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(54) **INKJET PRINTER ASSEMBLY AND METHOD FOR OPERATING AN INKEJET PRINTER ASSEMBLY**

(57) The invention provides an inkjet printer assembly (100) for printing an image on a recording medium and a method for operating an inkjet printer assembly (100). The inkjet printer assembly (100) comprises individual UV-radiation-emitting lamps (21-i) arranged within the print swath of a print head (12). Each of the UV-radiation-emitting lamps (21-i) of the first set is individually and independently controllable to operate in at least three different lamp operation modes. The at least three lamp operation modes comprise an off-mode in which no UV radiation is emitted and at least two different radiation-emitting modes. Each radiation-emitting mode is characterized by a different intensity with which the UV radiation is emitted in that radiation-emitting mode.

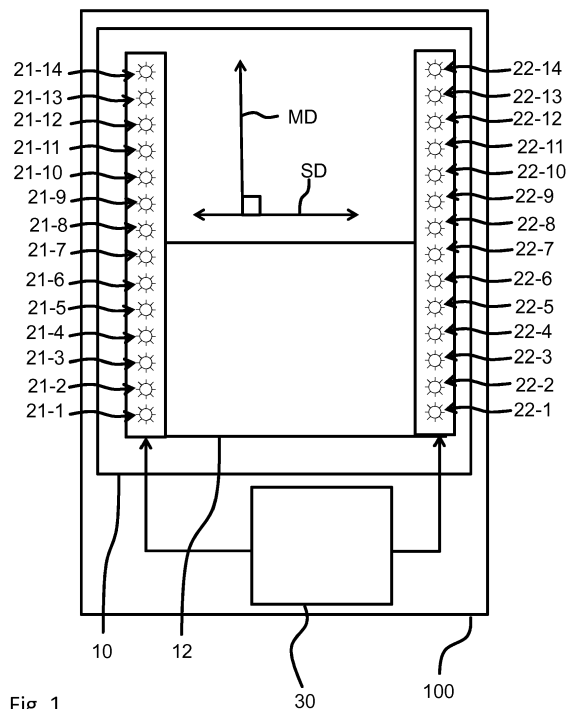


Fig. 1

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Description**FIELD OF THE INVENTION**

[0001] The present invention relates to an inkjet printer assembly for printing an image on a recording medium using UV curable ink and to a method for operating an inkjet printer assembly for printing an image on a recording medium using UV curable ink.

BACKGROUND ART

[0002] Inkjet printers are printers using ink for printing images on recording media. Also known in the art are ink compositions curable by application of radiation. Often UV radiation is used in combination with so-called UV curable ink. Inkjet printers using UV curable ink are often used in the graphical arts printing industry.

[0003] The term "UV", or "UV radiation", as used herein, refers to "ultraviolet" electromagnetic radiation, or light, which generally has a wavelength anywhere from 10 nm (ten nanometers) to 400 nm (four hundred nanometers), shorter than that of visible light but longer than that of X-rays.

[0004] UV curable ink is a type of ink that is cured by being subjected to UV radiation of specific wavelengths that may vary from ink to ink. UV curable inks typically contain reactive monomers, photo initiators, oligomers, pigments and additives that, when introduced to an UV-radiation-emitting unit (or "UV lamp" for short), such as a UV arc lamp or a UV light emitting diode (UV-LED), create a rigid film. The reactive monomers contained in the UV curable ink crosslink to provide a cured, cross-linked coating on the recording medium. In other words, images may be formed by applying UV curable ink to a recording medium and curing the UV curable ink subsequently.

[0005] UV curable inks are usable on a wide range of substrates from metals, glass, and ceramics to flexible packaging, thin-gauge polymeric films, and more. The advantages of UV curable inks include good print quality, adhesion, scratch resistance, light fastness and color density.

[0006] One challenging issue in connection with inkjet printers using UV curable ink is the following: on the one hand, it is preferable to fully cure the UV curable ink after applying it to an area of the recording medium only when no more layers of UV curable ink are going to be applied to that area, because after the full curing adding more UV curable ink to the same area is not feasible. On the other hand, it is preferable to expose the UV curable ink to UV radiation as soon as it is applied in order to reduce a time for which uncured UV curable ink is present.

[0007] Uncured, exposed UV curable ink is an issue for at least two reasons: first, contact with uncured (or "wet") ink may cause components in the ink to adhere to an operator's skin, or parts of the inkjet printer assembly, coming into contact with the printed recording medium.

Second, uncured or "wet" ink is a source of undesired chemical emissions such as ink mist or volatile organic compounds, VOCs.

[0008] So-called pin-and-cure systems therefore typically make use of two separate UV-radiation-emitting lamps: a first lamp, arranged trailing behind the print head in the print swath, is dedicated to pinning the ink with a comparatively lower UV dosage. A second lamp, arranged away from the print swath, is dedicated to fully, and finally, curing the ink using a comparatively higher UV dosage.

[0009] For example, US 9 022 514 B2 describes a carriage of an inkjet printer assembly with a printer head, a preliminary curing unit arranged to cover a print swath of the print head and a full curing unit located downstream (in a medium transport direction) of the print head. The full curing unit emits UV radiation with a higher dosage than the preliminary curing unit. Individual lines of the print swath may be subjected to different integrated quantities of applied UV radiation by setting a radiation intensity output of the preliminary and the full curing units to a fixed value based on the number of passes that the respective curing unit will make over said line of the print swath after that line has been printed.

[0010] In the above-mentioned prior art document, all of the pixels within one line of the printed image (one line corresponding e.g. to the minimum step cadence by which the recording medium is moved with respect to the print head along the medium transport direction) are subjected to the same integrated quantity of applied UV radiation, as all of the pixels within one line are passed the same number of times by the carriage. In this prior art, different pixels within one and the same such line cannot be subjected to different integrated quantities of applied UV radiation.

[0011] WO 2008/068 211 A1 describes a curing method in UV curable inkjet printing using a combination of partial curing followed by a final curing step. The printing is organized in a first set of printing passes during which partial curing takes place, followed by a second set of passes during which not partial curing but only full curing takes place. A separate step of scanning the medium with a single UV-radiation-emitting lamp that is controlled to emit radiation at a single intensity output is used.

[0012] It is therefore desirable to provide an inkjet printer assembly for printing an image on a recording medium using UV curable ink having an improved system for curing the UV curable ink.

