US012393286B2

(12) United States Patent
Antonakis

(10) **Patent No.: US 12,393,286 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **WRITING IMPLEMENTS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/690,616**

(22) PCT Filed: **Sep. 8, 2022**

(86) PCT No.: **PCT/EP2022/074978**

§ 371 (c)(1),
(2) Date: **Mar. 8, 2024**

(87) PCT Pub. No.: **WO2023/036869**

PCT Pub. Date: **Mar. 16, 2023**

(65) **Prior Publication Data**

US 2024/0402838 A1 Dec. 5, 2024

(30) **Foreign Application Priority Data**

Sep. 10, 2021 (EP) 21196016

(51) **Int. Cl.**
G06F 3/0354 (2013.01)
B43K 29/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06F 3/03542*** (2013.01); ***B43K 29/10*** (2013.01); ***G02B 5/23*** (2013.01); ***G06F 3/03545*** (2013.01); ***G06F 3/0386*** (2013.01)

(58) **Field of Classification Search**
CPC . G06F 3/03545; G06F 3/03542; G06F 3/0386
See application file for complete search history.

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(57) **ABSTRACT**

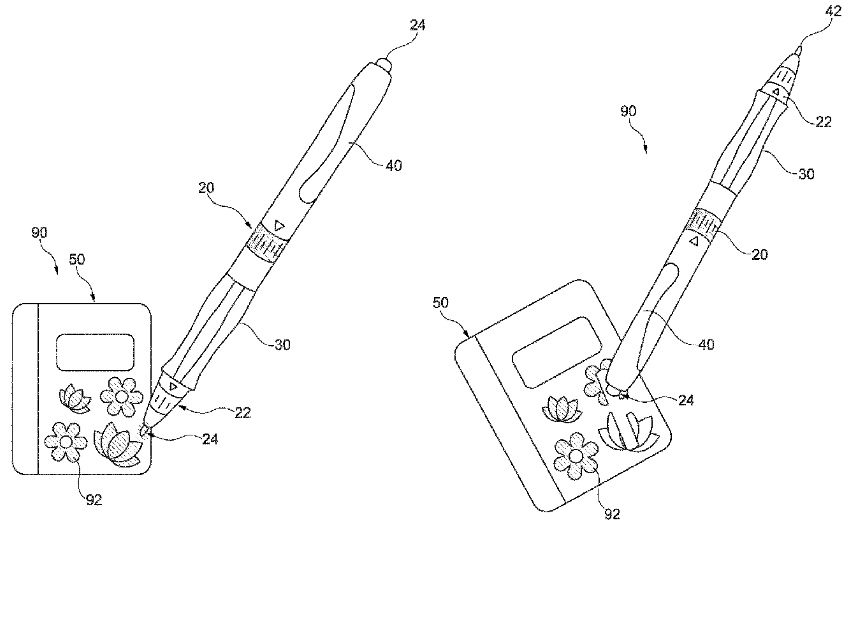
A writing implement configured to emit light for altering the appearance of a substrate including at least one photochromic material, wherein the writing implement includes:

an elongate body portion enabling a user to grip the writing implement, wherein the body portion comprises a proximal end and a distal end;

a first light source configured to emit light from the proximal end, wherein the emitted light comprises at least a first colour component within a first wavelength range, wherein the first wavelength range at least partially corresponds to a deactivation spectrum of a first photochromic material of the substrate; and

a controller configured to receive input from a user, and to generate signals for controlling the first light source based on the received user input.

18 Claims, 7 Drawing Sheets



(51) **Int. Cl.**

G02B 5/23	(2006.01)
G06F 3/038	(2013.01)

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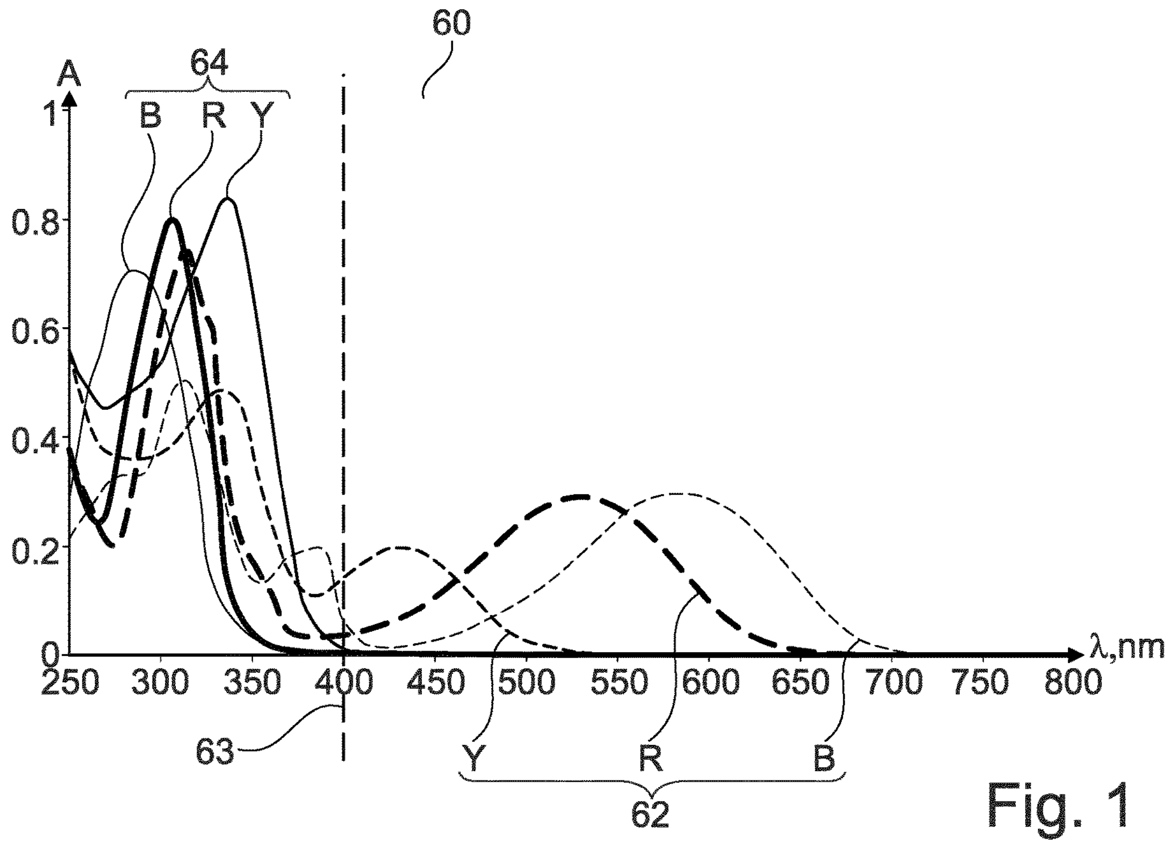
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64
B R Y
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Y R B
62

Fig. 1

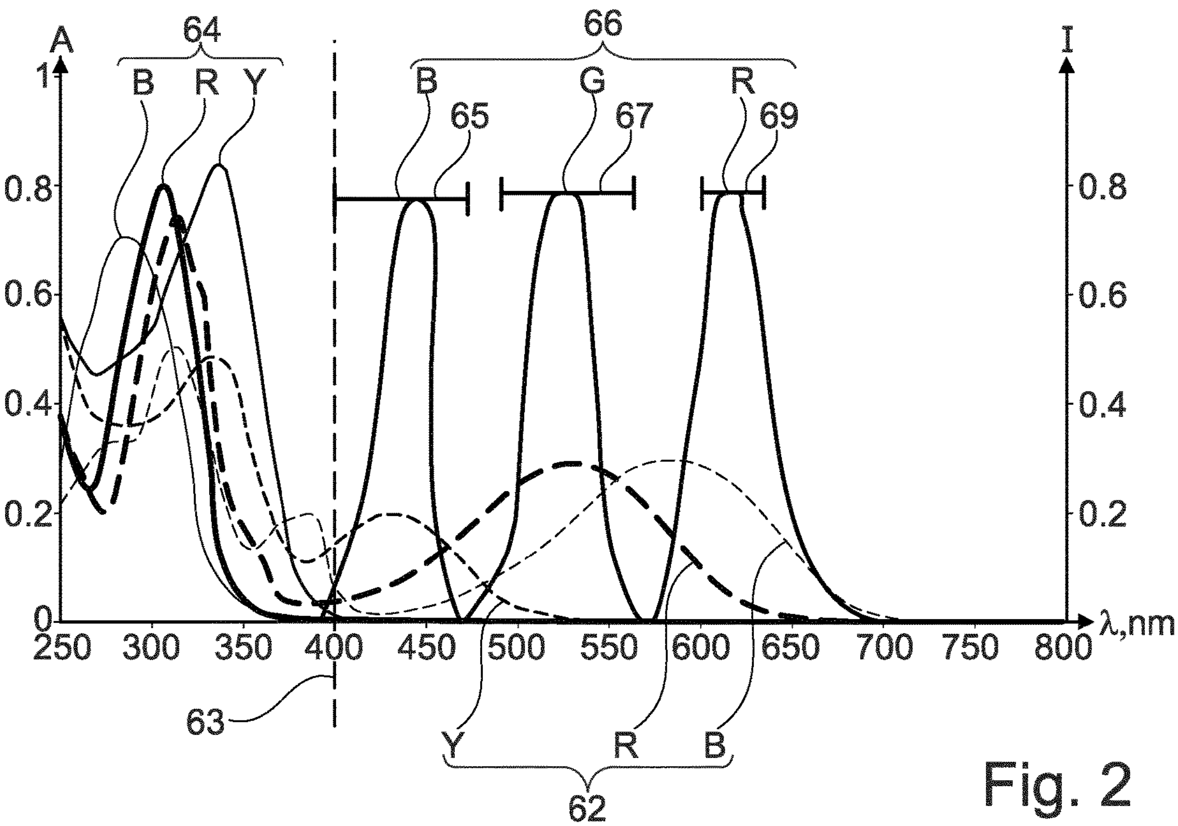
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Fig. 2

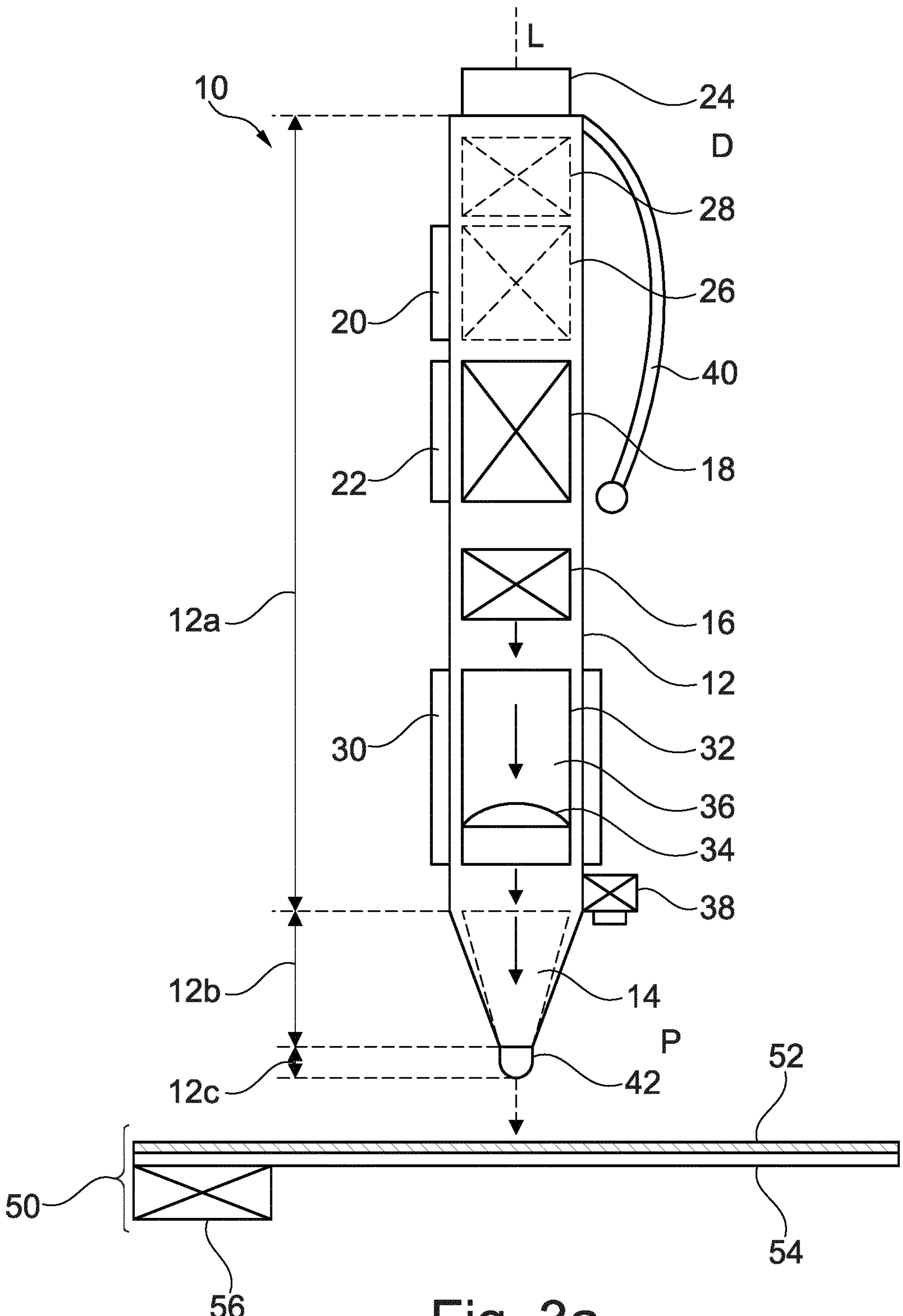
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Fig. 3a

