

COLORIMETRY DEVICE AND METHOD

Cross Reference to Related Application(s)

- 5 The present disclosure claims the benefit of Singapore Patent Application No. 10202009809Q filed on 02 October 2020, which is incorporated in its entirety by reference herein.

Technical Field

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The present disclosure generally relates to a colorimetry device and method. More particularly, the present disclosure describes various embodiments of a device and method for colorimetric measurement of a sample.

15 Background

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Colorimetry is a technique for determining the concentration of coloured compounds in a sample such as coloured solution or coloured surface. A colorimeter is a device to determine the concentration by measuring its absorbance of a specific wavelength of light.

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Figures 1A and 1B illustrate an existing colorimeter device 100 which is designed to measure scattered light from a sample 50. The sample 50 is held in a sample holder or container 52 that is coupled to the device 100. The sample holder 52 has a narrow and deep aperture or well 54 for propagation of light to and from the sample 50. The device 100 includes an optical assembly 120 and a measurement device 140 connected to the optical assembly 120. The optical assembly 120 includes a set of light emitting diodes (LEDs) 122, a semi-transparent mirror 124, a lens 126, and a photodetector 128. To measure the sample 50, the LEDs 122 emit light towards the mirror 124 which reflects the light towards the sample 50 through the narrow aperture / deep well 54. The sample 50 scatters the light and the scattered light propagates through the mirror 124 and lens 126 to the photodetector 128. The lens 126 focuses the scattered light for detection by the photodetector 128. The measurement device

140 measures the colour concentration of the sample 50 based on the scattered light detected by the photodetector 128. The measurement device 140 includes a controller such as an Arduino controller for controlling various components of the optical assembly 120. A cover 150 blocks out ambient light to prevent light contamination which would affect the measurements.

One problem of the existing colorimeter device 100 is that the sample holder 52 is coupled to the device 100 using a standard syringe body that requires screwing. Depending on the user, the screwing of the sample holder 52 can place the sample 50 at different distances relative to the optical assembly 120. This affects the optical path from the LEDs 122 to the sample 50 and the photodetector 128, as the optical assembly 120 has been calibrated for precise positioning of the sample 50 along the optical path. Different positions of the sample 50 along the optical path would result in inaccurate measurements of the sample 50. Another problem is that the optical assembly 120 requires more space to accommodate the mirror 124 and lens 126, thus making the device 100 bulky with an optical length of approximately 120 mm as indicated by the black line in Figure 1A. As the scattered light needs to pass through the mirror 124 and lens 126 before reaching the photodetector 128, dust that may be present on the mirror 124 and/or lens 126 can create background noise and compromise the measurement results. The background noise can range from a marginally acceptable 5% to an unacceptable 15% due to accumulation of dust on the mirror 124 and/or lens 126.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved colorimetry device and method.

Summary

According to a first aspect of the present disclosure, there is a device for colorimetric measurement of a sample. The device comprises:

an elongated body comprising a proximal end and a distal end, the distal end arranged to receive the sample;

an optical assembly coupled to the proximal end of the elongated body, the optical assembly comprising a light source and a photodetector;

a tunnel defined in the elongated body and divided into a first tunnel section and a second tunnel section, the first tunnel section arranged to transmit light from the light source to the sample, the second tunnel section arranged to transmit light scattered by the sample to the photodetector; and

a measurement device configured for colorimetric measurement of the sample based on the scattered light detected by the photodetector.

According to a second aspect of the present disclosure, there is a method for colorimetric measurement of a sample. The method comprises:

transmitting light from a light source through a first tunnel section of a tunnel defined in an elongated body to a sample at a distal end of the elongated body;

scattering, by the sample, the light received from the light source; transmitting the scattered light from the sample through a second tunnel section of the tunnel, the first and second tunnel sections divided from each other;

detecting the scattered light by a photodetector at a proximal end of the elongated body; and

performing colorimetric measurement of the sample based on the scattered light detected by the photodetector.

A device and method for colorimetric measurement of a sample according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figures 1A and 1B are illustrations of an existing colorimeter device.

Figures 2A to 2C are schematic illustrations of a device for colorimetric measurement of a sample, according to embodiments of the present disclosure.

Figure 3 is an illustration of different samples.

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Figures 4A and 4B are photographic illustrations of the device, according to embodiments of the present disclosure.

Figures 5A and 5B are further photographic illustrations of the device, according to
10 embodiments of the present disclosure.

Figure 6 is a photographic illustration of the device housed in a handheld box, according to embodiments of the present disclosure.