SUMMARY OF THE INVENTION

[0013] According to a first aspect of the present invention, a method for operating an inkjet printer assembly for printing an image on a recording medium is provided, the inkjet printer assembly comprising:

a carriage configured to move forward and backward along an axis in reciprocation in a scanning direction

(SD), the carriage carrying at least one print head; wherein the carriage comprises a print head configured to apply UV curable ink to the recording medium in a print swath;

a first set of individual UV-radiation-emitting units arranged at the carriage, the UV-radiation-emitting units being arranged and configured to emit UV radiation onto UV curable ink applied to the recording medium;

wherein the first set of UV-radiation-emitting units is arranged at a trailing end of the carriage with respect to a forward movement along the axis of the carriage; wherein each of the UV-radiation-emitting units of the first set is individually and independently controllable to operate in at least three different lamp operation modes (O, L, P, C);
the at least three lamp operation modes (O, L, P, C) comprising:

- an off-mode (O) in which no UV radiation is emitted and
- at least two different radiation-emitting modes (L, P, C), each

characterized by a different intensity with which the UV radiation is emitted in that radiation-emitting mode;

the method comprising the steps of:

- a. In a first swath, applying a first droplet of UV curable ink onto a first position of the recording medium, wherein in the first swath a first UV-radiation-emitting unit of the set of UV-radiation-emitting units is positioned at the same position in the sub-scanning direction as the first position of the recording medium, and wherein the first UV-radiation-emitting unit is controlled to operate in a first mode of the at least two different radiation-emitting modes;
- b. Moving the carriage and the recording medium with regard to one another in a sub-scanning direction, the sub-scanning direction being essentially perpendicular to the scanning direction, thereby bringing a second UV-radiation-emitting unit of the set of UV-radiation-emitting units to a position having the same position in the sub-scanning direction as the first position of the recording medium;
- c. Moving the carriage in the scanning direction in a second swath, wherein the second UV-radiation-emitting unit is at a position having the same position in the sub-scanning direction as the first position of the recording medium and the second UV-radiation-emitting unit is controlled to operate in a second mode of the at least two different radiation-emitting modes.

[0014] The recording medium is preferably a type of

paper, although other recording mediums such as flexible plastic, metal foils, textiles and so on may be used in some embodiments.

[0015] One idea of the present invention is to make use of individually controllable UV-radiation-emitting units in order to individually emit radiation intensities of UV radiation onto each section, for example pixel, of the recording medium exactly in accordance with a current state or curing need of that section or pixel.

The UV-radiation-emitting units may be e.g. LED units. A plurality of LED units may be grouped in a lamp. A plurality of UV-radiation-emitting units may be placed along a line essentially perpendicular to the scanning direction. There may be a spacing in between two neighboring UV-radiation-emitting units.

A UV-radiation-emitting unit may also be referred to as UV-radiation-emitting lamp.

[0016] Even within a single line of pixels of the print swath, some pixels, or sections of the recording medium consisting of a plurality of pixels, for example, have only a single and final layer of a UV curable ink applied to them, whereas other pixels, or sections, may carry a first layer of ink onto which (at least) a second layer of ink is going to be applied in the course of the printing, according to a bitmap of the image to be printed.

[0017] Then, while the first set of pixels with the one and final layer of ink could, in principle, be completely cured immediately, the pixels onto which at least one additional layer of ink is going to be applied are preferably treated using only partial curing, or "pinning". The inkjet printer assembly according to embodiments of the first aspect makes this possible: those UV-radiation-emitting lamps whose current target sections consist only of pixels that are to be cured immediately, may be controlled to operate in a curing mode of the radiation-emitting modes, while those UV-radiation-emitting lamps whose current target sections comprise pixels onto which at least one additional layer of ink is going to be applied, may be controlled to operate in a pinning mode of the radiation-emitting modes, wherein the pinning mode is characterized by a lower emitted intensity of UV radiation than the curing mode.

[0018] In this way, even for very complicated images with vastly differing amounts of layers of UV curable ink in close proximity to each other, the correct dosage of UV radiation may be accurately and precisely applied in order to achieve the best possible printing result.

[0019] Using the different radiation-emitting modes with the different intensity (or emission power) with which the UV radiation is emitted, allows to create and to realize strategies that maximize dwell time, media coverage and print consistency while minimizing any issues associated with problems of uncured ink layers.

[0020] Using the off-mode for areas that are current target sections of some or all of the UV-radiation-emitting units, but which are not yet covered in UV curable ink, allows to prevent any local changes in the surface energy of the recording medium which otherwise could result in,

for example, banding.

[0021] The off-mode may also be used during final curing segments to ensure that all regions of the printed image on the recording medium obtain an equal number and/or an equal integrated quantity of radiation applied to that section. An integrated quantity of radiation may be calculated by multiplying the intensity of UV radiation applied to a section by the time for which UV radiation with that intensity is applied to that section.

[0022] As the carriage is configured to move forward and backward along an axis in reciprocation in a scanning direction, the individual UV-radiation-emitting units may be controlled to be in different lamp operation modes during the forward movement on one hand and during the backward movement based on, for example, how the UV curable ink is built up. Of course, even a pixel-specific control of the UV-radiation-emitting lamps for all of the pixels within a single line of the bitmap (or, equivalently, to a single printed line of pixels on the recording medium) is possible.

[0023] According to a second aspect of the invention, an inkjet printer assembly for printing an image on a recording medium is provided, the inkjet printer assembly (100) comprising:

a carriage (10) configured to move forward and backward along an axis in reciprocation in a scanning direction (SD);

wherein the carriage (10) comprises a print head (12) configured to apply UV curable ink to the recording medium (1) in a print swath;

a first set of individual UV-radiation-emitting units (21-i) arranged at the carriage (10), the UV-radiation-emitting units (21-i) being arranged and configured to emit UV radiation onto UV curable ink applied to the recording medium (1);

wherein the first set of UV-radiation-emitting units (21-i) is arranged at a trailing end of the carriage (10) with respect to a forward movement along the axis of the carriage (10);

wherein each of the UV-radiation-emitting units (21-i) of the first set is individually and independently controllable to operate in at least three different lamp operation modes (O, L, P, C);

the at least three lamp operation modes (O, L, P, C) comprising:

- an off-mode (O) in which no UV radiation is emitted and
- at least two different radiation-emitting modes (L, P, C), each characterized by a different intensity with which the UV radiation is emitted in that radiation-emitting mode; and

a controller (30) configured to control the inkjet printing assembly (100) to perform a method according to the present invention.

[0024] The method according to the second aspect has the same advantages as have been, and will be, described with respect to the inkjet printer assembly according to the first aspect in the foregoing and in the following.

[0025] Additional advantages, and the solution of additional problems, will be apparent from the subject-matter of the dependent claims as well as from the description and the drawings.

[0026] According to an embodiment of the inkjet printer assembly, the lamp operation modes comprise, in addition to the off-mode, at least three different radiation-emitting modes, each characterized by a different intensity with which the UV radiation is emitted in that radiation-emitting mode. In this way, an even more precise application of UV radiation is possible.

[0027] According to a further embodiment of the inkjet printer assembly, the controller is further configured to control each of the UV-radiation-emitting units, at least of the first set, individually and independently to operate at a specific one of the lamp operation modes further based on image information about the respective current target section of the respective UV-radiation-emitting unit. The image information may comprise any, or all, of:

- whether UV curable ink has previously been, or is going to be, applied to the current target section of the individual UV-radiation-emitting lamp;
- how much UV curable ink has previously been, or is going to be, applied to the current target section of the individual UV-radiation-emitting lamp;
- what type or what types of UV curable ink has or have previously been, or is or are going to be, applied to the current target section of the individual UV-radiation-emitting lamp.

[0028] In this way, as has been discussed above, for example a line of the print swath or a specific pixel may receive a different radiation intensity and/or a different integrated quantity of UV radiation based on, for example, whether a single layer of UV curable ink presently applied to that line or pixel is also the final layer, or whether there are going to be additional layers of UV curable ink to be applied to (i.e. deposited on) that layer. Furthermore, it is possible that different types of UV curable inks are used by one and the same inkjet printer assembly, for example because those inks have different colors and/or different optical properties like shininess, scratch-resistance and so on. Some or all of those different UV curable inks may require different radiation intensities and/or integrated quantities of radiation to be sufficiently or properly cured.