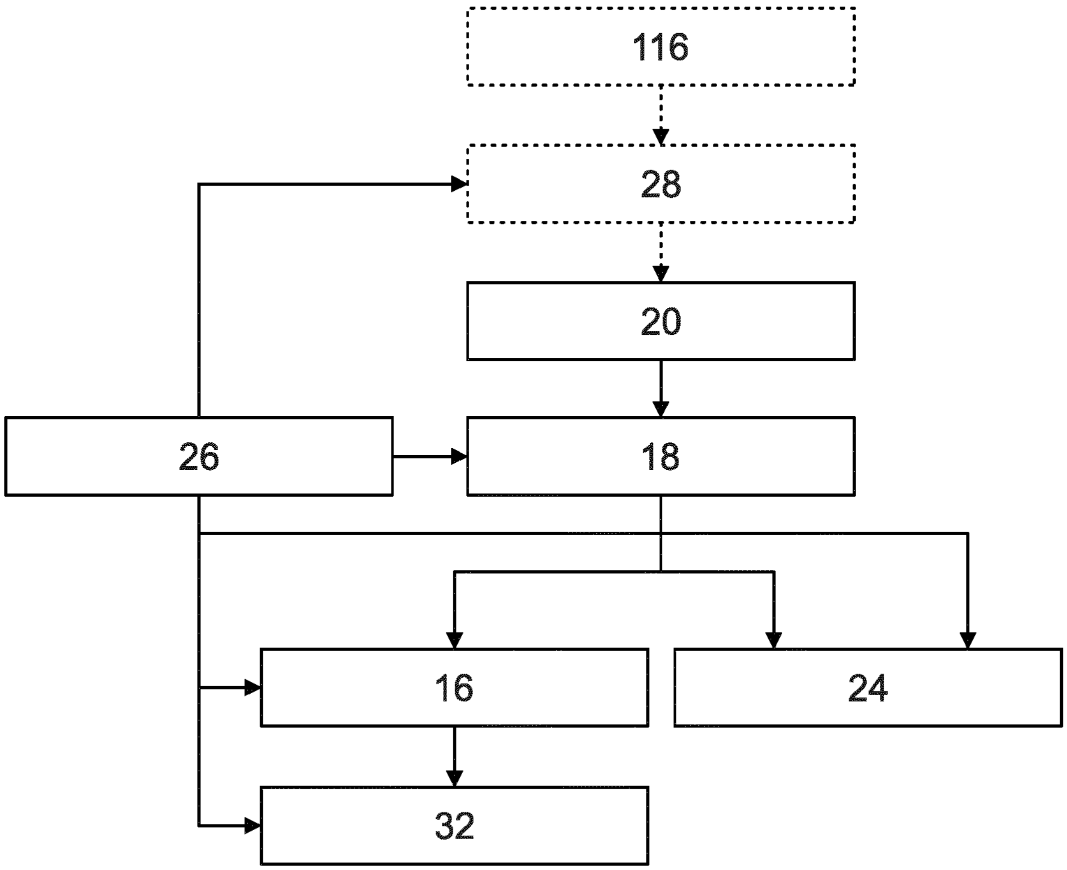

Fig. 3b

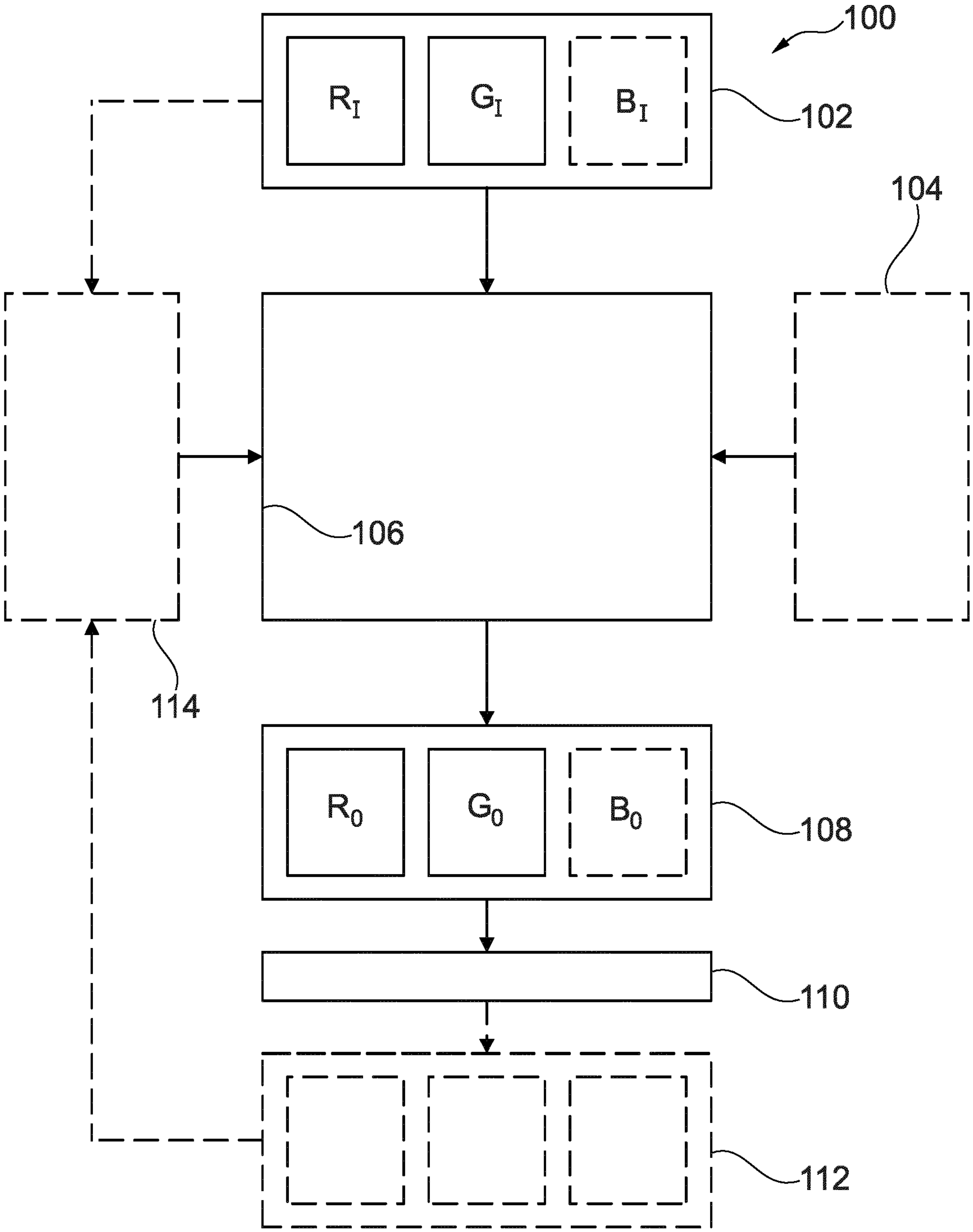

Fig. 4

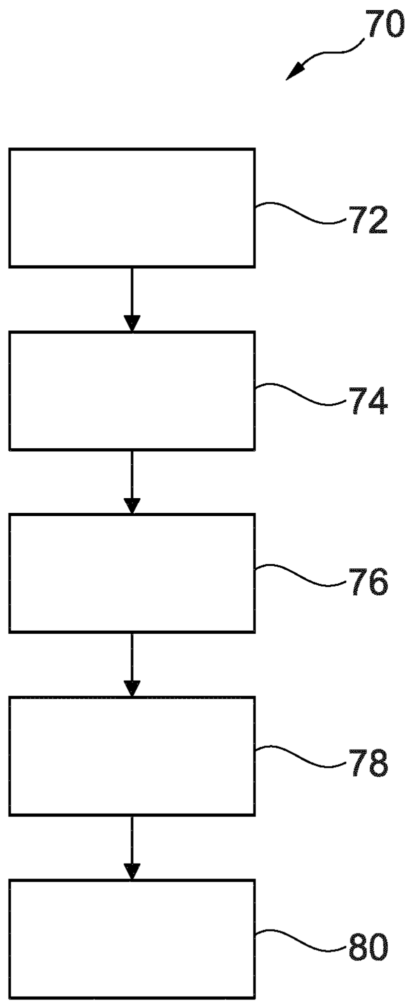

Fig. 5

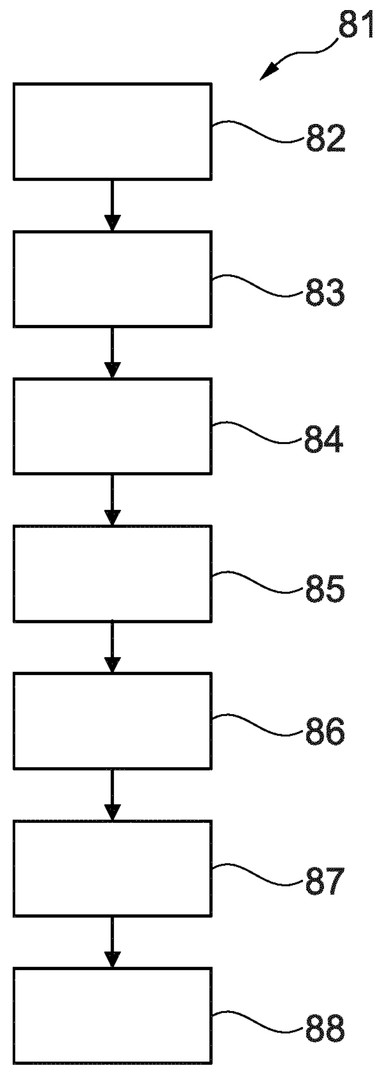

Fig. 6

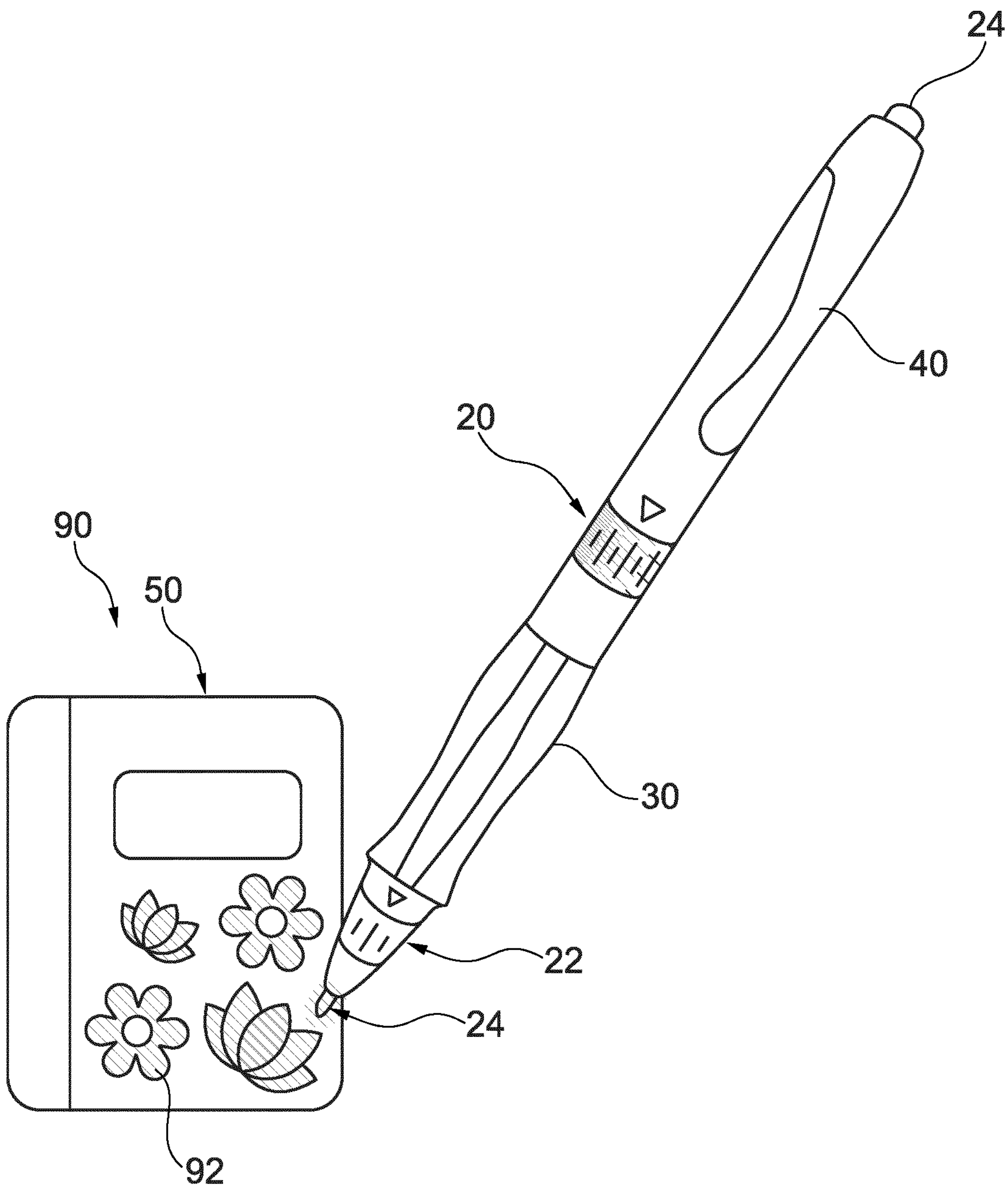

Fig. 7

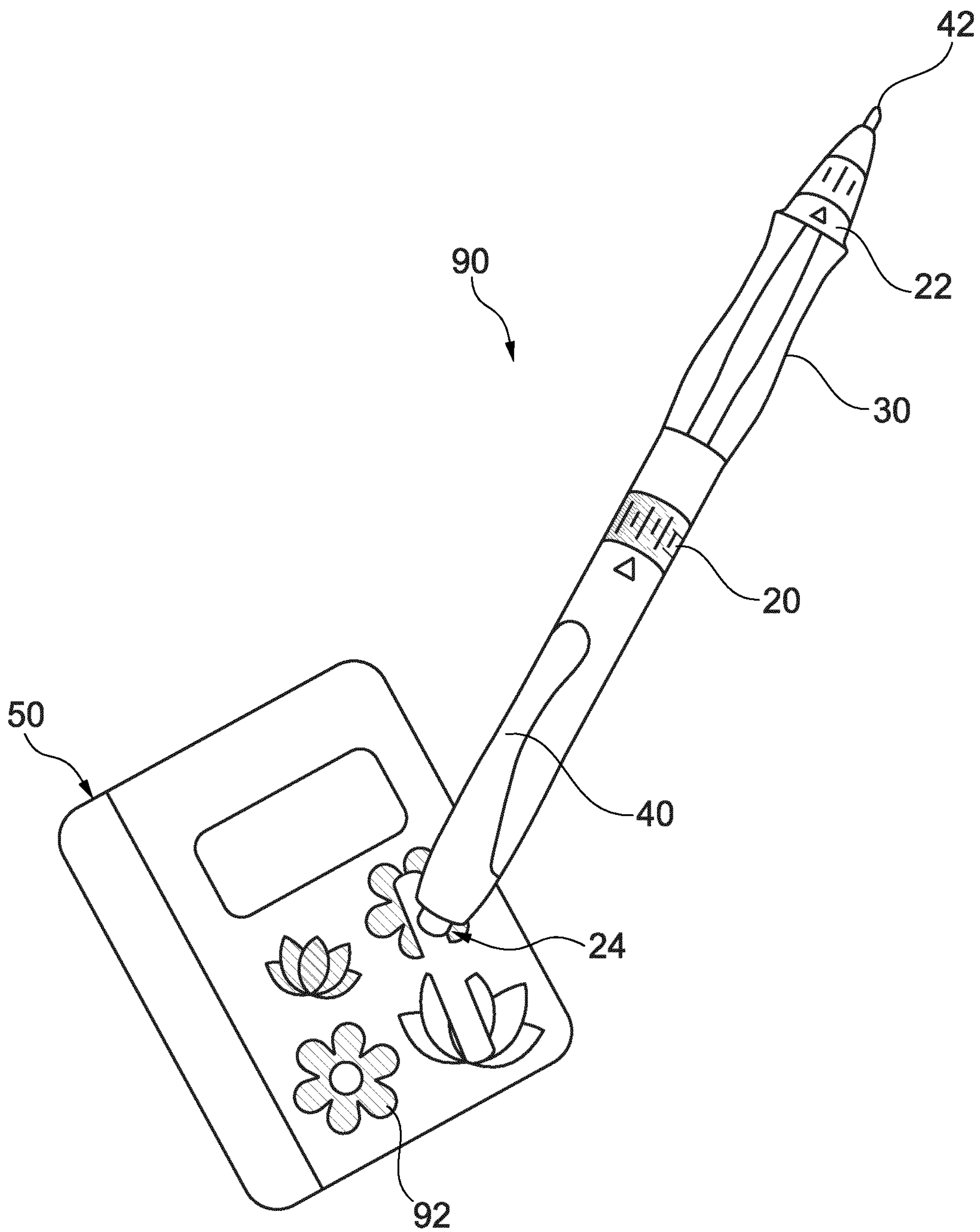

Fig. 8

WRITING IMPLEMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a National Stage Application under 35 U.S.C. § 371 of International Application No. PCT/EP2022/074978, filed Sep. 8, 2022, now published as WO 2023/036869 A1, which claims priority to European Patent Application No. 21196016.6, filed on Sep. 10, 2021, the entireties of which are incorporated herein by reference.

TECHNICAL FIELD

The embodiments described in the following disclosure relate to a writing implement configured to emit light for altering the appearance of a substrate comprising at least one photochromic material, and an associated method, photochromic writing system, computer program element, and computer readable medium.

BACKGROUND

Some options for writing or drawing on a substrate include the use of a pen and permanent ink to write on paper, the use of pencil to write on paper, or the use of a non-permanent ink to write on a whiteboard surface, for example the BIC Velleda™ whiteboard.

Erasability, or the ability of an ink formulation to be removed from a surface after it has been deposited and allowed to dry is a difficulty in the stationery category. The majority of available solutions focus on single colour writing products. Changing the colour of an inscribed surface typically requires re-scribing on the surface using a different ink colour. This slows down the user, and is a non-resettable process. Furthermore, changing the colour of the surface using incompatible inks could lead to peeling, blistering, or running of the two or more colours into each other.

Modern consumers are typically becoming more interested in personalised writing products having added functionality. Such products can be personalised to the needs of individual users. Furthermore, writing options enabling re-use of the writing media may increase in importance as environmental concerns continue to increase in prominence.

Writing instruments providing greater user flexibility and improved environmental outcomes may, therefore, be provided.

SUMMARY

According to a first aspect, there is provided a writing implement configured to emit light for altering the appearance of a substrate comprising at least one photochromic material.

The writing implement comprises an elongate body portion enabling a user to grip the writing implement, wherein the body portion comprises a proximal end and a distal end.

The writing implement further comprises a first light source configured to emit light from the proximal end, wherein the emitted light comprises at least a first colour component within a first wavelength range.

The writing implement further comprises a controller configured to receive input from a user, and to generate signals for controlling the first light source based on the received user input.

The writing implement further comprises a user-actuatable colour selector configured to receive a colour setting command from a user of the writing implement, and to provide the colour setting command to the controller.

According to this aspect, a light-emitting writing implement capable of providing a non-permanent marker capable of marking using at least one colour is provided. A user is enabled to write or draw on the substrate of a photochromic surface with one or more colours using a single light-emitting writing implement, and without depositing any ink, making a graphite mark, or requiring ink refills. This is possible because the writing medium containing the substrate is covered with at least one substance that changes its colour based on the intensity and wavelength of light that the substrate is exposed to. The light-emitting writing implement can emit one or more colours of light from its tip with a varying intensity that accordingly changes the colour of the light activated photochromic material on the writing medium.