15 Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a device and method for colorimetric measurement of a sample, in accordance with the drawings. While aspects of the present disclosure will
20 be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims.

25 Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number
30 of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range. The terms “first”, “second”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms.

In representative or exemplary embodiments of the present disclosure, as shown in Figures 2A to 2C, there is a device or colorimeter 200 for colorimetric measurement of a sample 50. The sample 50 is held in a sample holder or container 52 that is coupleable to the device 200. The sample holder 52 has a narrow and deep aperture or well 54 for propagation of light to and from the sample 50. For example, the sample 50 is a coloured submicron membrane filter approximately 4 mm in diameter and the narrow aperture / deep well 54 approximately 10 mm deep.

The device 200 includes an elongated body 210 having a proximal end 212 and a distal end 214, the distal end 214 arranged to receive the sample 50. For example as shown in Figure 2B, the sample holder 52 is placed over the elongated body 210 such that the sample 50 sits on the distal end 214 of the elongated body 210. Alternatively as shown in Figure 2C, the sample 50 can be placed directly on the distal end 214 without the sample holder 52. The device 200 includes an optical assembly 220 coupled to the proximal end 212 of the elongated body 210. The optical assembly 220 includes a light source 222 and a photodetector 224. For example, the light source 222 includes a set of LEDs.

In some embodiments, the light source 222 includes a plurality of LEDs. The LEDs may comprise a first LED configured to emit light having a wavelength of approximately 512 nm, a second LED configured to emit coloured light having a wavelength of approximately 640 nm, and a third LED configured to emit coloured light having a wavelength of approximately 850 nm. The LEDs are preferably configured for strobing such that the coloured light can be emitted in various colour sequences exchangeable so that desired colours of light can be used for desired purposes. In some embodiments, the light source 222 includes a single LED and strobing may not be needed.

The device 220 includes a tunnel 230 defined in the elongated body 210 and the tunnel 230 is divided into a first tunnel section 232 and a second tunnel section 234. The first tunnel section 232 is arranged to transmit light from the light source 222 to the sample 50, and the first tunnel section 232 may be referred to as the illumination tunnel section. The second tunnel section 234 is arranged to transmit light scattered by the sample

50 to the photodetector 224, and the second tunnel section 234 may be referred to as the detection tunnel section.

5 The device 200 includes a measurement device 240 connected to the optical assembly 220 and configured for colorimetric measurement of the sample 50 based on the scattered light detected by the photodetector 224. Specifically, the photodetector 224 detects the scattered light in a set of colours from the sample 50 and measures the colour intensity. The photodetector 224 then generates a voltage signal, which is proportional to the intensity of the scattered light, and sends the
10 voltage signal to the measurement device 240. The measurement device 240 may include a voltmeter and is configured to enable the user to read the voltage signal and determine the concentration of compounds in the sample 50. The variable resistors R1 and R2 are normally set to 10 k Ω and 50 k Ω , respectively.

15 The device 200 includes a cover 250 configured to open and close over the distal end 214 of the elongated body 210. When the cover 250 is closed over the distal end 214 where the sample 50 is, the cover 250 blocks out ambient light from reaching the sample 50 to prevent light contamination which would affect the measurements.

20 In various embodiments, there is a method for colorimetric measurement of a sample 50. The method may be performed using various devices or colorimeters, including the device 200 as described herein. In these embodiments of using the device 200, the method includes a step of transmitting light from a light source 222 through a first tunnel section 232 of a tunnel 230 defined in an elongated body 210 to the sample 50
25 at a distal end 214 of the elongated body 210. The method includes a step of scattering, by the sample 50, the light received from the light source 222. The method includes a step of transmitting the scattered light from the sample 50 through a second tunnel section 234 of the tunnel 230, the first and second tunnel sections 232,234 divided from each other. The method includes a step of detecting the scattered light by a
30 photodetector 224 at a proximal end 212 of the elongated body 210. The method includes a step of performing colorimetric measurement of the sample 50 based on the scattered light detected by the photodetector 224.

The device 200 and method for colorimetric measurements can be used for various applications including quantitative measurements of compounds in solutions, such as bacteria collected from water. Figure 3 illustrates various samples 50 containing different concentrations of bacteria immobilized in the filters. Reagents such as metallic nano stains are applied to stick to the bacteria and make them darker. The device 200 is configured to perform colorimetric measurements of the samples 50 to determine the darkness of the samples 50 and consequently the concentration of bacteria in the samples 50. Notably, the darker samples 50, such as those having 10^6 and 10^7 bacteria concentrations per cubic centimetre, have lower light scattering.