[0029] The image information is easily obtained since a print controller of the inkjet printer assembly necessarily must determine the image information in some way in order to control the print head to apply the UV curable ink correctly for printing the intended image onto the recording medium.

[0030] According to another embodiment of the inkjet printer assembly, the controller is further configured to control each of the UV-radiation-emitting units, at least of the first set, individually and independently to operate at a specific one of the lamp operation modes further based on radiation-emitting information about the current target section. The radiation-emitting information may comprise information about any or all of the following:

- how long the radiation has previously been emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting lamp;
- how often has UV radiation previously been emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting lamp;
- with which intensity has UV radiation been previously emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting lamp.

[0031] It is to be understood that the terms "is to be ... in the future" and "is going to be ..." refer to the necessary remaining actions for printing the intended image onto the recording medium. As discussed above, different types of UV curable inks may require different intensities and/or different integrated radiation quantities of UV radiation to be sufficiently or properly cured at different times during the printing process.

[0032] According to a further embodiment of the inkjet printer assembly, the controller is configured to control each individual UV-radiation-emitting unit to operate in the off-mode when the image information indicates that the current target section of that individual UV-radiation-emitting lamp is a section to which no UV curable ink has yet been applied. In this way, local changes in the surface energy of the recording medium are avoided or minimized.

[0033] According to yet another embodiment of the inkjet printer assembly, the controller is configured to control each individual UV-radiation-emitting unit to operate in a first radiation-emitting mode when the image information indicates that the current target section of that individual UV-radiation-emitting unit is a section to which:

- a) a single, first layer of UV curable ink has been applied so far, and
- b) at least one more layer of UV curable ink is (going) to be applied in the future.

[0034] In some advantageous embodiments, the controller is configured to control each individual UV radiation emitting unit to operate in a second radiation-emitting mode when the image information indicates that the current target section of that individual UV-radiation-emitting unit is a section to which

- a) more than one layer of UV curable ink has been

applied so far and

- b) at least one more layer of UV curable ink is (going) to be applied in the future.

5 **[0035]** In some advantageous embodiments, the controller is configured to control each individual UV radiation emitting unit to operate in a third radiation-emitting mode when the image information indicates that the current target section of that individual UV-radiation-emitting unit is a section to which

- a) at least one layer of UV curable ink has been applied so far and

10 15 b) no more layers of UV curable ink are (going) to be applied in the future.

[0036] According to yet another embodiment of the inkjet printer assembly, the UV-radiation-emitting units of the first set are arranged at the carriage along a line perpendicular to the axis and parallel to the recording medium. This provides a very space-saving yet very efficient arrangement of the UV-radiation-emitting lamps.

20 **[0037]** According to yet a further embodiment of the inkjet printer assembly, at least one of the UV-radiation-emitting units of the first set is arranged outside of the print swath of the print head. Such lamps may be advantageously used for full curing of applied UV curable ink in regions where the print head will no longer apply any UV curable ink.

25 30 **[0038]** According to another embodiment of the inkjet printer assembly, a second set of UV-radiation-emitting units is arranged at a trailing edge of the carriage with respect to a backward movement along the axis of the carriage. By arranging the first set of individual UV-radiation-emitting units at the trailing end of the carriage with respect to the forward movement, and by arranging the second set of UV-radiation-emitting lamps at the trailing edge of the carriage with respect to the backward movement, it is made sure that in whatever direction the carriage is currently moving, there is a set of UV-radiation-emitting units trailing the print head and therefore available to immediately pin and/or cure, that is to apply any amount of UV-radiation necessary, to the ink layer deposited immediately before by the print head during that leg of the movement.

35 40 45 **[0039]** Along the line of the first set of UV-radiation-emitting units of the first set (and/or, equally, along the line of the second set), further UV-radiation emitting units may be arranged outside of the print swath of the print head. These further UV-radiation emitting units may be capable of only operating in two different lamp operation modes, e.g. in the off-mode and a full curing mode. In this way, simpler hardware may be used, reducing overall cost and complexity of the carriage.

50 55 **[0040]** In some advantageous embodiments of the method according to the second aspect, each of the UV-radiation-emitting units of the first set is individually and independently controlled to operate at a specific one of

the lamp operation modes further based on image information; the image information comprising information about whether and/or how much and/or what type or types of UV curable ink has or have previously been applied, or is or are to be applied in the future, to the current target section of the individual UV-radiation-emitting unit.

[0041] In some advantageous embodiments of the method according to the second aspect, each of the UV-radiation-emitting units of the first set is individually and independently controlled to operate at a specific one of the lamp operation modes further based on UV-radiation-emitting information; the UV-radiation-emitting information comprising information about how long and/or how often and/or with which intensity UV radiation has previously been emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting unit.

[0042] In some advantageous embodiments of the method according to the second aspect, the lamp operation modes comprise, in addition to the off-mode, at least three different radiation-emitting modes, each characterized by a different intensity with which the UV radiation is emitted onto the current target section in that radiation-emitting mode, e.g. realized as, and providing the same advantages, as discussed above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] The present invention will become more fully understood from the detailed description given herein below and the accompanying schematic drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

- Fig. 1 schematically shows a representation of an inkjet printer assembly according to an embodiment of the first aspect;
- Fig. 2 schematically shows details of the inkjet printer assembly during use thereof; and
- Fig. 3 schematically shows further details of the inkjet printer assembly during use thereof.

DETAILED DESCRIPTION OF THE DRAWINGS

[0044] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0045] Fig. 1 schematically shows a representation of an inkjet printer assembly 100 for printing an image on a recording medium according to an embodiment of the first aspect. With reference to Fig. 1, also embodiments of the method according to the second aspect will be described. It should be understood that the method according to the second aspect is usable with the inkjet

printer assembly 100, and that the method may be adapted or modified according to all modifications and variations described herein with respect to the inkjet printer assembly according to the first aspect, and vice versa.

[0046] The inkjet printer assembly 100 comprises a carriage 10 configured to move forward and backward along an axis in reciprocation in a scanning direction SD. The carriage 10 comprises a print head 12 configured to apply UV curable ink to the recording medium in a print swath, as will be explained in more detail with reference to Fig. 2 and Fig. 3 in the following.

[0047] Accordingly, the method according to the second aspect comprises the step of controlling the print head 12 of the carriage 10 of the inkjet printer assembly 100 to apply UV curable ink in a print swath to the recording medium based on the image to be printed. Furthermore, the method comprises the step of controlling the carriage 10 to move forward and backward along the axis in reciprocation in the scanning direction SD.

[0048] A first set of individual UV-radiation-emitting lamps 21-1, 21-2, .. , 21-14 (collectively designated in the following as 21-i) are arranged at the carriage 10 in a line, preferably essentially perpendicular, more preferably exactly perpendicular, to the scanning direction SD. The number of fourteen individual UV-radiation-emitting lamp 21-i is chosen as an example here; it should be understood that more or fewer UV-radiation emitting lamps 21-i may be provided.

[0049] In particular, the individual UV-radiation-emitting lamps may comprise, or consist of, UV-radiation-emitting light-emitting diodes, UV LEDs, although also other types of UV-radiation-emitting lamps may be used. It is also possible to provide some of the UV-radiation emitting lamps formed as UV LEDs, and some of the UV-radiation emitting lamps formed by other designs. For example, the UV-radiation emitting lamps 21-1 to 21-7 arranged inside the print swath of the print head 12 might be realized as comprising, or consisting of, UV-LEDs, whereas the UV-radiation emitting lamps 21-7 to 21-14 arranged outside the print swath are configured differently.