Combinations of light source, or single light sources capable of emitting a large range of colours, combined with combinations of photochromic material on the substrate of the writing medium, enable a large gamut of colour space to be displayed to a writer. In examples, a writing system may comprise a single photochromic material and a stylus configured to emit a single colour spectrum. In this case, a similar system can be provided performs the artistic function of a monochromic ink pen.

Photochromic materials are typically resettable (erasable) by the application of radiation in a specific wavelength range, specifically UV, to portions of the substrate. Such portions appear opaque once radiation in that specific wavelength (for example, ultraviolet radiation) is applied to the substrate. This process is referred to as activating the at least one photochromic material.

A light-based actuation of the photochromic medium means that the effective nib size of the stylus may be changed by changing the focal characteristics of the at least one light source of the stylus.

According to a second aspect, there is provided a method for using a writing implement configured to emit light to alter the appearance of a substrate comprising at least one photochromic material, comprising:

- receiving, from a user-actuatable colour selector of the writing implement, a colour setting command from a user of the writing implement;
- providing the colour setting command to a controller of the writing implement;
- computing a required setting for at least a first colour component to be emitted by the first light source of the writing implement;
- controlling the first light source to emit light comprising at least the computed first colour component, wherein the first colour component is within a first wavelength range, that at least partially corresponds to a deactivation spectrum of a first photochromic material of a substrate of a proximate writing medium; and
- disposing the proximal end of the writing implement relative to the proximate writing medium to expose the substrate of the proximate writing medium comprising at least the first photochromic material to the light generated by the first light source.

According to a third aspect, there is provided a photochromic writing system comprising

a writing implement according to the first aspect or its embodiments, and a writing medium **50** (surface) comprising a substrate treated with a photochromic material. The writing implement is configured, in use, to emit light in the visible spectrum capable of deactivating the photochromic material comprised in the substrate of the writing medium to thus change the appearance of a portion of the writing medium.

According to a fourth aspect there is provided a computer program element comprising machine-executable instructions which, when executed on a computer processor, cause the processor to perform the steps according to the method of the second aspect.

According to a fifth aspect, there is provided a computer readable medium comprising the computer program element of the fourth aspect.

In this specification and claims, the term "proximal end" means an end of a stylus that, in use, is held closest to a writing medium compared to the "distal end" of the stylus. In a case where a stylus comprises a first light source for writing on a substrate, and a second light source at an opposite end of the stylus for erasing the substrate, the convention in this specification is that the proximal end of the stylus is the end of the stylus comprising the first light source for writing on the substrate.

