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(54) **HAIR STYLING DEVICE**

(57) A hair styling device comprises an optical radiation source (L) for radiating hair (H), a sensor unit (S) for measuring effects from radiating hair (H), and a feedforward control device for controlling the optical radiation source (L) in dependence on a signal from the sensor unit (S). The optical radiation source (L1, L2) may produce a first flash having a first energy density that may be lower than required for photo-thermal hair reshaping, the optical radiation source being controlled to produce a subsequent flash in dependence on a sensor signal obtained in response to the first flash, which subsequent flash may have at least the first energy density. The sensor unit (S) may include a sensor arranged before the optical radiation source in a hair flow direction. The hair styling device may comprise, along a direction in which the hair (H) is guided, a first sensor (S1), a first LED unit (L1) being controlled in dependence on a signal from the first sensor (S1), a second sensor (S2), and a second LED unit (L2) being controlled in dependence on a signal from the second sensor (S2). The direction in which hair is guided through the hair styling device may determine which part of the optical radiation source will act as the first LED unit (L1). The hair styling device may comprise a drive mechanism (D) to move the hair (H) along the optical radiation source (L) at a speed controlled by the feedforward control device in dependence on the signal from the sensor unit (S).

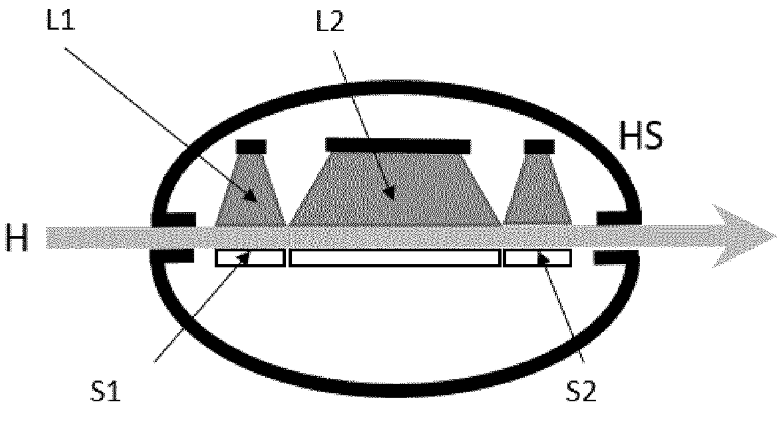

Fig. 3a

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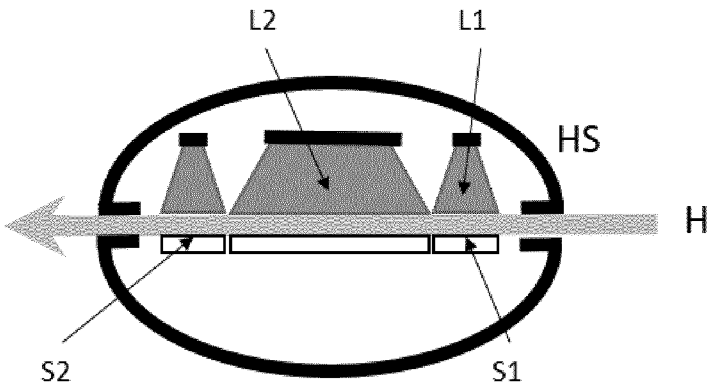

Fig. 3b

Description

FIELD OF THE INVENTION

[0001] The invention relates to a hair styling device for e.g. hair crimping, curling, perming and straightening.

BACKGROUND OF THE INVENTION

[0002] EP2861096 discloses a hair shaping device for use for hair shaping comprising a number of radiation sources for hair shaping, and a control device for the emission of radiation.

SUMMARY OF THE INVENTION

[0003] It is, inter alia, an object of the invention to provide an improved hair styling device. The invention is defined by the independent claims. Advantageous embodiments are defined in the dependent claims.