In many embodiments as shown in Figure 2C, the elongated body 210 is tubular and has a divider 216 through the centre that equally divides the tunnel 230 into the first tunnel section 232 and second tunnel section 234, each having a semi-circular cross-section. Scattered light from the centre of the sample 50, which is aligned to the longitudinal axis of the tunnel 230, would reflect from the internal surface of the second tunnel section 234 and focus on the centre of the photodetector 224, which is also aligned to the longitudinal axis. Similarly, light transmitted from the light source 222 would reflect from the internal surface of the first tunnel section 232 and focus on the centre of the sample 50. The internal surfaces of the first and second tunnel sections 232, 234 may include reflective coatings, such as by silvering to achieve mirror finishes, to increase the intensity of light reaching the photodetector 224.

In one embodiment, the light source 222 and photodetector 224 are disposed at the proximal end 212 of the elongated body 210. In this arrangement, light is transmitted from the light source 222 directly to the sample 50 through the first tunnel section 232, and likewise reflected from the sample 50 directly to the photodetector 224 through the second tunnel section 234. In another embodiment as shown in Figure 2C, the photodetector 224 is larger and the optical assembly 220 does not have enough space to accommodate the light source 222 at the proximal end 212. In this embodiment, the light source 222 is disposed at a side of the elongated body 210 and the optical assembly 220 further includes a mirror 226 arranged to reflect light from the light source 222 to the sample 50. The elongated body 210 may include a hole 218 at the

side for propagation of light from the light source 222 to the mirror 226. Alternatively, the elongated body 210 may include a transparent element in place of the hole 218.

Figures 4A and 4B illustrate the device 200 without and with the sample 50. The shape and size of the narrow aperture / deep well 54 of the sample holder 52 is approximately the same as the shape and size of the elongated body 210. It will be appreciated that the overall length of the tunnel 230 is more than the overall width, i.e. an aspect ratio of more than 1:1. The aspect ratio is determined by the narrow aperture / deep well 54, such that the sample holder 52 can fit over the elongated body 210. Additionally, the depth of the narrow aperture / deep well 54 is approximately equal to the length of the exposed distal end 214 of the elongated body 210, such that the sample 50 can sit on the distal end 214 and a substantial portion of the optical length is shared by the tunnel 230 and narrow aperture / deep well 54, allowing the device 200 to be more compact.

As shown in Figure 2B, the sample holder 52 can be easily fitted over the exposed distal end 214 of the elongated body 210 without screwing like the existing device 100. The sample 50 would always rest on the distal end 214 of the elongated body 210 and at the same distance relative to the optical assembly 220. The optical assembly 220 is calibrated for an optical path from the light source 222 to the photodetector 224 and the sample 50 would always be precisely positioned along this optical path, thereby ensuring accurate colorimetric measurements of the sample 50.

In the device 200, the scattered light from the sample 50 propagates directly to the photodetector 224 without passing through any optical element, unlike the existing device 100 which has the mirror 124 and lens 126. Without these optical elements, the risk of dust contamination on such optical elements is eliminated, thereby reducing background noise and improving accuracy of the colorimetric measurements. Moreover, without these optical elements, the optical assembly 220 can be smaller with an optical length of approximately 22 mm as indicated by the black line in Figure 4A, compared to the existing device 100 which has an optical length of approximately 120 mm. The optical length extends over the depth of the narrow aperture / deep well 54 and the light source 222 and/or photodetector 224. The overall size of the device

200 is approximately 4 cm³ compared to the existing device 100 which has an overall size of approximately 54 cm³.

Due to the smaller optical assembly 220 for the optical path through the tunnel 230, or tunnel optics, the device 200 can be more compact and less expensive. For example, the electronic components including the measurement device 240 and connections to the optical assembly 220 can be assembled on one circuit board which would reduce costs. Figures 5A and 5B illustrate a more compact device 200 without and with the sample 50, the compact device 200 having a circuit board approximately 40 mm in width. The compact size allows the device 200 to be housed in a handheld box 260 as shown in Figure 6. The user can easily carry around the portable handheld box 260 containing a built-in colorimeter device 200.