In this specification and claims, the term "photochromic material" (or "photochromic dye") concerns materials that make use of photochromism. Photochromism is the reversible transformation of chemical species between two forms mediated by the absorption of electromagnetic radiation. Typically, the two forms of the chemical species have different absorption spectra. To an observer, the resulting material can have the effect of providing a reversible change of colour when exposed to light. Photochromic materials can include photochromic dyes (paints or inks), photochromic films, or photochromic plastics. In other words, photochromic materials are light activated materials. To enable a photochromic material to be applied to a surface, it may in examples be mixed with an encapsulation agent such as a lacquer or a resin, for example.

In this specification, the term "writing implement" refers to, in examples, a stylus containing, at a proximal end, an optical source that can be held by a user, to produce a visible marking on a substrate of a writing medium containing at least one photochromic dye.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics will be apparent from the accompanying drawings, which form a part of this disclosure. The drawings are intended to further explain the present disclosure and to enable a person skilled in the art to practice it. However, the drawings are intended as non-limiting examples. Common reference numerals on different figures indicate like or similar features.

FIG. **1** illustrates a plot showing activation and deactivation spectra of three photochromic materials.

FIG. **2** illustrates a plot showing three light source spectra superimposed over activation and deactivation spectra of three photochromic materials.

FIG. **3***a* schematically illustrates a writing implement according to the first aspect and a photochromic writing system according to the third aspect.

FIG. **3***b* schematically illustrates a functional relationship of elements of a writing implement according to the first aspect.

FIG. **4** schematically illustrates an example of a computer executable algorithm for setting the intensity of a light source.

FIG. **5** schematically illustrates a method according to the second aspect.

FIG. **6** schematically illustrates an example method.

FIG. **7** schematically illustrates a writing implement writing on a photochromic writing system.

FIG. **8** schematically illustrates a writing implement being used to erase writing applied to a photochromic writing system.

DETAILED DESCRIPTION

Present writing instruments are susceptible to producing text or graphical traces that are easily smeared, owing to the relatively long ink drying time on some media. Mixing multiple ink colours when wet, in order to obtain a unique colour, can lead to unattractive smudging and uneven blending of the inks. The nib size of a conventional writing instrument is often fixed, and if a variety of nib sizes is desired by a user, then the user must purchase and store a variety of different pens. A reduction in the amount of paper waste, and the number of plastic and non-reusable products is increasingly important.

Photochromic materials can transform from a transparent state to a coloured state through the absorption of UV (ultraviolet) light. Application of UV light to a photochromic material puts the photochromic material into a so-called "activated" state, causing the photochromic material to display a colour. By absorbing visible light in a deactivation wavelength, the photochromic material is transformed back from displaying the colour to being substantially transparent (a so-called "deactivated state"). Each photochromic material (dye) has a distinct activation spectrum, wherein light applied to a portion of photochromic material falling within the activation spectrum will cause the portion of photochromic dye to activate, and become opaque. This more pronounced, or faster, the closer the wavelength of the incident light is to the peak of the activation spectrum for a given photochromic material.

It is possible to use a single photochromic material in a monocolour photochromic writing solution. However, two or more photochromic materials may be mixed together and isolated in a translucent resin or other clear material, for example, to enable a more complex colour space to be obtained, relative to a wavelength of the incident light.

FIG. **1** illustrates a plot showing activation and deactivation spectra of three photochromic materials.

The paper "*ColorMod: Recoloring* 3*D Printed Objects using Photochromic Inks*" by Punpongsanon, et. al, published at CHI 2018, Apr. 21-26, 2018, Montreal, QC, Canada (ISBN 978-1-4503-5620-6/18/04 discusses photochromic inks, and activation and deactivation spectra of three photochromic materials. The paper "*Photo-Chromeleon: Re-Programmable Multi-Color Textures Using Photochromic Dyes*" by Jin, Y et. al, published at UIST '19, Oct. 20-23, 2019, New Orleans, LA, USA, (ISBN N 978-1-4503-6816-2/19/10) discusses a different arrangement of dyes.

FIG. **1** is based on a chart available from Yamada Chemical Co., Ltd, of Kyoto, Japan (http://ymdchem.com) and discussed in the above papers. For example, FIG. **1** displays activation and deactivation spectra for DAE-0001 (blue), DAE-0004 (red), and DAE-0068 (yellow) available from Yamada Chemical Co., Ltd.

In FIG. **1**, the x-axis indicates wavelength of incident electromagnetic radiation used for activation or deactivation of a photochromic material. The y-axis indicates the normalized absorption of a given photochromic material at that wavelength.

In particular, dotted line **62**Y is the deactivation spectrum for the yellow photochromic material DAE-0068 (in the following, "yellow"), dotted line **62**R is the deactivation spectrum for the red photochromic material DAE-0004 (in the following, "red"), and dotted line **62**B is the deactivation spectrum for the blue photochromic material DAE-0001 (in the following, "blue"). Furthermore, solid line **64**B is the peak of the activation spectrum for the blue photochromic material, solid line **64**R is the peak of the activation spectrum for the red photochromic material, and **64**Y is the peak of the activation spectrum for the yellow photochromic material.

Boundary line **63** shows the approximate transition between ultraviolet (UV) and visible light wavelengths. Therefore, DAE-0001 (blue) has an activation peak at approximately 270 nm and a deactivation peak at approximately 580 nm, DAE-0004 (red) has an activation peak at approximately 310 nm and a deactivation peak at approximately 225 nm, and DAE-0068 (yellow) has an activation peak at approximately 350 nm and a deactivation peak at approximately 425 nm. The combination of the three identified photochromic dyes in FIG. **1** provides an RGB colour space, but is for exemplary purposes, and is not essential. For example, two or one photochromic materials could be utilized. More than three photochromic materials could be utilized.

For example, another exemplary colour combination is Yamada DAE-0001 (blue), DAE-0012 (magenta), and DAE-0068 (yellow) to obtain a CMY colour space. DAE-0012 has a deactivation peak at 530 nm. When all components of a CMY photochromic material mixture are activated, a black writing surface results.

FIG. **2** illustrates a plot showing three light source spectra for deactivating respective blue, green, and red photochromic materials superimposed over activation and deactivation spectra of three photochromic materials in the first example of a combination of DAE-0001, DAE-0004, and DAE-0068. The "I" axis on the right-hand side of this plot is an exemplary scale of normalized intensity of a blue, green, or red light source, respectively. The red light source spectrum has a spectral peak **66**R at approximately 620 nm. The green light source spectrum has a spectral peak **66**G at approximately 525 nm. The blue light source spectrum has a spectral peak **66**B at approximately 440 nm.

These wavelength ranges are exemplary, and other light sources with different wavelengths and/or different spectral linewidths could be used to deactivate the red, blue, or yellow photochromic materials in the example of FIG. **1**. Deactivation will be most effective, and more rapid, when the peak deactivation wavelength of a given light source is aligned with the deactivation peak of a corresponding dye. The linewidth of each of the blue **66**B, green **66**G, and red **66**R sources is illustrated by wavelength ranges **65**, **67**, and **69**, respectively. For example, wavelength ranges **65**, **67**, and **69** may be defined by the 3 dB drop-off point of the respective linewidth.

Depending on the combination of photochromic materials used, the light source linewidths may be chosen to deactivate the target dye to the greatest extent, whilst affecting the adjacent dye deactivation spectra as little as possible. However, linewidth requirements of the optical sources may be relaxed using several techniques. For example, the light sources may be applied to the substrate **52** in a rapidly repeating time sequence designed to minimize leakage between colour channels. The colour space may be restricted to colour options that do not lead to spectral mixing between the available photochromic materials and light sources.

Coloured photochromic dyes of base colours (for example, CMY) may be mixed together, and isolated in a resin or lacquer. This provides a photochromic paint formulation for application to a writing medium, such as a whiteboard or hand-held tablet (although in a basic option, only one photochromic material needs to be used). In an example with two or more photochromic materials, the paint formulation has the ability to change colour on demand, by deactivating each photochromic material individually.

In an example using a CMY colour space (via, for example, a paint formulation comprising DAE-0001, DAE-0004, and DAE-0068), the paint formulation is, firstly, activated (by exposure to UV light). As a result, the colours would all be fully saturated (in the example of a CMY colour selection, the paint formulation would appear to be black). If a user desires to paint with a yellow colour, the C and M dyes should be deactivated. Deactivation could be achieved by, in this example, exposing the paint formulation to light at 580 nm (Cyan) and 530 nm (Magenta) for a predetermined amount of time. Once the C and M dyes have been deactivated, the paint formulation appears to be yellow.

The paint formulation can be reset by exposure resaturate all of the dyes by exposure to UV light having a wavelength of 365 nm, for example. In an example, this resetting process involves a 30 second exposure of the paint formulation to UV light having an approximate power output of 5 mW per square centimetre, for example. Power-efficient UV Light Emitting Diodes (LEDs) capable of emitting light at a wavelength of 365 nm are available, as well as LEDs capable of emitting RGB colours, for example.

According to a first aspect, there is provided a writing implement **10** configured to emit light for altering the appearance of a substrate **52** comprising at least one photochromic material. The writing implement comprises an elongate body portion **12** enabling a user to grip the writing implement, wherein the body portion comprises a proximal end P and a distal end D. The writing implement further comprises a first light source **16** configured to emit light from the proximal end, wherein the emitted light comprises at least a first colour component within a first wavelength range **65**. The first wavelength range at least partially corresponds to a deactivation spectrum of a first photochromic material **62**Y of the substrate (**52**). The writing implement also comprises a controller **18** configured to receive input from a user, and to generate signals for controlling the first light source based on the received user input.

FIG. **3***a* schematically illustrates a writing implement **10** according to the first aspect and a photochromic writing system according to the third aspect.

For example, the writing implement **10** (or light pen, or light-emitting stylus) of FIG. **3***a* is an elongated object capable of being held in the hands of an adult or child, for example. The writing implement **10** has a proximal end P suitable for orienting at a writing medium **50** during deactivation, and a distal end D. In an example, the writing implement **10** has a circular, ovular, square, rectangular, pentagonal, hexagonal, or heptagonal cross-section along at least a segment. The writing implement **10** is, for example, illustrated as an elongated object aligned along a longitudinal axis L, but this is not essential. For example, the writing implement **10** may comprise a flexible segment (not illustrated) that can be realigned from the longitudinal axis L, with light from the first light source **16** being transferred via optical fibre along a portion of the writing implement, for example.

The form-factor of the elongate body **12** may change along the longitudinal axis L of the writing implement **10** to accommodate ergonomic variations or to enhance user comfort, for example (not illustrated). In the illustrated example, the writing implement **10** comprises a main body portion **12***a*, a tapering body portion **12***b*, and an optical nib portion **12***c*.

To contextualize the writing implement **10**, the writing medium **50** (with which the writing implement is intended to be used) may be considered to be, for example, a substantially planar rigid backing layer **54**, upon which is provided a photochromic substrate layer **52**. The photochromic substrate layer **52** may comprise one, or more photochromic materials (dyes) selected to provide a colour space of interest. It is not essential that the writing medium **50** is substantially planar, and the writing medium may be a physical object such as a carton, 3D-printed object, laptop casing, a whiteboard, or many other objects.

For example, the photochromic substrate layer **52** may comprise a mixture of Yamada DAE-0001 (blue), DAE-0012 (magenta), and DAE-0068 (yellow) to obtain a CMY colour space. In another example, photochromic substrate layer **52** comprise a mixture of Yamada DAE-0001 (blue), DAE-0004 (red), and DAE-0068 (yellow) available from Yamada Chemical Co., Ltd. A skilled person will appreciate that a wide range of photochromic materials may be applied, dependent on the intended end colour specification.

In examples, one photochromic material may be applied to the substrate **52**. In an example, the one or more photochromic dyes is mixed into a composition comprising a curable lacquer, enabling permanent application of the one or more photochromic dyes to the substrate **52**.

Although not essential, the writing medium **50** may comprise an electronic subsystem **56** comprising a second modem and memory. As will be explained, the electronic subsystem enables the writing implement **10** to obtain colour space data (such as the type of photochromic material used in a given writing medium **50**) from the writing medium **50**. In examples, the writing implement **10** may carry a lookup table of target writing media **50**, with an identifier of the writing medium selectable via a control of the writing implement **10**, or a smartphone application. This enables the writing medium **50** to be simplified and not to require a second modem and memory, for example.

