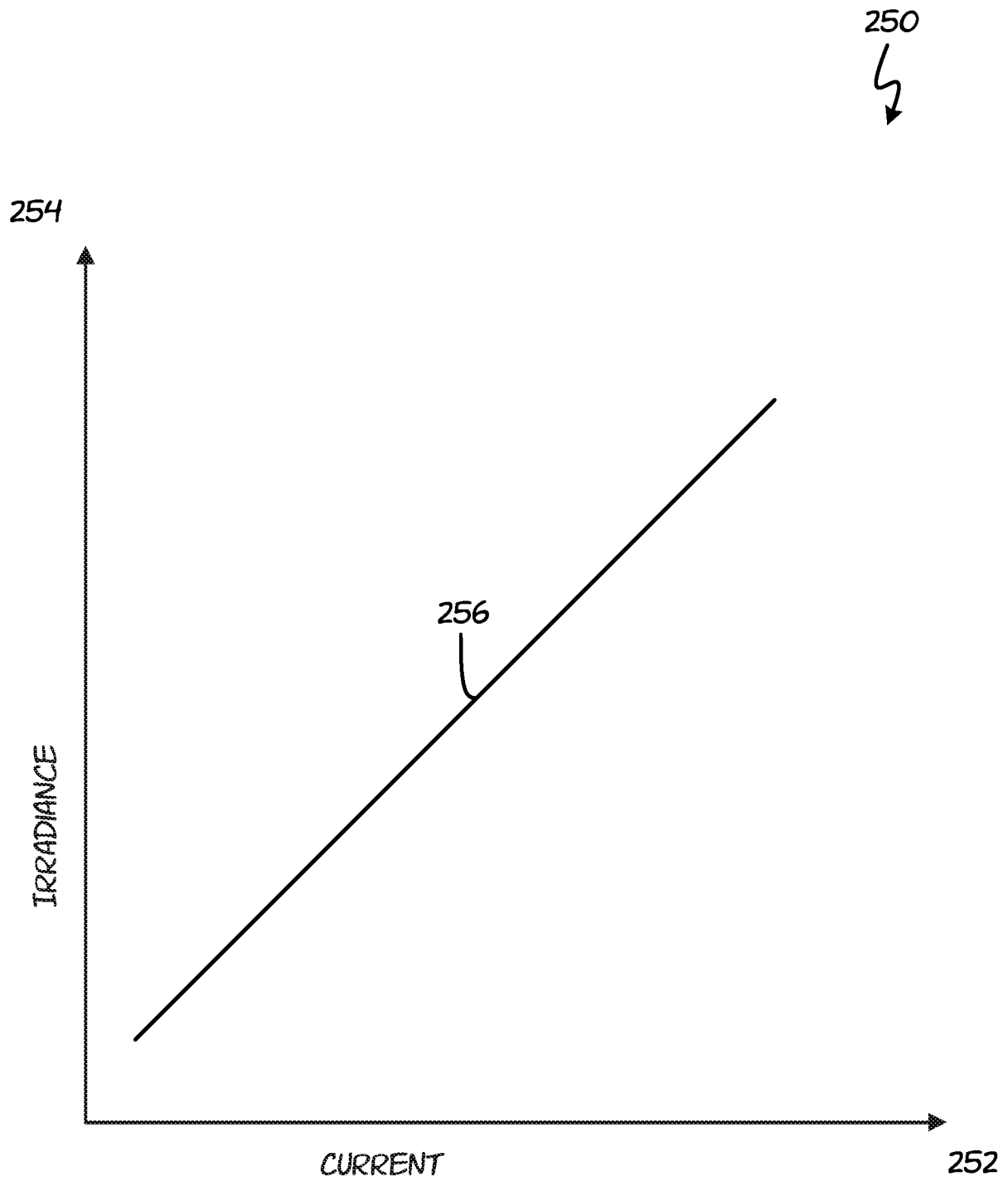


FIG. 2B

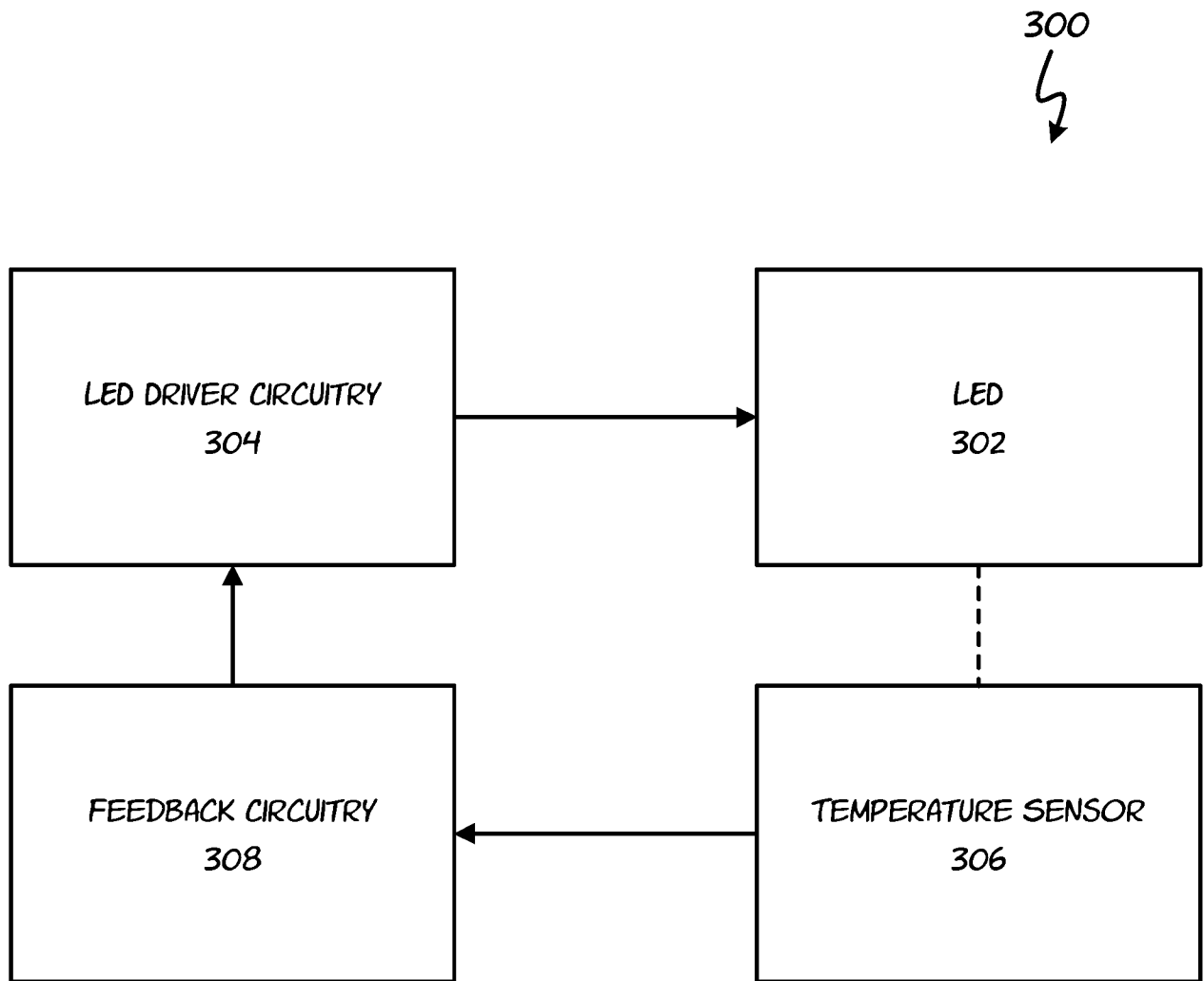


FIG. 3A

300
⚡

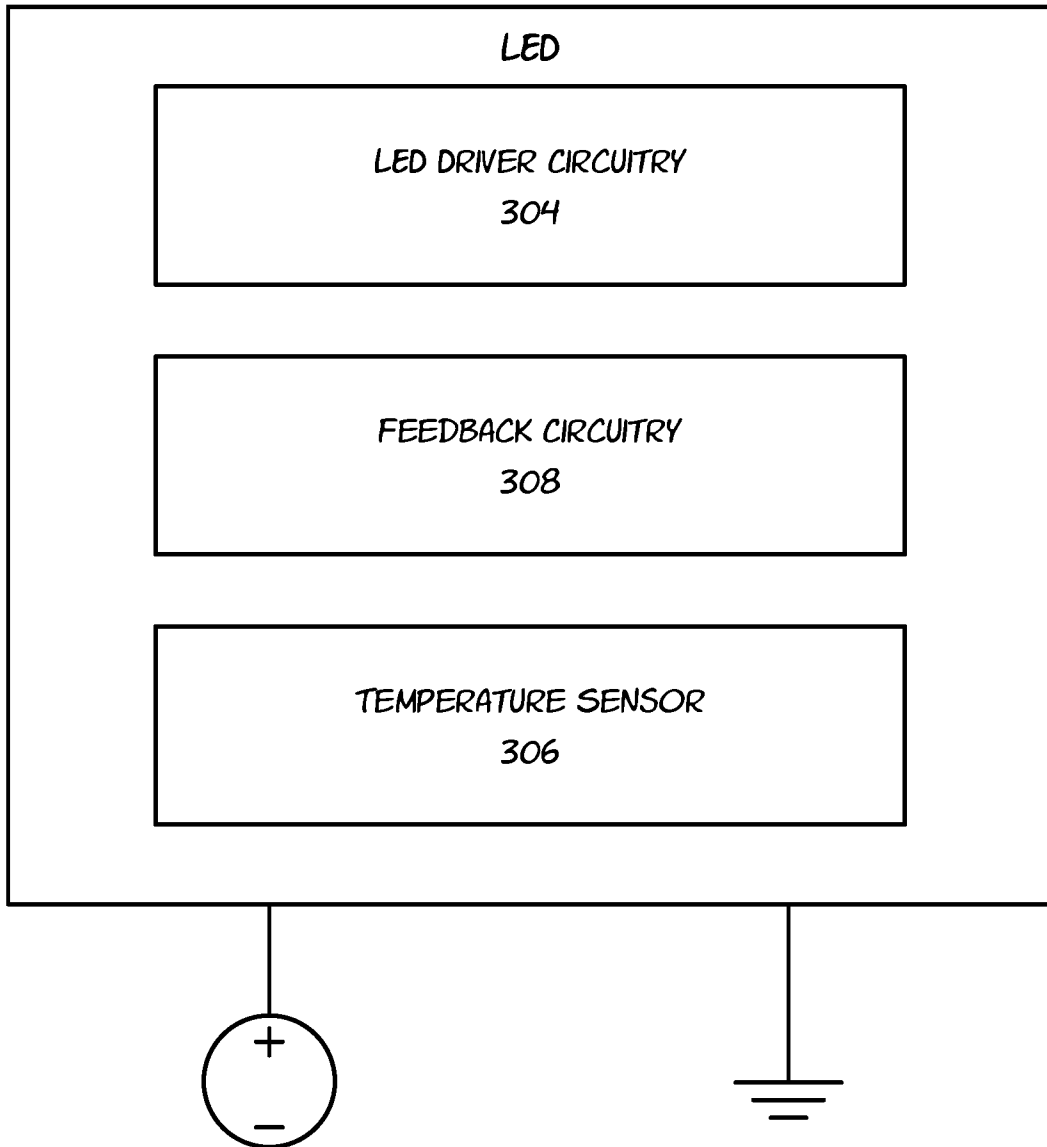


FIG. 3B

400
↘

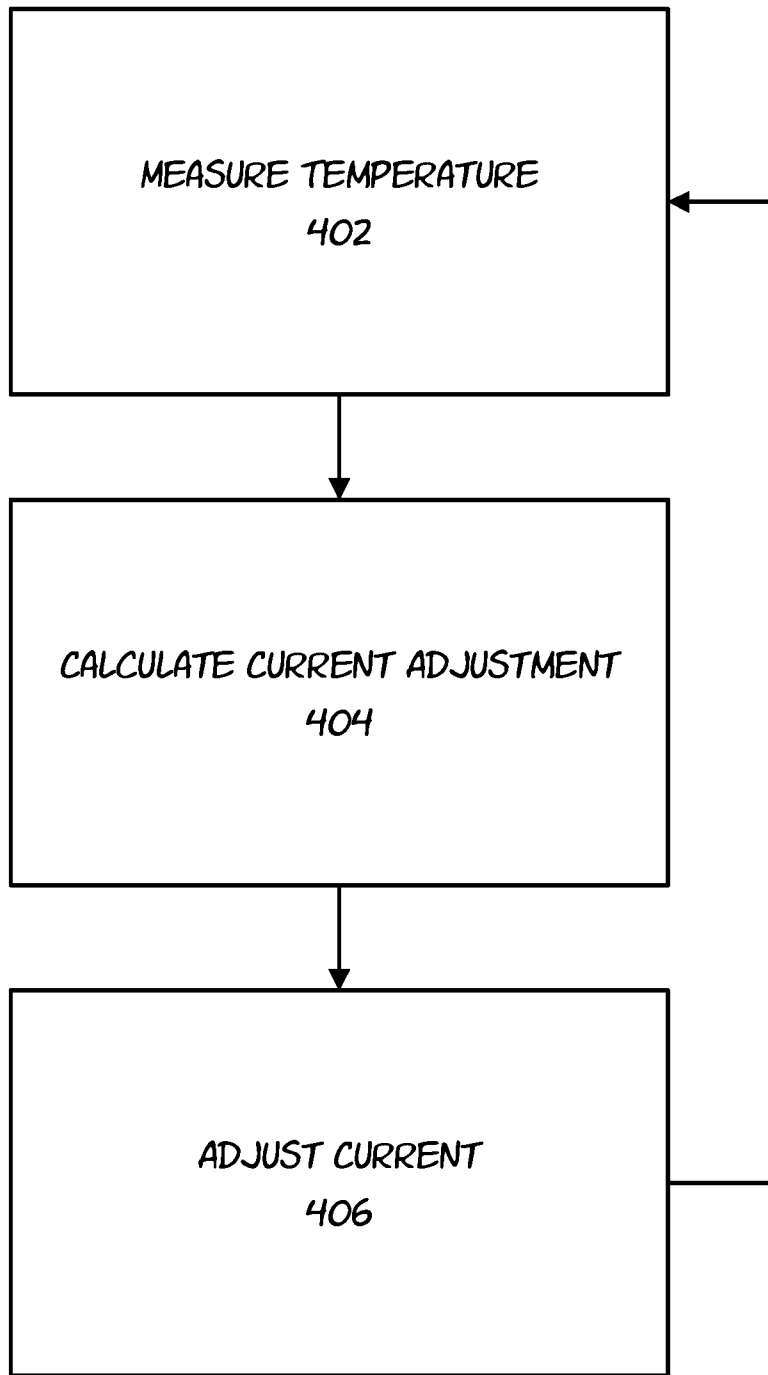


FIG. 4

A. CLASSIFICATION OF SUBJECT MATTER**H05B 33/08(2006.01)i, G01N 21/25(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
H05B 33/08; H05B 37/02; G02F 1/13357; G01N 21/01; G02F 1/133; G01N 21/25Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: LED, temperature, sensor, power, current, irradiance, colorimetric analyzer, wet chemistry analyzer**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------|
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| A | JP 55-068686 A (MATSUSHITA ELECTRIC IND. CO., LTD. et al.) 23 May 1980 See figures 2, 5. | 1-20 |
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| A | JP 2008-097864 A (HARISON TOSHIBA LIGHTING CORP.) 24 April See claim 1; and figure 1. | 1-20 |

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/014500

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