[0004] Embodiments of the invention are based on the following considerations. It is highly desired by the consumer to style hair without heat damage. For prior art hair styling (heating by conduction) the hair temperature is limited by the system. The hot plates are set at a maximum temperature. This is not the case for photo-thermal hair reshaping. Hairs can easily be heated above a damaging temperature (> 180 °C). Therefor it is necessary to determine the hair temperature during the process. This needs to be done at local level since hair characteristics will influence the hair temperature. Hair characteristics are various, and different hair characteristics can occur within the same hair tress, e.g. as regards color, thickness, volume, alignment, etc..

[0005] Embodiments of the invention provide a hair styling device that comprises an optical radiation source for radiating hair, a sensor unit for measuring effects from radiating hair, and a feedforward control device for controlling the optical radiation source in dependence on a signal from the sensor unit. The optical radiation source may produce a first flash having a first energy density that may be lower than required for photo-thermal hair reshaping, the optical radiation source being controlled to produce a subsequent flash in dependence on a sensor signal obtained in response to the first flash, which subsequent flash may have at least the first energy density. The sensor unit may include a sensor arranged before the optical radiation source in a hair flow direction. The hair styling device may comprise, along a direction in which the hair is guided, a first sensor, a first LED unit being controlled in dependence on a signal from the first sensor, a second sensor, and a second LED unit being controlled in dependence on a signal from the second sensor. The direction in which hair is guided through the hair styling device may determine which part of the optical radiation source will acts as the first LED unit. The hair styling device may comprise a drive mechanism to move the hair along the optical radiation source at a speed controlled by the feedforward control device in dependence on the signal from the sensor unit.

[0006] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figs. 1-5 illustrate various embodiments of the invention.

DESCRIPTION OF EMBODIMENTS

[0008] Hair damage, particularly due to the application of heat, is the biggest concern of consumers. Temperature is a major cause of damage done to the hair. It is therefore highly desired to style hair (hair crimping, curling, perming and straightening) without abundant heat. Abundant heat: a hair temperature higher than 180 °C at a certain treatment time (depending on hair characteristics).

[0009] For prior art contact heating this can be achieved by controlling the system temperature. If the system temperature is set to a maximum, each hair will never exceed this temperature. The maximum hair temperature is controlled by the system temperature. The latter does not hold for photo-thermal hair reshaping.

[0010] Applicant's earlier application EP3216368 (Applicant's ref. 2016PF00294), incorporated herein by reference, describes a photo-thermal hair reshaping, e.g. styling, curling, straightening, by using pulse-driven light emitting diodes (LEDs). Light selectively heats up the hair by absorption within a narrow range of wavelengths (preferably between 400 and 900 nm, and more preferably between 450 and 550 nm) and within a short period of time (preferably shorter than or equal to 300 ms). An embodiment may include an optical feedback system e.g. LED light sensor, positioned in the inner surface of a sliding optical shield or in line with the array of LEDs, to sense light, e.g. transmitted and/or reflected light, to provide feedback to the control unit to configure electrical parameters for delivery of light optimized for hair curling. An alternative embodiment could also include a temperature and time sensor to adapt the treatment settings. The system described in this earlier application is an example of a system that can be advantageously provided with the feedforward control of the present invention.

[0011] Light selectively heats up the hair, in particular the melanin of the hair, by absorption within a certain range of wavelengths (preferably between 400 and 900 nm and more preferably between 400 and 550 nm) and within a short period of time (preferably shorter than 300 ms). After the exposure of a light pulse, the hair temperature will increase depending on its volume, absorption rate and initial temperature.

[0012] In an embodiment of the present invention, the LED hair styler regulates the current (amount and time) through the LED regardless of variations in power supply or changes in forward voltage. This driver also ensures that the current does not exceed the maximum current rating of the LED. After the release of a predefined light pulse the hair heats to a certain temperature. The temperature increase depends among others by the absorption rate of the hair. The absorption rate of the hair is on its turn determined by the hair characteristics: color, shape, thickness, melanin content, ... Large variations in hair characteristics can be found.