In an example, the total length of the writing implement **10** in the longitudinal direction L is between 50 mm and 200 mm, and specifically 140 mm. In an example, when the writing implement **10** has a circular cross-section, the maximum diameter of the writing implement is in the range of 6 mm to 20 mm, and specifically 9 mm. The elongate body of the writing implement **10** may, for example, comprise injection moulded from polystyrene or polypropylene.

In the illustrated example, the external surface of the writing implement **10** comprises, near to its distal end, a clip **40** for facilitating attachment to a user's pocket, for example. The writing implement **10** comprises, near to the proximal end, a user grip **30** comprised of a resilient material such as rubber. The user grip **30** may be moulded to achieve an ergonomic match with a typical user profile, to enhance writing comfort.

The elongate body portion **12** of the illustrated writing implement **10** encloses a first light source **16** (a deactivation light source for at least one photochromic material), a focussing element **32**, and an optical coupler **14** having a protruding optical nib portion **42**. The first light source **16** is configured to generate deactivation light for deactivating a photochromic dye. In the illustrated example, the aforementioned elements are aligned along the longitudinal axis L so that deactivation light is transmitted from the first light source **16**, via the focussing element **32** and the optical coupler **14**, and out of the protruding nib optical nib portion **42**, such that a separate photochromic substrate layer **52** of a separate writing medium **50** is deactivated using light having the wavelength, or wavelengths, supplied by the first light source **16**. In another example, the first light source does not need to be aligned along the longitudinal axis L with other elements within the elongate body **12**. Optical radiation from the first light source **16** may be distributed using a light-pipe or optical fibre, for example.

A user-actuatable colour selector is configured to receive a colour setting command from a user of the writing implement **10**, and to provide the colour setting command to the controller.

The writing implement **10** comprises a colour selector **20**, and a beam size selector **22**, to be discussed subsequently in more detail. The colour selector **20**, and the beam size selector **22** are accessible on an external surface of the elongate body portion **12**, for example. The colour selector **20**, and a beam size selector **22** are configured to provide input signals to the controller **18**. The controller **18**, the first light source **16**, and the focussing element **32**, receive electrical energy from a power source **26**.

In an embodiment, the controller **18** is configured to perform one or more of the following functions: to execute a colour setting computation of the first light source **16**; to drive the display of the colour selection system; to control the first and/or second light emitting sources; to accept input from the beam size selector **22** and to accordingly control the focussing element **32**; and to monitor and control the power source **26**, and/or the first modem **28**. The controller may be, for example, a microprocessor or a microcontroller.

FIG. **3***b* schematically illustrates a functional relationship of elements of a writing implement **10** according to the first aspect.

In an embodiment, the colour selector **20** comprises a fixed selection of pre-set buttons for selecting the available colour options. In an embodiment, the colour selector **20** may be a rotating wheel or sliding selector on the elongate body portion **12** enabling selection of a predefined colour by moving the selector by a predefined displacement.

In an example, the writing implement **10** may comprise a display (not illustrated) connected to the controller **18**. The display may be configured to illustrate to a user the selected, or available, colour and/or nib size settings. In an example, the display may comprise one or a colour LCD, a colour OLED, a polychromatic LED, or a thin film transistor display, for example. In examples, the display may be a plurality of stand-alone LEDs displayed around or along the elongate body **12**, for example, indicating discrete colour options.

In an example, the power source **26** may be a rechargeable "AA" battery, or one of many alternatives. The power source may comprise a wired or wireless charging system, for example.

The writing implement **10** may, in an example, comprise a second light source **24** (capable of activating at least one photochromic dye). The writing implement **10** may, in an example, comprise a third light source **24** (capable of activating at least one photochromic dye). In the illustrated example, the second light source is provided at the distal end D of the writing implement **10**, intuitively in place of the eraser of a conventional pencil. The second light source **24** may be an ultraviolet light source capable of activating at least one photochromic material. Specifically, the second light source **26** may be configured to emit light having a spectral peak of 365 nm.

The writing implement **10** may comprise a camera **38** for providing feedback to the controller **18** of a colour of a substrate **52** obtained whilst operating the writing implement **10** in combination with a specific combination of photochromic materials. This embodiment will be described subsequently.

The writing implement **10** may comprise a first model **28** capable of transmitting data from the controller **18** to another modem, and capable of receiving data from another modem **18** and providing it to the controller **18**. Applications of providing the writing implement 1ß with data connectivity will be discussed subsequently.

In operation, a user obtains a writing medium **50** comprising a substrate **52** containing at least one photochromic material. In a usual starting condition, the at least one photochromic material comprised in the substrate **52** is in a substantially or fully activated state, such that the substrate appears to a user as being saturated. In an example where the substrate **52** comprises a mixture of CMY photochromic materials, the substrate **52** appears to be substantially black. The user turns on the stylus **10** and selects a colour and/or intensity via the colour selector **20**. The controller **18** receives the colour and/or intensity input signal provided from the colour selector **20**. A lookup table, or an algorithm, is used to calculate the intensity of at least one component light source comprised in the first light source **16**. The at least one component light source of the first light source **16** is then activated at the intensity calculated, or obtained, by the controller **18**.

In an example, the user may select a beam size using the beam size selector **22** (operably coupled to the focussing element **32**). The use then holds the stylus **10** so that the proximate end P of the stylus **10** is close enough to the substrate **52** of the writing medium **50** that the at least one photochromic material comprised in the substrate **52** is deactivated. The user may draw a simple or complicated pattern, or write down desired information on the substrate **52**. In an example, the user may adjust one or more of the colour and/or intensity via the colour selector **20**, and/or the beam size using the beam size selector **22**. After the writing or drawing session using the writing medium **50** has been completed, the user can erase what has been written on the substrate **52** using, for example, ultraviolet light to activate the traces provided on the substrate **52**.

According to an embodiment, the first light source **16** of the writing implement is additionally configured to emit light comprising a second colour component within a second wavelength range **67**, wherein the second wavelength range at least partially corresponds to a deactivation spectrum of a second photochromic material **62**R of the substrate **52**, and wherein the first and second colour components are capable of being emitted from the first light source (i) individually, (ii) simultaneously, or (iii) in a predefined alternating sequence.

The first colour component is defined by optical radiation having a first wavelength range with a spectral maximum within one of the ranges: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, or 625 nm-700 nm.

According to an embodiment, the second colour component is defined by optical radiation having a second wavelength range with a spectral maximum within one of the ranges: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, or 625 nm-700 nm.

In examples, the first wavelength range is 400 nm-425 nm, and the second wavelength range is 425 nm-475 nm. The first wavelength range is 400 nm-425 nm, and the second wavelength range is 475 nm-525 nm. The first wavelength range is 400 nm-425 nm, and the second wavelength range is 525 nm-560 m. The first wavelength range is 400 nm-425 nm, and the second wavelength range is 560 nm-590 nm. The first wavelength range is 400 nm-425 nm, and the second wavelength range is 590 nm-625 nm. The first wavelength range is 400 nm-425 nm, and the second wavelength range is 625 nm-700 nm.

In examples, the first wavelength range is 425 nm-475 nm, and the second wavelength range is 475 nm-525 nm. The first wavelength range is 425 nm-475 nm, and the second wavelength range is 525 nm-560 nm. The first wavelength range is 425 nm-475 nm, and the second wavelength range is 590 nm-625 nm. The first wavelength range is 425 nm-475 nm, and the second wavelength range is 526 nm-700 nm.

In examples, the first wavelength range is 475 nm-525 nm and the second wavelength range is 525 nm-560 nm. The first wavelength range is 475 nm-525 nm, and the second wavelength range is 560 nm-590 nm. The first wavelength range is 475 nm-525 nm, and the second wavelength range is 590 nm-625 nm. The first wavelength range is 475 nm-525 nm, and the second wavelength range is 625 nm-700 nm.

In examples, the first wavelength range is 525 nm-560 nm and the second wavelength range is 560 nm-590 nm. The first wavelength range is 525 nm-560 nm and the second wavelength range is 590 nm-625 nm. The first wavelength range is 525 nm-560 nm and the second wavelength range is 625 nm-700 nm.

In examples, the first wavelength range is 560 nm-590 nm and the second wavelength range is 590 nm-625 nm. The first wavelength range is 560 nm-590 nm and the second wavelength range is 625 nm-700 nm.

In examples, the first wavelength range is 590 nm-625 nm and the second wavelength range is 625 nm-700 nm.

According to an embodiment, the light emitted by the first light source further comprises a third colour component having a spectral maximum within a third wavelength range. In examples, the third wavelength range is selected to comprise a maximum within one of the ranges 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm.

The first light source **16** may, in examples, be configured to output light consisting of one colour component within a first wavelength range **65**. Such provision may be appropriate for a substrate **52** comprising one photochromic material.

According to an embodiment, the first light source **16** is selected from the group of: a light emitting diode configured to emit light in at least the first wavelength range, an adjustable variable colour LED, one or more laser light sources, or one or more polychromatic LEDs comprising corresponding filtering elements in at least the first wavelength range.

For example, the first light source may comprise a single multi-coloured LED configured to emit one, two, or three colours, for example RGB. The first light source may comprise a single multi-coloured LED configured to emit a range of colours in an adjustable colour gamut. The first light source is configured to emit light having a spectral maximum in at least two of the following ranges: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm. In an example, the first light source may also be configured to generate UV, or specifically UV-A light, to enable the proximal end of the writing implement to activate detailed portions of substrate **52** and thus to act as a fine eraser.

According to an embodiment, the controller **18** is configured to receive the colour setting command from the user-actuatable colour selector **20**, to compute a required intensity setting of at least the first colour component of the first light source enabling a desired colour to be displayed on a substrate **52** comprising at least one photochromic material, and to control the first light source **16** to emit light comprising at least the computed first colour component at the computed intensity. In an example, the controller **18** is configured to compute a required intensity of a second and/or third colour component to be emitted by the first light source.

FIG. **4** schematically illustrates an example of a computer executable algorithm for setting the intensity of a light source, in the form of computer-executable colour control instructions **100**.

The exemplary computer-implemented algorithm for controlling the first light source **16** may be executed by the controller **18**. In examples, the input colour setting **102** may be transmitted via the first modem **28** of the writing implement **10** to an external processing means, such as a smartphone executing a smartphone or digital tablet application linked to the writing implement **10**, for example. In this case, the external processing means may compute output intensity values and/or sequence information of colours of the first light source **108**, and transmit them back to the controller **18** of the writing implement **10** for implementation on the writing implement **10**. This latter technique is applicable when the controller **18** comprised in the writing implement does not have appropriate computational resources in view of the colour selection algorithm required.

In an example, input colour setting **102** is received, for example from the colour selector **20** of the writing implement **10**. A colour setting computation **106** comprises receiving one of a plurality of quantized selections from a colour space, such as the RGB colour space. The colour setting computation **106** may comprise interrogating a lookup table using the input colour setting **102**. The lookup table comprises pre-computed values mapping the input colour setting **102** to output **108** intensity values and/or intensity sequence information of the first light source **16**. The controller **18** sets **110** the first light source **16** based on the output intensity values and/or sequence information **108**. The first light source **16** emits one or more wavelengths or spectra at one or more appropriate photochromic material deactivation colours, to achieve the desired input colour setting **102**, or a colour as close to it as possible.

In an example, the input colour setting **102** may comprise one colour setting, corresponding to a first colour desired to be displayed on a substrate **52** of a writing medium **50**. In this case, the output intensity values and/or sequence information **108** comprise output intensity values and/or sequence information of the first colour component within the first wavelength range. This corresponds to a use case with a writing medium **50** having one photochromic dye, or to a use case with a writing medium **50** comprising a plurality of photochromic dyes that are intended to be deactivated only by the first colour component. In an example, the colour component may be considered to be defined by the wavelength of the spectral maximum of a spectrum of a light source.