As shown in Figures 5A and 5B, the performance of the device 200 was examined using a clean sample 50 (original white filter) approximately 4 mm in diameter. The clean sample 50 was placed in the sample holder 52 with black sponge lining its internal surface. The sample holder 52 is coupled to the device 200 over the elongated body 210 and the black sponge presses the clean sample 50 against the distal end 214 of the elongated body 210. Colorimetric measurement was performed on the clean sample 50 and the voltage signal generated by the photodetector 224 was adjusted to 100 mV using the variable resistor R1, as shown in Figures 2A and 2B. The clean sample 50 was then removed and the empty sample holder 52 was placed over the elongated body 210. Colorimetric measurement was performed on the black sponge and the photodetector 224 generated a voltage signal of 2 mV. These results show that the voltage signal is sufficient for accurate colorimetric measurements, as the background noise or dark signal that was present in the empty sample holder 52 is acceptably low at 2%.

Compared to the existing colorimeter device 100, the colorimeter device 200 according to various embodiments of the present disclosure is more compact and portable. Fewer optical elements are required which reduces the size and cost of the device 200. Moreover, the performance of the tunnel optics in colorimetric measurements is

well acceptable with an acceptably low background noise of just 2%, whereas the background noise for the existing device 100 is much higher ranging from 5% to 15%.

In the foregoing detailed description, embodiments of the present disclosure in relation
5 to a device and method for colorimetric measurement of a sample are described with
reference to the provided figures. The description of the various embodiments herein
is not intended to call out or be limited only to specific or particular representations of
the present disclosure, but merely to illustrate non-limiting examples of the present
disclosure. The present disclosure serves to address at least one of the mentioned
10 problems and issues associated with the prior art. Although only some embodiments
of the present disclosure are disclosed herein, it will be apparent to a person having
ordinary skill in the art in view of this disclosure that a variety of changes and/or
modifications can be made to the disclosed embodiments without departing from the
scope of the present disclosure. Therefore, the scope of the disclosure as well as the
15 scope of the following claims is not limited to embodiments described herein.

Claims

1. A device for colorimetric measurement of a sample, the device comprising:
 - an elongated tubular body comprising a proximal end and a distal end,
5 the distal end arranged to receive the sample;
 - an optical assembly coupled to the proximal end of the elongated tubular body, the optical assembly comprising a light source and a photodetector;
 - a tunnel defined in the elongated tubular body and divided into a first
10 tunnel section and a second tunnel section, each tunnel section having an equal semi-circular cross-section, the first tunnel section arranged to transmit light from the light source to the sample, the second tunnel section arranged to transmit light scattered by the sample to the photodetector; and
 - a measurement device configured for colorimetric measurement of the
15 sample based on the scattered light detected by the photodetector.
2. The device according to claim 1, wherein the light source is disposed at a side of the elongated body and the optical assembly further comprises a mirror arranged to reflect light from the light source into the first tunnel section.
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3. The device according to claim 1 or 2, wherein internal surfaces of the first and second tunnel sections comprise reflective coatings, such that:
 - the light transmitting through the first tunnel section is reflected from
the semi-circular internal surface of the first tunnel section to the sample; and
 - 25 the scattered light transmitting through the second tunnel section is reflected from the semi-circular internal surface of the second tunnel section to the photodetector.
4. The device according to any one of claims 1 to 3, wherein the measurement
30 device comprises a voltmeter.
5. The device according to any one of claims 1 to 4, wherein the light source comprises a set of light emitting diodes (LEDs).

6. A method for colorimetric measurement of a sample, the method comprising:
transmitting light from a light source through a first tunnel section of a
tunnel defined in an elongated tubular body to a sample at a distal end of the
5 elongated tubular body, the light source coupled to a proximal end of the
elongated tubular body;
scattering, by the sample, the light received from the light source;
transmitting the scattered light from the sample through a second
tunnel section of the tunnel to a photodetector at the proximal end of the
10 elongated tubular body, the first and second tunnel sections divided from each
other, each tunnel section having an equal semi-circular cross-section;
detecting the scattered light by the photodetector; and
performing colorimetric measurement of the sample based on the
scattered light detected by the photodetector.

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7. The method according to claim 6, wherein transmitting the light from the light
source to the sample comprises reflecting the light from the light source from a mirror
into the first tunnel section.

20 8. The method according to claim 6 or 7, wherein internal surfaces of the first
and second tunnel sections comprise reflective coatings, such that:
the light transmitting through the first tunnel section is reflected from
the semi-circular internal surface of the first tunnel section to the sample; and
the scattered light transmitting through the second tunnel section is
25 reflected from the semi-circular internal surface of the second tunnel section
to the photodetector.