[0050] The line of the first set of UV-radiation emitting lamps 21-i is arranged at a trailing end of the carriage 10, or, more importantly, of the print head 12, with respect to a first direction of movement along the scanning direction SD. The first direction will in the following also be called - arbitrarily - a "forward" direction or a "rightward" direction, referring to the right side of Fig. 1 and, similarly, to the right side of Fig.2 and Fig. 3 as well.

[0051] The UV-radiation-emitting lamps 21-i are arranged and configured to emit UV radiation onto UV curable ink applied to the recording medium by the print head 12 according to an image to be printed onto the recording medium.

[0052] Preferably, at least two of the individual UV-radiation-emitting lamps 21-i of the first set are arranged within the print swath of the print head 12 and as will be explained in more detail with respect to Fig. 2 and Fig.

3. The print swath (or simply "swath" for short) is indicated by the extension of the print head 12 in a direction perpendicular to the scanning direction SD, which will herein be designated as a medium transport direction, or a medium movement direction MD.

[0053] The medium movement direction MD is a direction in which the recording medium is moved with respect to the axis along which the print head 12 moves in reciprocation in the scanning direction SD, or vice versa. For example, in roll-to-roll devices, the recording medium is usually moved along the medium movement direction MD with respect to the print head 12 and the rest of the inkjet printer assembly 100, whereas, e.g. in sheet printing devices, it may also be the case that the scanning direction SD axis of the print head 12 is moved with respect to the recording medium and to the rest of the inkjet printer assembly 100.

[0054] In the embodiment shown in Fig. 1, seven UV-radiation emitting lamps 21-1, ... 21-7 are arranged within the print swath of the print head 12. Seven other UV-radiation emitting lamps 21-8, ..., 21-14 are arranged outside of the print swath in the medium movement direction MD downstream of the print head 12, i.e. in the direction the recording medium is being moved to. It should be understood that more or fewer than seven UV-radiation emitting lamps 21-i may be arranged inside and/or outside the print swath of the print head 12.

[0055] Preferably, the number of UV-radiation emitting lamps 21-i is an integer multiple of a maximum number of steps in the medium movement direction MD that the print head may take in moving once through a region of the width (along the medium movement direction MD) the same size as the print swath. When the recording medium is moved with respect to the print head, this is usually done in steps of a certain minimum size, e.g. due to constructional issues. When there is at least one UV-radiation-emitting lamp 21-i provided for each step and at a corresponding location with respect to the print head 12, then even when the recording medium moves the minimum distance along the medium movement direction MD, it is guaranteed that even UV curable ink applied in the small area covered just now by the minimum distance movement may be supplied with UV radiation tailored specifically for that task.

[0056] Each UV-radiation-emitting lamp 21-i is configured to emit the UV radiation into its own current target section on the recording medium. Preferably, the individual UV-radiation-emitting lamps 21-i are arranged such that their respective current target sections are not distanced from one another. It is particularly preferred that their respective current target sections are directly adjacent to one another without, or substantially without, overlapping.

[0057] In order to clearly set a current target section of an individual UV-radiation-emitting lamp 21-i, some, or all, of the UV-radiation-emitting lamps 21-i may comprise, in addition to a UV radiation source such as a UV-LED, a radiation guide comprising, or consisting of, e.g. a

screen member and/or optical elements such as lenses, blends and so forth. The UV-LED may also be formed itself in such a way that it may be arranged at the carriage 10 such as to have a clearly defined and set current target section.

[0058] The carriage 10 of the embodiment shown in Fig. 1 preferably comprises an optional second set of UV-radiation-emitting lamps 22-1, 22-2, .. , 22-14 (in the following designated collectively as 22-i). Although the ideas expressed herein work equally well when there is only the first set of UV-radiation-emitting lamps 21-i provided (e.g. when the inkjet printer assembly 100 is in any case only configured to print during the forward movement along the scanning direction SD, in the following the embodiment will be described further with reference to both the first set of UV-radiation-emitting lamps 21-i and the second set of UV-radiation emitting lamps 22-i.

[0059] Preferably, the second set of UV-radiation-emitting lamps 22-i is configured, and arranged, in the same way at the carriage 10 as the first set of UV-radiation emitting lamps 21-i, the only difference being that, whereas the first set is arranged at the trailing end of the carriage with respect to the first direction (forward), the second set of UV-radiation emitting lamps 22-i is arranged at a trailing end of the carriage 10 with respect to a second direction of movement along the scanning direction SD. The second direction will in the following also be called a "backward" direction or a "leftward" direction, referring to the left side of Fig. 1 and, similarly, to the left side of Fig.2 and Fig. 3 as well.

[0060] Accordingly, it is preferred that both the first set and the second set of UV-radiation-emitting lamps 21-i, 22-i are arranged at the carriage 10 along lines perpendicular to scanning direction SD of the print head 12 and parallel to the recording medium, and in parallel to each other. The first and the second set may be configured such that there is a one-to-one-correspondence between each individual lamp 21-i of the first set and each individual lamp 22-i of the second set. In other words, for each of the individual lamps 21-i of the first set there may be one corresponding individual lamp 22-i of the second set arranged directly along the scanning direction SD of the individual UV-radiation-emitting lamp 21-i of the first set.

[0061] Alternatively, the first and the second set of UV-radiation-emitting lamps 21-i, 22-i may have different numbers of individual lamps 21-i, 22-i and/or the individual lamps 22-i of the second set may be arranged with an offset (in the medium movement direction MD) with respect to the individual lamps of the first set 21-i. In this way, a better coverage of the recording medium, on average, may be achieved.

[0062] Each of the UV-radiation-emitting lamps 21-i of the first set, and each of the individual UV-radiation emitting lamps 22-i of the second set, is individually and independently controllable to operate in at least three different lamp operation modes. In the embodiment of Fig. 1, each individual UV-radiation emitting lamp 21-i, 22-i

(of both the first and the second set) is individually and independently controllable to operate in four different lamp operation modes.

[0063] Preferably, there is only the single set (e.g. arranged in a single line) of the first set of UV-radiation-emitting lamp 21-i arranged at the one end (trailing during the forward movement) of the carriage 10 and of the print head 12, and only the single set (e.g. arranged in a single line) of the second set of UV-radiation emitting lamps 22-i arranged at the other end (trailing during the backward movement) of the carriage 10 and of the print head 12, so that the advantages described herein may be achieved with comparatively little expenditure for hardware.

[0064] The inkjet printer assembly 100 comprises a controller 30 configured to control each of the UV-radiation-emitting lamps 21-i, 22-i of the first set and of the second set individually and independently to currently operate at a specific one of the lamp operation modes based on a current target section of that UV-radiation-emitting lamp 21-i, 22-i. The current target section is a section of the recording medium onto which that individual UV-radiation-emitting lamp 21-i, 22-i is currently positioned to emit the UV radiation.

[0065] The controller 30 may be formed as, or realized as, a microcontroller, a PC, a combination of a CPU and a memory, an ASIC, a FPGA, or any other logical circuitry.

[0066] In the following, reference signs and depictions in Fig. 2 and Fig. 3 will be used to explain the different lamp operation modes and the advantages associated therewith.