In an example, the input colour setting **102** may comprise two colour settings, corresponding to a mixture of the first and second colour coordinates in a limited colour space desired to be displayed on a substrate **52** of a writing medium **50**. In this case, the output intensity values and/or sequence information **108** comprises at least two output intensity values and/or sequence information of the first colour component within the first wavelength range and a second colour component within the second wavelength range. This corresponds to a use case with a writing medium **50** having two or more photochromic dyes, or to a use case with a writing medium **50** comprising a plurality of photochromic dyes that are intended to be deactivated by the first and second colour components.

In an example, the input colour setting **102** may comprise three or more colour settings, corresponding to a mixture of first, second, and third colour coordinates in a colour space (such as RGB, CMY, and the like) desired to be displayed on a substrate **52** of a writing medium **50**. In this case, the output intensity values and/or sequence information **108** comprises at least three output intensity values and/or sequence information of the first colour component within the first wavelength range, a second colour component within the second wavelength range, and a third colour component within a third wavelength range. This corresponds to a use case with a writing medium **50** having two or more photochromic dyes, or to a use case with a writing medium **50** comprising a plurality of photochromic dyes that are intended to be deactivated by at least the first, second, and third colour components.

In an example, writing medium parameters **104** are provided as part of the colour setting computation **106**. For example, a smartphone application configured to perform the colour setting computation **106**, and/or the controller **18** configured to perform the colour setting computation **106**, may be furnished with writing medium parameters **104**.

In a practical example, the writing medium **50** comprises an electronics subsystem **56** comprising at least a second modem and memory, for example. The memory stores parameters relating to the photochromic materials comprised in the substrate **52** of the writing medium **50**, or at least the deactivation spectra of those materials. Thus, the writing implement **10** and/or a connected smartphone or tablet application may download information detailing the photochromic materials comprised in the substrate **52** of the writing medium **50** in a wired, or wireless data transmission, such as a Bluetooth™, Wi-Fi™, ZigBee™ or NFC communication.

In examples, a user may identify the type of writing medium used by entering a code into a smartphone or tablet application, and thus by implication identify the photochromic materials comprised in the substrate **52** of the writing medium **50**. If the colour setting computation **106** has a priori knowledge of the photochromic materials comprised in the substrate **52** of the writing medium **50**, a more accurate set of output intensity values of the first light source **16** may be computed.

In an example, the input colour setting **102** is received via a smartphone or tablet application.

In an example, the colour setting computation comprises a computation of a mapping in a colour gamut (colour space) between the input colour setting and the output intensity values and/or the sequence information of the first light source **106**.

In an embodiment, the first light source **16** is configured to emit output at least the first and second colour components polychromatically, in other words, simultaneously, and in a steady state.

In other words, the colour setting computation **106** responsible for generating, using the first light source, the appropriate combination, or sequence, of light that results in the desired colour (chosen by the colour selector **20**) on the substrate **52** of the writing medium **50**. The input of the algorithm is, for example, the output of a colour selector **20**, or its analogous implementation in a smartphone or tablet implementation. For example, if a user desires to write in the colour red, the blue and green channels may need to be deactivated from a saturated substrate **52**. Thus, the output of the colour setting computation **106** is a signal defining the intensity per colour channel. Thus, the R channel may be set to 0% Hue, 0% intensity; the G channel to 100% Hue, 100% intensity, and the blue channel to 100% Hue, 100% intensity.

In another embodiment, the first light source **16** is configured to emit the first colour component in a first time interval, and to emit the second colour component in a second time interval that does not overlap with the first time interval.

In this embodiment, when first and second photochromic materials are mixed in the same area of a substrate **52**, the deactivation of the first photochromic material may also partially deactivate the second photochromic material. Thus, a greater portion of the available colour gamut may be achievable if a first colour component is applied to the substrate in isolation to a second colour component. For given combinations of photochromic materials, experiments may enable an exposure sequence to be generated for a given set of input colour settings that achieves tolerable performance within the intended colour space, for example. Computation of whether to expose the first or second colour components first, and for how long, may be experimentally derived, or may be computed a priori using an optimization algorithm such as gradient descent, for example. In an example, the first time interval has a duration in the range 10 ms to 1 s. In an example, the second time interval has a duration in the range 10 ms to 1 s.

In another embodiment, following setting the first light source **110** using the computed output intensity values or sequence information **118**, an element such as the writing implement **10**, a smartphone comprising a camera (not illustrated), or another feedback element may observe the colour and intensity of the trace as it eventually appears on the substrate **52** of the writing medium **50**.

FIG. **3***a* illustrates an example using a camera **38** for this purpose, for example. The camera may be a CMOS or CCD camera with appropriate optics, provided in a protrusion from the elongate body portion **12** enabling a field of view over the substrate **52**. The optical camera **38** enables monitoring **112** of the colour of the substrate to thus provide colour feedback data. A divergence between an intended colour output at a given setting of the colour selector **20**, and a resultant colour of the substrate **52**, may be detected. The colour setting computation is, in an embodiment, configured to detect the divergence, and to recompute the output intensity values and/or sequence information of the first light source **16** to express the intended output colour more accurately on the substrate **52**.

In an embodiment, a writing medium **50** and associated writing implement **10** may be configured to undergo a calibration sequence performed by a user. An example of a calibration sequence is that the first light source will be set to emit light having a first wavelength at a known intensity. Via a smartphone application, tablet computer, or PC, the user is instructed to draw a shape on the substrate **52**. An image of the shape is captured. The image may be captured using a camera **38** integral to the writing implement **10**, or by a smartphone camera, for example. The image may be captured to include an image of a related "swatch" of a test booklet next to the shape drawn on the substrate **52**. A deviation between the brightness and/or hue of the expected image on the substrate **52**, versus, for example, the image on the "swatch" or test booklet, is used to compute a correction factor. This calibration process may be repeated for all primary colours, for example. In examples, the calibration can be performed for arbitrary colour selections. According to the foregoing calibration method, it is not necessary for the writing medium **50** to contain electronics capable of transmitting data defining the photochromic composition of the substrate **52**, because the calibration can be performed from the test swatch or test booklet. This enables different photochromic materials from different photochromic material manufacturers to be matched more carefully.

According to an embodiment, an optical coupler is provided between the first light source **16** and the proximal end P of the writing implement **10**. The optical coupler functions to guide light emitted by the first light source **16** to the proximal end P where the light is emitted onto the writing medium.

In an example, the optical coupler **14** is a transparent structure that guides electromagnetic waves in the optical spectrum from the first light source to the proximal end P. The optical coupler **14** may be an optical fibre or a transparent dielectric waveguide of plastic or glass, for example. The optical coupler **14** may be a light pipe. The end of the optical coupler **14** disposed at the proximal end P of the writing implement may be integrally formed to comprise a static focussing element.

In an example, the optical coupler **14** and/or the protruding optical nib portion may be omitted, so that the path of transmission of the light beam from the first light source to the substrate **52** is via free space.

According to an embodiment, the writing implement **10** further comprises a focussing element **32** configured to adjust an extent of an illuminated region on a surface of a facing substrate by adjusting the beam size from the first and/or second light sources.

FIG. **3***a* schematically illustrates an example of a focussing element **32** as comprising a movable lens, such as a plano-convex lens, in the path of transmission of the light beam from the first light source **16**.

According to an embodiment, a user-actuatable beam size selector **22** capable of receiving a beam sizing command from the user, and controlling the focussing element **32** to provide the beam size selected by the user, wherein the focussing element **32** is actuated via a mechanical linkage to the beam size selector. In examples, focussing is performed by an electronically-actuated member via the controller **18**.

The focussing element **32** is responsible for changing the effective nib size of the writing implement **10**. The focussing element **32** may, for example, comprise an assembly of one or more movable lenses that accept the light from the first light source **16** and manipulate it in such a way as to change its focus point, effectively changing the nib size. For example, an unfocussed light beam may simulate a large nib size (greater than 2 mm, up to 10 mm in diameter). An in-focus light beam may replicate a fine nib size (for example, having a diameter of 0.5 mm). This focussing element may be electronically actuated via the beam size selector **22** and the controller **18**.

The plano-convex lens illustrated in FIG. **3***a* may be adjusted along the longitudinal axis **52** of the writing implement **10** using a rack and pinion mechanism (not illustrated), or at least one stepping motor or linear motor controlled by the controller **18**, for example.

The beam size selector **22** may be a mechanism operably coupled to the focussing element **32** and capable of, for example, adjusting the position of a lens within the focussing element **32** based on a rotary or sliding movement of such a mechanical beam size selector **22**.

However, other focussing modalities may be applied. For example, the focussing element **32** may comprise at least one electro fluidic lens. An electro fluidic lens contains a focussing liquid and can change its shape, and thus focussing characteristic, based on an applied electrostatic field, for example.

In an example, the beam size selector **22** is a mechanical selection wheel disposed on the elongate body portion **12** of the writing implement **10**. For example, the mechanical selection wheel may be mechanically coupled to a lens of the focussing element **32** and be configured to directly change the distance between at least one movable lens and the first light source **16**.

In an example, the beam size selector **22** may be a sliding selector having a similar function to the mechanical selection wheel disposed on the side of the elongate body portion **12** of the writing implement **10**, coupled to the focussing element **32** via a mechanism.

In an example, beam size selector **22** may be one, or more, selection buttons for incrementing through the available nib size options. A single button may be provided on the elongate body portion **12** to cycle through the available nib sizes.

In an example, beam size selector **22** may be a menu option on a smartphone application, configured to address the controller **18** via the first modem **28**.

Of course, a skilled person appreciates that the eventual nib size also depends on contextual factors such as how far away the substrate **52** is held from the protruding optical nib portion **42**, or the proximal end P of the writing implement **10**. Appropriate instructions can be provided to a user of the writing implement to ensure that the nib resizing options can be used. For example, the writing implement **10** may be provided with instructions stating that an optimal separation between the proximal end P of the writing implement **10** and a substrate **52** is a given distance, such as 5 mm. In examples, the default separation distance between the proximal end P of the writing implement **10** and a substrate **52** may be a pre-settable menu option of a smartphone configuration application, for example.

According to an embodiment, the focussing element **32** comprises one or more movable lenses **34** aligned on an optical axis between the first light source **16** and the optical coupler. In an example, a beam sizing element comprises an iris.

An iris comprises a plurality of planar leaves such that as a rotary motion of the leaves is performed relative to a longitudinal axis of the writing implement **10**, each leaf progressively intersects the beam from the first light source **16** to a greater extent, thus providing another option to control the nib size.

According to an embodiment, the writing implement **10** does not comprise a focussing element **32** and a beam size selector **22**.

According to an embodiment the writing implement **10** further comprises a second light source **24** capable of generating light in a further spectrum at least partially corresponding to activation spectra of at least the first and/or second photochromic materials, wherein the second light source generates light having a wavelength in the range of 315-400 nm, or specifically 345 nm.

The second light source **24** may be considered to be the erasing mechanism of the stylus **10**. Its inclusion in the writing implement **10** is not essential, because a separate erasing modality using light having a wavelength in the range of 315-400 nm, or specifically 345 nm may be provided using a separate device, such as a stand-alone eraser wand emitting light having a wavelength in the range of 315-400 nm, or specifically 345 nm.

In an example, the second light source **24** is configured to provide activation light to at least one photochromic material comprised on a substrate **52**, an in examples, to two, three, or more photochromic materials.

In an example, the second light source **24** is configured to emit ultraviolet, or near ultraviolet, light.

In this embodiment, the second light source **24** may be integral to the writing implement **10**. In an example, the second light source **24** is provided at or substantially proximate to the distal end of the writing implement **10**, performing an analogous function to a conventional pencil-mounted rubber eraser. In an example, the second light source **24** is provided as a substantially linear element along a length of the elongated body portion **12**. In an example, the second light source **24** is provided as a substantially linear element extending 25% of the total length of the elongated body portion **12**. In an example, the second light source **24** is provided as a substantially linear element extending 50% of the total length of the elongated body portion **12**. In an example, the second light source **24** is provided as a substantially linear element extending 75% of the total length of the elongated body portion **12**. For example, the substantially linear element may be a leaky optical bar or leaky optical fibre enabling the propagation of the light from the second light source **24** to a large surface area of the substrate **52** to enable fast application of activation light from the second light source **24** to large areas of the substrate **52**.