[0013] For example, in an extreme case: bleached hair has no melanin (a major chromophore contributing to photo-thermal hair reshaping), which makes it challenging to use photo-thermal hair reshaping. In a less extreme case: blond hair needs a considerably higher light density (J/cm^2) than brown hair to heat the hair to a comparable temperature.

[0014] Next, also variations within the hairs occur. For instance, during the lifetime of hair, hair will get thinner because of external factors e.g. chemicals, UV, brushing, etc. The hair characteristics will change during lifetime. For instance, the hair diameter and the chromophore concentrations can change along the hair. From top to tip, the hair diameter may decrease.

[0015] Furthermore, it is of importance to know how much hairs will be irradiated. Assuming that the photon recycling is 100%, the smaller the amount of hair that is exposed to the same light pulse, the larger the temperature increase of the exposed hairs will be.

[0016] Overall, the above mentioned hair variations should be taken into account before a potentially damaging photo-thermal light pulse is deployed. However, preventing light-induced heat damage caused by the variations between and within the hairs is not addressed by the prior art.

[0017] It is an object of embodiments of the present invention to mitigate light-induced heat damage to the hair. Hairs can easily be heated by absorption above damaging temperature (> 180 °C). Therefore, it is necessary to determine the hair temperature during the process. This needs to be done with high precision since hair characteristics will influence the hair temperature. Embodiments of the invention thus show one or more of the following features: during heating the hair by light irradiation, a feedforward loop is in control of the hair properties to overcome overexposure, and during or in-between light exposure (heating of the hairs) the hair properties are measured by one or more sensors before and/or within the treatment area. Advantageously, multiple sensor locations can be used, as shown in Figs. 5a and 5B, e.g. in a checkerboard configuration as shown in Fig. 5a.

[0018] Apart from emitting light when a current is applied to a LED, LEDs also have the property that they generate a current when light is applied to the LED when the LED is not used as a light source. So, if light is absorbed by the diode: an inverse current is generated. So, LEDs that are momentarily not used, can be used as light sensors.

[0019] A first aspect of the invention to mitigate light-induced heat damage to the hair provides a feedforward control using a double flash, i.e. a double light pulse within a short time interval (< 200 ms) with the same light source. The first pulse has a relatively low light intensity, and its reflection spectrum is measured with photoelectric sensors and/or the hair temperature is measured with an IR sensor. The sequential second pulse is adjusted to the reflectance rate of the first pulse (transfer function) and is used to photo-thermally heat the hair for reshaping. In this order each second light pulse will heat the hair without running the risk of over-treating the hair.

[0020] The first light flash is used to measure the status and the characteristics of the hair. Its intensity is between 0.5 and 7 J/cm^2, preferably between 0.5 and 2 J/cm^2. By the reflection signal of the hair, one can make an estimate about the hair color and thickness. From the signal of the IR sensor one can derive the current hair temperature. The sequential second light pulse (intensity > 2 J/cm^2) is adjusted accordingly to the information retrieved from the first light flash. Advantageously, both light flashes are produced by the same LEDs. Because the measurement area and treatment area are at the same location, the system will work independent from the direction the hair is guided through the styler.

[0021] Embodiments of this first aspect have one or more of the following features: The (same) light source in the hair care device is used for detection as well as for treatment. The hair properties of the hair are measured via a low(er) light exposure (flash 1). By a feedforward loop the gathered information from flash 1 (reflection, absorption, etc.) is fed to the system and a sequential second light exposure is calculated (timing and intensity) and delivered to the hairs. The system response time (interval between light flashes) is within milliseconds (not noticeable to consumer).

[0022] A second aspect of the invention to mitigate light-induced heat damage to the hair provides sensing and treatment for a feed forward control. In case the direction of the hair bundle through the styler is fixed (e.g. as in an auto-curler, like the Philips HPS940), the system can be separated in two sections.