[0067] Fig. 2 and Fig. 3 schematically show details of the inkjet printer assembly 100 in use. Fig. 2 and Fig. 3 show in particular a section of a recording medium 1 onto which the inkjet printer assembly 100 is printing. Fig. 2 shows a point in time during which the print head 12 moves in the forward (rightward) direction, and Fig. 3 shows a later point in time, when the print head 12 moves, during the immediately following leg, in the backward (leftward) direction. For illustration, in Fig. 2 and Fig. 3 the symbols representing the individual UV-radiation emitting lamps 21-i, 22-i have been replaced with letters (C, P, L, and O) designating the respective lamp operation mode in which each of the UV-radiation emitting lamps 21-i, 22-i is controlled to operate at the respectively shown point in time.

[0068] The four lamp operation modes comprise an off-mode, O, in which no UV radiation is emitted, and three radiation-emitting modes L, P, C, in which UV radiation is emitted with different intensities. The radiation-emitting modes are characterized in that they emit the UV radiation with different intensities (or emission power) and comprise, or consist of:

- a full cure mode, C, for finally curing the UV curable ink on the recording medium 1;
- a pinning mode, P, for pinning a UV curable ink layer

- deposited on another UV curable ink layer; and
- a low mode, L, for pinning a very first layer of UV curable ink applied to (i.e. deposited on) the recording medium.

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[0069] The intensity, or emission power, with which the UV radiation is emitted in the full cure mode, C, is higher than in the pinning mode, P, and the intensity, or emission power, with which the UV radiation is emitted in the pinning mode, P, is higher than in the low mode, L.

The intensity, or emission power, with which the UV radiation is emitted in the off mode, may be zero. The intensity, or emission power, with which the UV radiation is emitted in the low mode, may be in the range of 10% to 30% of the intensity with which the UV radiation is emitted in the full cure mode. The intensity, or emission power, with which the UV radiation is emitted in the pinning mode, may be in the range of 30% to 70% of the intensity with which the UV radiation is emitted in the full cure mode.

[0070] The radiation-emitting modes each may consist of a range of intensities, or may be characterized by essentially a single intensity value.

[0071] Methods to control one of the individual lamps 21-i, 22-i to emit a specific radiation intensity in a specific radiation-emitting mode may comprise controlling that lamp 21-i, 22-i to, when emitting, continuously emit UV radiation with a specific instantaneous intensity that changes with, but is constant at, each of the radiation-emitting modes. Alternatively the individual UV-radiation-emitting lamps 21-i, 22-i may be controlled to intermittently emit UV radiation with always the same instantaneous radiation intensity but with different percentages of emitting and non-emitting time periods, in the same way in which pulse-width modulation enables different voltage outputs (on average) by outputting a single constant instantaneous voltage over different time percentages of a time cycle.

[0072] In Fig. 2 and Fig. 3, for simplification, only the print head 12 and the first and the second sets of UV-radiation-emitting lamps 21-i, 22-i are shown with respect to the recording medium 1 positioned thereunder. The current target sections should be imagined as lying directly under the respective symbols C, P, L, or O.

[0073] In Fig. 2, a section 51 of the recording medium 1 has been completely printed, while further sections 52, 53, 54, each divided into a respective section 52-L, 53-L, 54-L currently to the left of the print head 12 and into a respective section 52-R, 53-R, 54-R currently to the right of the print head 12, are still undergoing printing. The same applies to Fig. 3; the difference is that in Fig. 3 the recording medium 1 has advanced one step along the medium movement direction MD with respect to the print head 12. In Fig. 3 it is evident that, by this advancement, one UV-radiation-emitting lamp 21-1, 22-1 of each of the first and second set has left the section 54, whereas one UV-radiation-emitting lamp 21-7, 22-7 of each of the first and the second set has entered the section 52, in

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accordance with the swath of the print head 12 moving with respect to the recording medium 1 in the same way.

[0074] Each of the UV-radiation-emitting lamps 21-i of the first set, and each of the UV-radiation-emitting lamps 22-i of the second set, is individually and independently controlled, by the controller 30, to operate at a specific one of the lamp operation modes O, L, P, C further based on image information. Image information should be understood as comprising information about whether and/or how much and/or what type or types of UV curable ink has or have previously been applied, or is or are (going) to be applied in the future, to the current target section of the individual UV-radiation-emitting lamp, as has been discussed in the foregoing, and as will be explained in more detail in the following.

[0075] Further, each of the UV-radiation-emitting lamps 21-i of the first set, and each of the UV-radiation-emitting lamps 22-i of the second set, is individually and independently controlled, by the controller 30, to operate at a specific one of the lamp operation modes O, L, P, C further based on UV-radiation-emitting information. UV-radiation-emitting information should be understood as comprising information about how long and/or how often and/or with which intensity UV radiation has previously been emitted, or is (going) to be emitted in the future, to the current target section of the individual UV-radiation-emitting lamp, as has been discussed in the foregoing and as will be explained in more detail in the following.

[0076] In the present embodiment, the controller 30 is, at least with respect to the UV-radiation emitting lamps 21-1 to 21-7 and 22-1 to 22-7 arranged within the print swath of the print head 12 (but possible for all of the lamps 21-i, 22-i), configured to:

- control each individual UV-radiation-emitting lamp 21-i, 22-i to operate in the low mode, L, when the image information indicates that the current target section of that individual UV-radiation-emitting lamp 21-i, 22-i is a section to which
 - a) a single, first layer of UV curable ink has been applied so far and
 - b) at least one more layer of UV curable ink is to be applied in the future;
- control each individual UV-radiation-emitting lamp 21-i, 22-i to operate in the pinning mode, P, when the image information indicates that the current target section of that individual UV-radiation-emitting lamp 21-i, 22-i is a section to which
 - a) more than one layer of UV curable ink has been applied so far and
 - b) at least one more layer of UV curable ink is to be applied in the future;
 - and/or
- control each individual UV-radiation-emitting lamp

21-i, 22-i to operate in the full curing mode, C, when the image information indicates that the current target section of that individual UV-radiation-emitting lamp 21-i, 22-i is a section to which

- a) at least one layer of UV curable ink has been applied so far and
- b) no more layers of UV curable ink are to be applied in the future.

[0077] In other embodiments, other rules for controlling the UV-radiation emitting lamps 21-i, 22-i to operate in the different lamp operation modes O, L, P, C, and/or other lamp operation modes, may be applied.

[0078] Depending on the properties of the used UV curable ink, the maximum number of layers of UV curable ink deposited on top of each other, the interactions of the different UV curable inks with each other and so on, even more different radiation-emitting modes having even more different levels of emitted UV radiation intensity may be provided. For example, there may be two (or more) pinning modes characterized by different UV radiation intensities between the low mode and the full curing mode, two (or more) low modes characterized by different UV radiation intensities between the pinning mode (or modes) and the off-mode, and so on.

[0079] The radiation-emitting modes may even form a continuum of infinitely many radiation-emitting modes, that is, each of the UV-radiation-emitting lamps may be configured to be able to be controlled to emit, within a certain range, any specific radiation intensity in a continuous way. Alternatively or additionally, one, any, or all, of the radiation-emitting modes may be characterized by discrete radiation intensities as based in regular and/or irregular intervals from each other.