As illustrated in FIG. **3***a*, the second light source **24** is provided as a light source at the distal end D of the elongate body portion **12**. In an example, the second light source **24** may be an illuminated switch that is activated and deactivated (toggled) as the switch is pressed, and recoils, in the direction of the longitudinal axis L of the writing implement **10**.

According to an embodiment, the second light source **24** is provided at the distal end of the writing implement **10**.

In an embodiment, either a proximity sensor, and/or an accelerometer comprised within the writing implement **10**, is configured to detect the translation of the writing implement **10** between a first state where the first light source **16** is proximate (in optical contact) with the substrate **52**, to a second state where the second light source **24** is in proximate (in optical contact) with the substrate **52**, and vice versa. When transitioning into the first state, the second light source **24** is automatically deactivated by the controller **18**. When transitioning into the second state, the first light source is automatically deactivated by the controller **18**.

In another example (not illustrated), the second light source **24** is co-located with the first light source **16** inside the elongate body **12**, and may use the same optical transmission path to the substrate **52** as the first light source **16**. This enables finer erase precision, for example. In an example, the second light source **24** may be controlled using the colour selector **20**, for example as the extreme or boundary setting of the colour selector **20**.

In an example, the second light source **24** generates light in the activation wavelength of at least one, and specifically all, of the photochromic materials (dyes) used in the substrate **52**. In an example, the second light source **24** is configured to generate UV light in the wavelength range 100-400 nm. In an example, the second light source **24** is configured to generate UV-A light in the wavelength range 315 nm-400 nm, specifically 345 nm. The second light source **24** is, in an example, capable of increasing or decreasing its intensity based on, for example, a command from the controller.

According to an embodiment, the first **16** and/or second **24** light sources is/are configured to automatically deactivate when not proximate to the substrate **52**.

For example, the first **16** and/or second **24** light sources are provided with a proximity detector. The controller **18** monitors whether, or not, the first **16** and/or second **24** light sources satisfy a proximity criterion to a substrate **52**. If the first **16** and/or second **24** light sources do not satisfy a proximity criterion to a substrate **52**, this implies that the first **16** and/or second **24** light sources may be pointing towards the eye of a user, or another person. If the proximity criterion is not met, the controller **18** may, for example, deactivate, or reduce in intensity, the intensity of the electromagnetic radiation emitted from the first **16** and/or second **24** light sources.

In an example, the proximity detector may comprise a reciprocating or sprung mechanical switch fitted to the second **24** light source or, for example, the protruding optical nib portion **42**, if present. In one example where the second **24** light source is provided at the distal end of the writing implement **10**, if the distal end of the writing implement **10** is not in contact with a surface, then the mechanical switch is not activated, and the controller **18** does not illuminate the second light source **24** for safety reasons. An analogous arrangement can be provided for the first light source **16**, actuatable via a mechanical switch in contact with the protruding optical nib portion **42**, for example.

The proximity detector may be provided as a photodiode, phototransistor, light dependent resistor, or other electronic actuator capable of sensing the proximity of the first **16** and/or second **24** light sources to the substrate **52**, for example. The proximity detector may be a time of flight sensor provided at the distal and/or proximal end of the writing implement **10**, for example.

According to an embodiment, a portion of an optical coupler **42** protrudes from the proximal end of the writing implement **10**, and comprises a hardened, transparent material capable, in use, of providing haptic feedback to a user of the writing implement **10** when the protruding portion of the writing implement **10** is in contact with a substrate of a writing tablet.

Accordingly, the protruding portion of the optical nib **42** functions as a transparent nib of the writing implement **10**. The transparent nib comes into direct contact with the substrate **52**, for example. This provides haptic feedback to a user of the writing implement **10** enabling the feeling of writing on a surface to be emulated. The protruding portion of the optical nib **42** may enable the spacing of the writing implement **10** from the substrate **52** to be predictably regulated, to ensure even sizing of the optical nib, for example.

According to an embodiment, the first light source is fixed at the proximal end P of the writing implement **10**, so that the light source functions as a nib that may contact a writing medium. For example, a single-colour or multi-colour LED may be mounted at the proximal end P of the writing implement **10**. In this case, an optical coupler and/or a focussing element are not required.

The protruding portion of the optical nib **42** may be integrally formed with optical coupler **14**, and thus be formed from optical glass, plastic, or an encapsulated gel, for example.

In another example, a protruding portion of the optical nib **42** is not present. For example, the writing implement **10** could be provided with instructions detailing that it should be held within a range of distances form a substrate **52** to ensure a correctly sized optical nib. In another example, the optical nib diameter may be fixed (and thus, the focussing element **34** may be non-adjustable). In this case, the size of the optical nib is varied by moving the writing implement **10** closer to, or further away from, the substrate **52**.

According to an embodiment, the writing implement **10** further comprises a first modem **28**, configured to enable the controller to communicate with an external communications node, or a second modem comprised within a writing medium **50**. For example, the wired modem may be a USB™ modem. For example, the wireless modem may be one of a WiFi™ compatible modem, a Bluetooth™ compatible modem, a Near-Field communications (NFC) modem, or a ZigBee™ Modem.

According to an embodiment, the controller **18** is configured to interrogate, via the first modem **28**, an electronic subsystem of a writing medium **50** comprising a substrate **52**, and to receive from the electronic subsystem of the writing medium **50** designation data describing at least a first and a second photochromic material comprised within the substrate of the writing medium **50**. The controller **18** is configured to compute the required setting for the one or more of the first and second colour components of the first light source based on the received writing medium designation data.

In an embodiment, a smartphone, tablet, or personal computer comprises an application capable of communicating with the writing implement **10** via a first modem **28** of the writing implement **10**. The application is capable of controlling the functionality of the writing implement **10**, such as the colour selection, beam size, and the like. In examples, the writing implement **10** does not require a colour selector **20** and/or a beam size selector **22**, because the writing implement **10** is programmed with the colour and beam size setting via the application. In a further example, the application is configured to perform the colour setting computation and to communicate the output intensity values or sequence display information of the first light source **16** via the first modem **28**.

According to a second aspect, there is provided a method **70** for using a writing implement **10** configured to emit light to alter the appearance of a substrate comprising at least one photochromic material, comprising:

- receiving **72**, from a user-actuatable colour selector of the writing implement, a colour setting command from a user of the writing implement;
- providing **74** the colour setting command to a controller of the writing implement;
- computing **76** a required setting for at least a first colour component to be emitted by the first light source of the writing implement;
- controlling **78** the first light source to emit light comprising at least the computed first colour component, wherein the first colour component is within a first wavelength range, that at least partially corresponds to a deactivation spectrum of a first photochromic material of a substrate **52** of a proximate writing medium **50**; and
- disposing **80** the proximal end of the writing implement relative to the proximate writing medium **50** to expose the substrate of the proximate writing medium **50** comprising at least the first photochromic material to the light generated by the first light source.

FIG. **5** schematically illustrates a method **70** according to the second aspect.

FIG. **6** schematically illustrates an example method **81**.

In a first step **82** of the example method **81**, the user activates the writing implement **10** by turning the device on, for example by using a dedicated power switch (not illustrated) or by using one of the colour selector **20** or the beam size selector **22** (if present) as a surrogate power switch.

A desired colour may be selected **83** by the user via the colour selector **20**. For example, a user can rotate a colour selection wheel until a desired colour is displayed on a colour selection display of the writing implement **10**, or a connected smartphone or tablet application. It is assumed that the substrate **52** of the writing medium **50** has previously been partially, or fully, activated using UV or UV-A light.

A user may adjust the nib size **84** using the beam size selector **22**. For example, the user may adjust a nib size selection wheel or slider located on the elongate body portion of the writing implement **10**.

Having made the selection, the colour setting computation **106** is performed **85** and the first light source **16** is set to emit the computed colour.

The user then initiates **86** writing on the substrate **52** of the writing medium **50**. The application of the selected deactivation colour to the substrate **52** enables a sketch or writing to be displayed on the substrate **52** of the writing medium **50**.

A user may, in examples, decide to erase a portion of the substrate **52**. Therefore, the second light source **24** may in circumstances be activated **87** by the user. For example, the user can flip the writing implement **10** over to provide the distal end of the writing implement **10** in proximity (optical contact) to the substrate **52**. When the second light source **24** is proximate to the substrate **52**, the at least one photochromic material comprised in the substrate **52** is deactivated at the portion of the substrate **52** in optical contact with the second light source **24**. A user may in circumstances decide to reset **88** (activate) the entire substrate **52**, for example, by exposing the substrate **52** to a UV or UV-A wand or light source, or in examples, by leaving it in direct sunlight for a predefined time period.

Further steps of the method may comprise:

initializing a management application for the writing implement **10** on a personal computing device or a smartphone;

establishing a data communication connection between the personal computing device or the smartphone and the controller **18** of the writing implement **10**;

selecting, via the management application, one or more parameters including: a desired writing colour of the writing implement **10**, the beam size, and “on” or “off” state of the second light source **24**, power management features of the writing implement, or a photochromic material configuration of a user-chosen writing medium **50**, and

transmitting the one or more parameters to the controller of the writing implement, and configuring the writing implement based on the transmitted parameters.

Accordingly, many physical interface features of a writing implement **10** may be omitted, such as a colour selector **20** and a beam size selector **22**, when the writing implement **10** is controlled via a smartphone, tablet, or personal computing application. This can simplify the design of the stylus itself.

According to a third aspect, there is provided a photochromic writing system **90** comprising a writing implement **10** according to the first aspect or its embodiments, and a writing medium **50** comprising a substrate **52** containing at least one photochromic material.

The writing implement **10** is configured, in use, to emit, from the proximal end P, light in the visible spectrum capable of deactivating the at least one photochromic material comprised in the substrate **52** of the writing medium **50** to thus change the appearance of a portion of the writing medium **50**.

The substrate **52** of the photochromic writing system **90** may be chosen to comprise at least one photochromic material having a maximum deactivation wavelength in a range of wavelengths matched to the first light source **16** of the writing implement **10**.

For example, the substrate **52** may comprise one photochromic material.

In a case where the substrate **52** comprises one photochromic material, the maximum of the deactivation spectrum of the one photochromic material is within one of the wavelength ranges 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm.

For example, the substrate **52** may comprise a combination of at least first and second photochromic materials having the following deactivation wavelength maxima as defined by any combination of ranges from the first and second columns of Table 1:

TABLE 1

Maximum of the deactivation spectrum of first photochromic material in wavelength range:	Maximum of the deactivation spectrum of second photochromic material in wavelength range:
400 nm-425 nm	One range selected from: 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm
425 nm-475 nm	One range selected from: 400 nm-425 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm
475 nm-525 nm	One range selected from: 400 nm-425 nm, 425 nm-475 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, and 625 nm-700 nm
560 nm-590 nm	One range selected from: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 590 nm-625 nm, and 625 nm-700 nm
590 nm-625 nm	One range selected from: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, and 625 nm-700 nm

TABLE 1-continued

Maximum of the deactivation spectrum of first photochromic material in wavelength range:	Maximum of the deactivation spectrum of second photochromic material in wavelength range:
625 nm-700 nm	One range selected from: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, and 590 nm-625 nm.

The substrate **52** of the photochromic writing system **90** may comprise three photochromic materials. In this case, the first light source **16** of the writing implement **10** (optical stylus, light emitting stylus) is capable of generating light at three spectral maxima corresponding to the three deactivation wavelengths (or wavelength ranges) of the three photochromic materials.

For example, the photochromic substrate layer **52** may comprise a mixture of Yamada DAE-0001 (blue), DAE-0012 (magenta), and DAE-0068 (yellow) to obtain a CMY colour space. In another example, photochromic substrate layer **52** comprise a mixture of Yamada DAE-0001 (blue), DAE-0004 (red), and DAE-0068 (yellow) available from Yamada Chemical Co., Ltd. A skilled person will appreciate that a wide range of photochromic materials may be applied, dependent on the intended end colour specification.