[0080] As an example, in Fig. 2 the right side 54-R of the section 54 is still clear of any UV curable ink while the print head 12 is traveling in the rightward direction. Accordingly, the lowest two UV-radiation emitting lamps 22-1, 22-2 of the second set, arranged at the leading edge of the print head 12 during that leg of the reciprocating movement along the scanning direction SD, are controlled by the controller 30 to operate in the off-mode, O. In this way, when the print head 12 continues (and finishes) its movement to the rightward side of the recording medium 1, the section 54-R consists of current target sections of those UV-radiation emitting lamps 22-1, 22-2 during that leg of the movement of the print head 12. As the lamps 22-1, 22-2 operate in the off-mode, no UV radiation is applied to the section 54-R.

[0081] By contrast, the sections 52-R and 53-R above, on which already at least one layer of ink was present before the current leg of the movement of the print head 12, will be subjected to UV radiation according to the UV-radiation emitting lamps 21-3, 21-4, 21-5, 21-6 and 22-3, 22-4, 22-5, 22-6 operating in the pinning mode, P into their respective current target sections.

[0082] During the movement of the print head 12

shown in Fig. 2, UV curable ink will be applied to the part of section 54 between the sections 54-R and 54-L, to which part in the future additional layers of UV curable ink will be applied. For this reason, the (trailing) UV-radiation emitting lamps 21-1, 21-2 are set to the low mode, L in Fig. 2.

[0083] In Fig. 3, the situation is shown in which the additional layer has been applied to the section 54-R so that the (now trailing) UV-radiation emitting lamps 22-1, 22-1 are set to the pinning mode P, whereas the (now leading) UV-radiation emitting lamps 21-1, 21-2 are still set to the low mode, L.

[0084] The controller 30 may further be configured to track the total integrated quantity of UV radiation (which may be a part of the radiation-emitting information) applied to each section, or pixel, of the recording medium 1, and to control the UV-radiation emitting lamps 21-8 to 21-14 of the first set and/or the UV-radiation emitting lamps 22-8 to 22-14 of the second set, which are arranged outside the print swath of the print head 12, in such a way that, after the carriage 10 has completely moved away from the recording medium 1, every section, or pixel, of the recording medium 1 has been exposed to the same total integrated quantity of UV radiation. For that reason, e.g., the topmost UV-radiation emitting lamps 21-14 and 22-14 are in, in Fig. 3, controlled to operate in the off-mode, O.

[0085] While detailed embodiments of the present invention are disclosed herein, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any advantageous combination of such claims are herewith disclosed.

[0086] Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. The terms "a" or "an", as used herein, are defined as one or as more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language).

[0087] It will be evident that the described embodiments may be varied in many ways. All such modifications as would be evident to one skilled in the art starting from what is explicitly described are intended to be included.

Claims

1. A method for operating an inkjet printer assembly (100) for printing an image on a recording medium (1), the inkjet printer assembly (100) comprising:

a carriage (10) configured to move forward and backward along an axis in reciprocation in a scanning direction (SD), the carriage carrying at least one print head (12);
 wherein the carriage (10) comprises a print head (12) configured to apply UV curable ink to the recording medium (1) in a print swath;
 a first set of individual UV-radiation-emitting units (21-i) arranged at the carriage (10), the UV-radiation-emitting units (21-i) being arranged and configured to emit UV radiation onto UV curable ink applied to the recording medium (1);
 wherein the first set of UV-radiation-emitting units (21-i) is arranged at a trailing end of the carriage (10) with respect to a forward movement along the axis of the carriage (10);
 wherein each of the UV-radiation-emitting units (21-i) of the first set is individually and independently controllable to operate in at least three different lamp operation modes (O, L, P, C);
 the at least three lamp operation modes (O, L, P, C) comprising:

- an off-mode (O) in which no UV radiation is emitted and
- at least two different radiation-emitting modes (L, P, C), each **characterized by** a different intensity with which the UV radiation is emitted in that radiation-emitting mode;

the method comprising the steps of:

- a. In a first swath, applying a first droplet of UV curable ink onto a first position of the recording medium, wherein in the first swath a first UV-radiation-emitting unit of the set of UV-radiation-emitting units is positioned at the same position in the sub-scanning direction as the first position of the recording medium, and wherein the first UV-radiation-emitting unit is controlled to operate in a first mode of the at least two different radiation-emitting modes;
- b. Moving the carriage and the recording medium with regard to one another in a sub-scanning direction, the sub-scanning direction being essentially perpendicular to the scanning direction, thereby bringing a second UV-radiation-emitting unit of the set of UV-radiation-emitting units to a position

having the same position in the sub-scanning direction as the first position of the recording medium;

c. Moving the carriage in the scanning direction in a second swath, wherein the second UV-radiation-emitting unit is at a position having the same position in the sub-scanning direction as the first position of the recording medium and the second UV-radiation-emitting unit is controlled to operate in a second mode of the at least two different radiation-emitting modes.

2. The method according to claim 1,

wherein each of the UV-radiation-emitting units (21-i) is individually and independently controlled to operate at a specific one of the lamp operation modes (O, L, P, C) further based on image information;

the image information comprising information about whether and/or how much and/or what type or types of UV curable ink has or have previously been applied, or is or are to be applied in the future, to the current target section of the individual UV-radiation-emitting unit (21-i).

3. The method according to claim 2, wherein each of the UV-radiation-emitting units (21-i) is individually and independently controlled to operate at a specific one of the lamp operation modes (O, L, P, C) further based on UV-radiation-emitting information; the UV-radiation-emitting information comprising information about how long and/or how often and/or with which intensity UV radiation has previously been emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting unit (21-i).

4. The method according to claim 2 or 3, wherein the lamp operation modes comprise (O, L, P, C), in addition to the off-mode (O), at least three different radiation-emitting modes (L, P, C), each **characterized by** a different intensity with which the UV radiation is emitted onto the current target section in that radiation-emitting mode.

5. An inkjet printer assembly (100) for printing an image on a recording medium (1), the inkjet printer assembly (100) comprising:

a carriage (10) configured to move forward and backward along an axis in reciprocation in a scanning direction (SD); wherein the carriage (10) comprises a print head (12) configured to apply UV curable ink to the recording medium (1) in a print swath;

a first set of individual UV-radiation-emitting units (21-i) arranged at the carriage (10), the UV-radiation-emitting units (21-i) being arranged and configured to emit UV radiation onto UV curable ink applied to the recording medium (1); wherein the first set of UV-radiation-emitting units (21-i) is arranged at a trailing end of the carriage (10) with respect to a forward movement along the axis of the carriage (10); wherein each of the UV-radiation-emitting units (21-i) of the first set is individually and independently controllable to operate in at least three different lamp operation modes (O, L, P, C); the at least three lamp operation modes (O, L, P, C) comprising:

- an off-mode (O) in which no UV radiation is emitted and
- at least two different radiation-emitting modes (L, P, C), each **characterized by** a different intensity with which the UV radiation is emitted in that radiation-emitting mode; and

a controller (30) configured to control the inkjet printing assembly (100) to perform a method according to any of the claims 1-4.

6. The inkjet printer assembly (100) according to claim 5, wherein the lamp operation modes (O, L, P, C) comprise, in addition to the off-mode (O), at least three different radiation-emitting modes (L, P, C), each **characterized by** a different intensity with which the UV radiation is emitted in that radiation-emitting mode (L, P, C).