In an embodiment, the writing medium **50** comprises an electronics subsystem **56**. The electronics subsystem **56** may comprise a memory configured to store identifiers, or spectral data, of the at least one photochromic material comprised in the substrate **52** of the writing medium **50**. The writing implement **10** is, in an embodiment, configured to interrogate the electronic subsystem (for example, via the second modem) to obtain the identifiers, or spectral data, of the at least one photochromic material comprised in the substrate **52** of the writing medium **50**. The controller **18** of the writing implement **10**, and/or a remote application on a smartphone, tablet, or a personal computer, may use the identifiers, or spectral data, of the at least one photochromic material comprised in the substrate **52** of the writing medium **50** to compute intensity values of the first light source **16** required to obtain one or more desired colours defined by a colour selector **20** of the writing implement **10**.

FIG. **7** schematically illustrates a photochromic writing system **90** comprising a writing implement **10** writing on a photochromic writing medium **50**.

FIG. **8** schematically illustrates a photochromic writing system **90** comprising a writing implement **10** being used to erase writing applied to a photochromic writing medium **50** using a second light source **24** of the writing implement **10**.

According to an embodiment of the third aspect, the photochromic writing system **90** further comprises a personal computing device or a smartphone. The personal computing device or smartphone is configured to initialize a management application for the writing implement **10**, to establish a data communication connection between the personal computing device or the smartphone and the controller of the writing implement **10**, and to select, via the management application, one or more parameters including: a desired writing colour of the writing implement **10**, the beam size, and "on" or "off" state of the second light source, power management features of the writing implement **10**, or a material configuration of a user-chosen writing medium **50**. The personal computing device or a smartphone is configured to transmit the one or more parameters to the controller of the writing implement **10**, and the controller is configured to update the writing implement **10** based on the transmitted parameters.

According to a fourth aspect there is provided a computer program element comprising machine-executable instructions which, when executed on a computer processor, cause the processor to perform the steps according to the method of the second aspect.

According to a fifth aspect, there is provided a computer readable medium comprising the computer program element of the fourth aspect.

According to a further aspect, there is provided a writing implement **10** configured to emit light for altering the appearance of a substrate comprising at least one photochromic material, wherein the writing implement **10** further comprises:

- an elongate body portion **12** enabling a user to grip the writing implement **10**, wherein the body portion comprises a proximal end P and a distal end D; and
- a first light source **16** configured to emit light from the proximal end, wherein the light comprises at least a first colour component within a first wavelength range **65**, wherein the first colour component is capable of being emitted in a predefined alternating sequence, and wherein the first wavelength range at least partially corresponds to a deactivation spectrum of a first photochromic material **62Y**, and a controller **18** configured to receive input from a user, and to generate signals for controlling the first light source based on the received user input.

Accordingly, it is possible to provide a writing implement **10** comprising a single colour light emitting source, thus eliminating the need for a colour selector and/or a controller **18** configured to computer a colour setting. According to this aspect, a monochromatic writing medium would be available.

According to a further aspect, there is provided a writing medium **50** comprising a substrate **52** containing at least one photochromic material, and an electronics subsystem **56**. The electronics subsystem **56** may comprise a memory configured to store identifiers, or spectral data, of the at least one photochromic material comprised in the substrate **52** of the writing medium **50**. In an example, the writing medium **50** comprises a second modem, and the second modem is configured, upon interrogation by a writing implement **10**, to interrogate the electronics subsystem **56** to obtain the identifiers, or spectral data, of the at least one photochromic material comprised in the substrate **52** of the writing medium **50**.

References throughout the preceding specification to "one embodiment", "an embodiment", "one example" or "an example", "one aspect" or "an aspect" means that a particular feature, structure, or characteristic described in connection with the embodiment or example is included in at least one embodiment of the present disclosure. Thus, appearances of the phrases "in one embodiment", "in an embodiment", "one example" or "an example", "one aspect" or "an aspect" in various places throughout this specification are not necessarily all referring to the same embodiment or example.

Furthermore, the particular features, structures, or characteristics may be combined in any suitable combinations and/or sub-combinations in one or more embodiments or examples.

It should be understood that the present disclosure can also be defined in accordance with the following embodiments:

REFERENCE NUMERALS

P	Proximal End	60	Exemplary Activation/ Deactivation Spectrum
D	Distal End		
10	Writing implement	62	Deactivation Spectra of Dye
12	Elongate body portion	64	Activation Spectra of Dye
12a	Main body portion	66	Light Source Spectra
12b	Tapering body portion	70	Method for using a Writing implement
12c	Optical nib portion		
14	Optical Coupler	72	Receiving . . .
16	First Light Source	74	Providing . . .
18	Controller	76	Computing . . .
20	Colour Selector	78	Controlling . . .
22	Beam Size Selector	80	Disposing . . .
24	Second Light Source	90	Photochromic Writing System
26	Power Source	100	Colour Control Instructions
28	First Modem	102	Input Colour Setting
30	User Grip	104	Writing Medium Parameters
32	Focussing Element	106	Colour Setting Computation
34	Lens	108	Output Intensity Values and/or Sequence Information of Light Source
36	Lens Motion Axis		
38	Camera	110	Setting the First Light Source
40	Clip	112	Monitoring the Colour of the Writing Medium
42	Protruding optical nib portion of Optical Coupler	114	Detecting a Divergence and Recomputing the Output Intensity Values and/or Sequence Information of the Light Source
50	Writing Medium		
52	Photochromic Substrate Layer		
54	Backing Layer		
56	Electronics subsystem	116	Mobile Phone Application
		L	Longitudinal Axis

The invention claimed is:

1. A writing implement configured to emit light for altering the appearance of a substrate comprising at least one photochromic material, wherein the writing implement comprises:

an elongate body portion enabling a user to grip the writing implement, wherein the body portion comprises a proximal end and a distal end;

a first light source configured to emit light from the proximal end, wherein the emitted light comprises at least a first colour component within a first wavelength range, wherein the first wavelength range comprises a spectral maximum within one of the ranges: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, or 625 nm-700 nm;

a controller configured to receive input from a user, and to generate signals for controlling the first light source based on the received user input;

a user-actuatable colour selector configured to receive a colour setting command from a user of the writing implement, and to provide the colour setting command to the controller; and

a first modem, configured to enable the controller to communicate with a second modem,

wherein the controller is configured to interrogate, via the first modem, to an electronic subsystem of a writing medium comprising a substrate, and to receive from the electronic subsystem of the writing medium designation data describing at least a first photochromic material comprised within the substrate of the writing medium, and

wherein the controller is configured to compute the required intensity setting for at least the first colour component emitted by the first light source based on the received writing medium designation data.

2. The writing implement according to claim **1**,

wherein the first light source is additionally configured to emit light comprising a second colour component within a second wavelength range, wherein the second wavelength range at least partially corresponds to a deactivation spectrum of a second photochromic material of the substrate, and wherein the first and second colour components are capable of being emitted from the first light source (i) individually, (ii) simultaneously, or (iii) in a predefined alternating sequence.

3. The writing implement according to claim **1**,

wherein the second wavelength range comprises a spectral maximum within one of the ranges: 400 nm-425 nm, 425 nm-475 nm, 475 nm-525 nm, 525 nm-560 nm, 560 nm-590 nm, 590 nm-625 nm, or 625 nm-700 nm.

4. The writing implement according to claim **1**,

wherein the first light source is selected from the group of: a light emitting diode configured to emit light in at least the first wavelength range, an adjustable variable colour LED, one or more laser light sources, or one or more polychromatic LEDs comprising corresponding filtering elements in at least the first wavelength range.

5. The writing implement according to claim **1**,

wherein the controller is configured to receive the colour setting command from the user-actuatable colour selector, to compute a required intensity setting at least the first colour component of the first light source enabling a desired colour to be displayed on a substrate comprising at least one photochromic material, and to control the first light source to emit light comprising at least the computed first colour component at the computed intensity.

6. The writing implement according to claim **1**,

wherein the writing implement further comprises a focussing element configured to adjust an extent of an illuminated region on a surface of a facing substrate by adjusting a beam size of a beam from the first light source.

7. The writing implement according to claim **6**, further comprising:

a user-actuatable beam size selector capable of receiving a beam sizing command from the user, wherein the beam size selector is configured to control the focussing element to provide the beam size selected by the user, wherein the focussing element is actuated via a mechanical linkage to the beam size selector, or via an electronic actuation member controlled by the controller.

8. The writing implement according to claim **1**, further comprising:

a second light source capable of generating light in a further spectrum at least partially corresponding to activation spectra of at least the first photochromic material, wherein the second light source generates light having a component in the wavelength range of 315-400 nm.

9. The writing implement according to claim **8**,

wherein the second light source is configured to automatically deactivate when not in contact with the substrate.

10. The writing implement according to claim **1**, further comprising:

a camera for providing feedback to the controller of a colour of a substrate obtained whilst operating the writing implement in combination with a specific combination of photochromic materials.

11. The writing implement according to claim **1**, further comprising:

a wireless or wired communications modem, configured to enable the controller to communicate with an external communications node.

12. The writing implement according to claim **11**,

wherein the controller is configured to interrogate, via the wireless or wired communications modem, an electronic subsystem of a writing surface comprising a substrate, and to receive from the electronic subsystem of the writing surface designation data describing at least a first and a second photochromic dye comprised within the substrate of the writing surface, and wherein the controller is configured to compute the required setting for the one or more of the first and second colour components of the first light source based on the received writing surface designation data.

13. A method for using a writing implement configured to emit light to alter the appearance of a substrate comprising at least one photochromic material, comprising:

receiving, from a user-actuatable colour selector of the writing implement, a colour setting command from a user of the writing implement;

providing the colour setting command to a controller of the writing implement;

computing a required setting for at least a first colour component to be emitted by the first light source of the writing implement;

controlling the first light source to emit light comprising at least the computed first colour component, wherein the first colour component is within a first wavelength range, that at least partially corresponds to a deactivation spectrum of a first photochromic material of a substrate of a proximate writing medium;

disposing the proximal end of the writing implement relative to the proximate writing medium to expose the substrate of the proximate writing medium comprising at least the first photochromic material to the light generated by the first light source;

communicating, via controller, with a second modem through a first modem; and

interrogating, via the first modem, to an electronic subsystem of a writing medium comprising a substrate, and to receive from the electronic subsystem of the writing medium designation data describing at least a first photochromic material comprised within the substrate of the writing medium, and wherein the controller is configured to compute the required intensity setting for at least the first colour component emitted by the first light source based on the received writing medium designation data.

14. The method for using a writing implement according to claim **13**, further comprising:

initializing a management application for the writing implement on a personal computing device or a smartphone;

establishing a data communication connection between the personal computing device or the smartphone and the controller of the writing implement;

selecting, via the management application, one or more parameters including: a desired writing colour of the writing implement, the beam size, and "on" or "off" state of the second light source, power management features of the writing implement, or a dye configuration of a user-chosen writing medium;

transmitting the one or more parameters to the controller of the writing implement, and configuring the writing implement based on the transmitted parameters.

15. A photochromic writing system comprising:

a writing implement according to claim **1**; and

a writing medium comprising a substrate containing at least one photochromic material;

wherein the writing implement is configured, in use, to emit, from its proximal end, light in the visible spectrum capable of deactivating the at least one photochromic material comprised in the substrate of the writing medium to thus change the appearance of a portion of the writing medium.

16. The photochromic writing system according to claim **15**, wherein the first wavelength range at least partially corresponds to a deactivation spectrum of the first photochromic material of the substrate.

17. The photochromic writing system according to claim **15**, further comprising:

a personal computing device or a smartphone;

wherein the personal computing device or a smartphone are configured to initialize a management application for the writing implement, to establish a data communication connection between the personal computing device or the smartphone and the controller of the writing implement, and to select, via the management application, one or more parameters including: a desired writing colour of the writing implement, the beam size, and "on" or "off" state of the second light source, power management features of the writing implement, or a dye configuration of a user-chosen writing surface, and wherein the personal computing device or a smartphone is configured to transmit the one or more parameters to the controller of the writing implement, and the controller is configured to update the writing implement based on the transmitted parameters.

18. A non-transitory computer readable medium comprising machine-executable instructions which, when executed on a computer processor, cause the processor to perform the steps of claim **11**.

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