7. The inkjet printer assembly (100) according to claim 5 or 6,

wherein the controller (30) is further configured to control each of the UV-radiation-emitting units (21-i) individually and independently to operate at a specific one of the lamp operation modes (O, L, P, C) further based on image information about the current target section; the image information comprising information about whether and/or how much and/or what type or types of UV curable ink has or have previously been applied, or is or are to be applied in the future, to the current target section of the individual UV-radiation-emitting unit (21-i).

8. The inkjet printer assembly (100) according to claim 7,

wherein the controller (30) is further configured to control each of the UV-radiation-emitting units

(21-i) individually and independently to operate at a specific one of the lamp operation modes (O, L, P, C) further based on radiation-emitting information about the current target section; the radiation-emitting information comprising information about how long and/or how often and/or with which intensity UV radiation has previously been emitted, or is to be emitted in the future, to the current target section of the individual UV-radiation-emitting unit (21-i).

9. The inkjet printer assembly (100) according to claim 7 or 8

wherein the controller (30) is configured to control each individual UV-radiation-emitting unit (21-i) to operate in the off-mode (O) when the image information indicates that the current target section of that individual UV-radiation-emitting unit (21-i) is a section to which no UV curable ink has yet been applied.

10. The inkjet printer assembly (100) according to any one of claims 7 to 9,

wherein the controller (30) is configured to control each individual UV-radiation-emitting unit (21-i) to operate in a first radiation-emitting mode (L) when the image information indicates that the current target section of that individual UV-radiation-emitting unit (21-i) is a section to which

- a) a single, first layer of UV curable ink has been applied so far and
- b) at least one more layer of UV curable ink is to be applied in the future.

11. The inkjet printer assembly (100) according to any one of claims 7 to 10,

wherein the controller (30) is configured to control each individual UV-radiation-emitting unit (21-i) to operate in a second radiation-emitting mode (P) when the image information indicates that the current target section of that individual UV-radiation-emitting unit (21-i) is a section to which

- a) more than one layer of UV curable ink has been applied so far and
- b) at least one more layer of UV curable ink is to be applied in the future.

12. The inkjet printer assembly (100) according to any one of claims 7 to 11,

wherein the controller (30) is configured to control each individual UV-radiation emitting unit (21-i) to operate in a third radiation-emitting mode (C) when the image information indicates that the current target section of that individual UV-radiation-emitting unit (21-i) is a section to which

- a) at least one layer of UV curable ink has been applied so far and
- b) no more layers of UV curable ink are to be applied in the future.

13. The inkjet printer assembly (100) according to any one of claims 5 to 12,

wherein the UV-radiation-emitting units (21-i) of the first set are arranged at the carriage (10) along a line perpendicular to the axis and parallel to the recording medium (1).

14. The inkjet printer assembly (100) according to any one of claims 5 to 13,

wherein at least one the UV-radiation-emitting units (21-i) of the first set is arranged outside of the print swath of the print head (12).

15. The inkjet printer assembly (100) according to any one of claims 5 to 14,

wherein a second set of UV-radiation-emitting units (22-i) is arranged at a trailing end of the carriage (10) with respect to a backward movement along the axis of the carriage (10).

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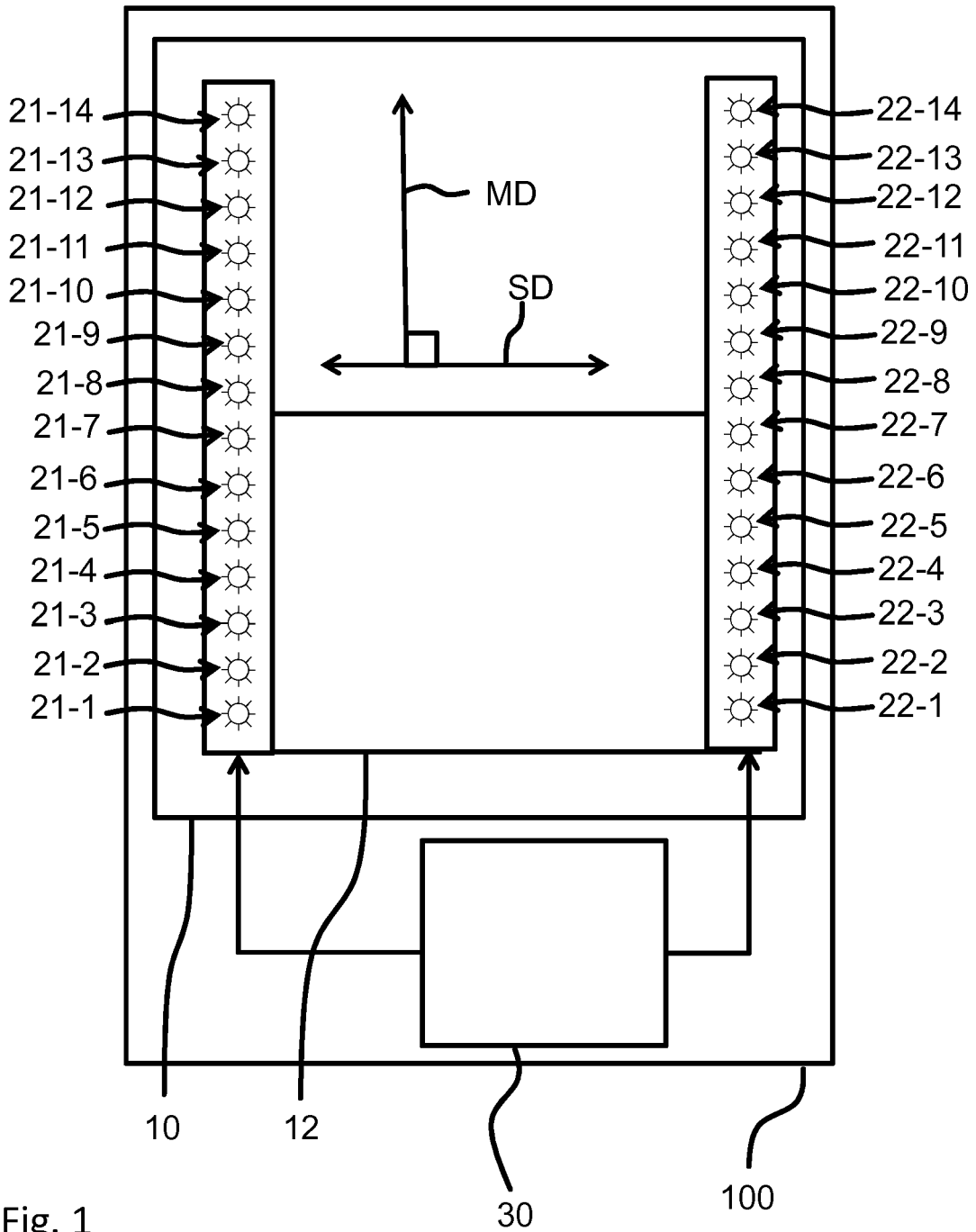


Fig. 1

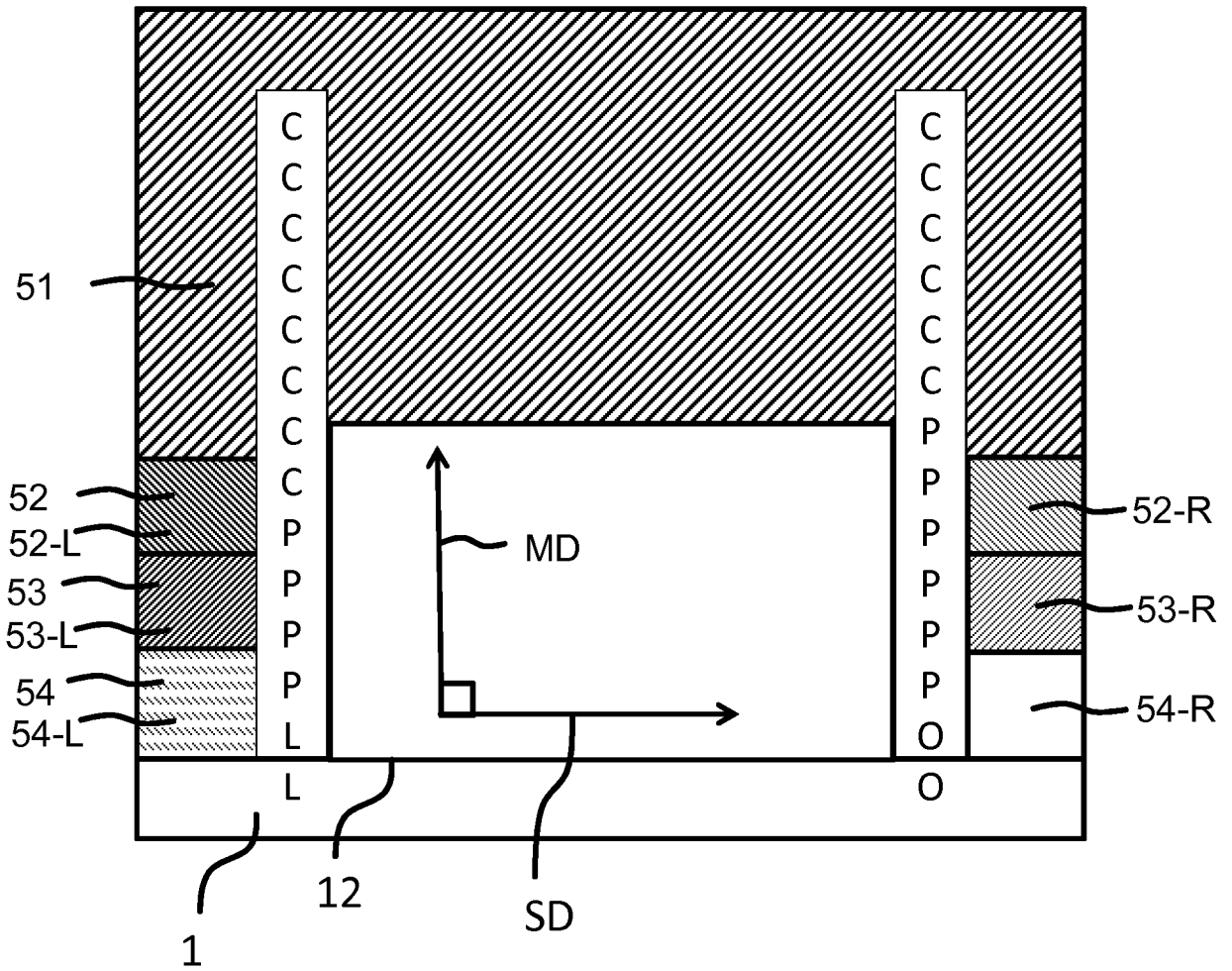


Fig. 2

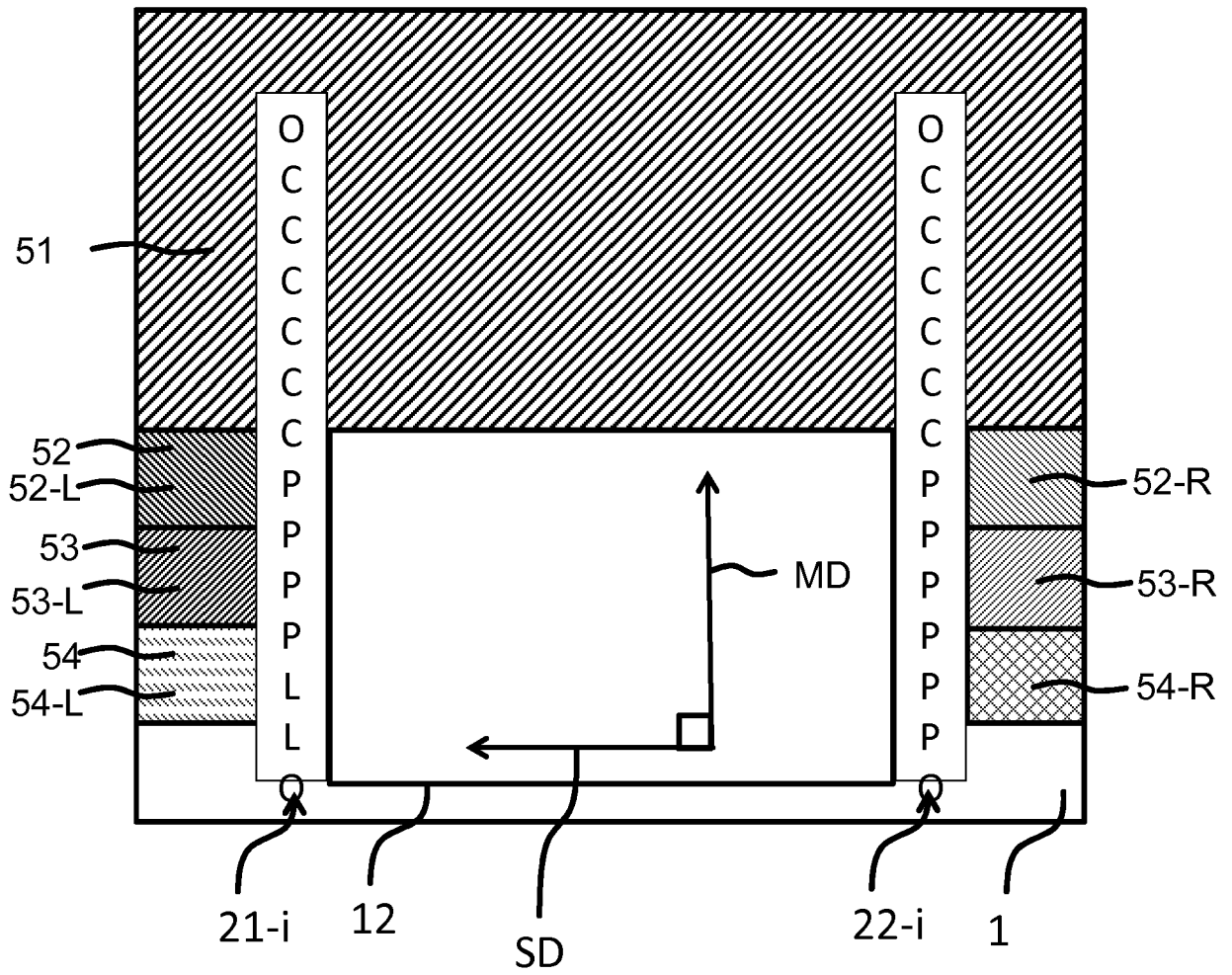


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 18 17 5699

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EP 18 17 5699

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