[0023] The first section serves to determine the optical characteristics of the bundle of hair. The bundle is exposed to a light source with a considerably lower intensity, but it has the same optical characteristics as the light source at the second section for heating and shaping the hairs. Its reflection spectrum is measured with photoelectric sensors and/or the hair temperature is measured with an IR sensor. The information derived from the reflection spectrum and/or the temperature sensor is a direct link to the optical behavior of that particular section of the hair tress exposed to that particular wavelength spectrum. In that way the relation between light intensity and increase in hair temperature for that particular part can be determined and be fed forward to the section in the hair where hair shaping takes place.

[0024] The second section serves to shape the hair by the described light exposing method. Because the speed of the hair tress in the system is known, also the optical characteristics, determined in the first section, of the tress passing this section are known. By continuously adapting the light intensity of the second section according the calculated values based on the previously determined characteristics, the temperature of the hair can be set to the desired.

[0025] A preferred execution provides a continuous flow of the hair through the system, but of course the method can also be applied to solutions, in which hair is stopped, exposed and measured in the first section, transported to the second session and exposed again with the final intensity.

[0026] If the direction of the hair bundle through the hair styler is unknown (e.g. as in a straightener) the same control principle can be used, in which case the active area is preferably separated into three sections. The central section is the treatment section. The outer sections are the measurement sections. The measurement sections contain at least a temperature sensor to determine the direction the hair is fed through the system, as the entrance temperature of a hair bundle is lower than the exit temperature. When the direction of the hair through the system is known, the feed forward principle is equal to the described method with the first and second section.

[0027] Embodiments of this second aspect of the invention show one or more of the following features: Measuring the optical hair properties prior to treatment. The sensor section has the same optical characteristics as the treatment section.

[0028] In a third aspect of the invention to mitigate light-induced heat damage to the hair, the light emitting treatment area is divided into more than one section, e.g. by wiring the light sources in clusters. A first light treatment area section is set to a certain intensity while the hair temperature is continuously measured. If the hair temperature exceeds a certain level, the light intensity of the next light emitting treatment area section can be lowered. Or vice versa. This way the speed of the treatment does not have to be adjusted. Differences between the hairs (e.g. as regards volume, thickness, color, alignment, etc.) are dealt with by means of different light intensity patterns. This method is suitable for devices with single or dual directional hair transport. For a single-directional hair transport styler, like an auto-curler, the entrance part of the hair in the device is known. The sensors simply need to determine the increase in hair temperature after each treatment area and calculate the intensity for subsequent section. When using this method in e.g. a straightener, the direction of the hair bundle through the system is not known. By using the temperature sensors in the system, the direction of the hair bundle can be determined as the entrance temperature of a hair bundle is lower than the exit temperature. When the direction of the hair is known, controlling the intensity of separate areas is equal to the method of the single directional solution.

[0029] Another solution is tuning of the speed (hair intake) of the haircare device. This way differences between the hairs (e.g. as regards volume, thickness, color, alignment, etc.) can be dealt with in different light exposure times. For example, the exposure time for thin black hair will be shorter (< 5 s) than for thick blond hair. Next to tuning the light intensity one can also think of varying the exposure timing by adjusting the hair intake speed. This way the light intensity remains the same however the light exposure time is adjusted. This method is particularly useful when the hair bundle is automatically transported through the styler (e.g. as in an auto-curler). As a side effect the overall treatment time of each hair strand will vary (e.g. between 0 and 20 s).

[0030] Embodiments of this third aspect show one or more of the following features: A first part of the light emitting treatment area (perpendicular to the hair input) is used for detection, and a next part of the same light emitting treatment area is used for treatment. Or vice versa. Furthermore, the treatment area can be gradually divided into multiple sections up to the amount of light sources perpendicular to the hair input. For example, the light emitting treatment area can be divided into 4 sensor sections alternated with 4 treatment sections. Starting with a sensor part or starting with a treatment part. This latter feature may be based on an LED checkerboard configuration as shown in Fig. 5a.

Fig. 1 shows a first embodiment of the invention, in a hair curler example. Hair H is wrapped around a cylinder C. The hair H is irradiated by an LED unit L, while a sensor S measures effects of the radiation. To mitigate the risk of overexposure to the hair H, the sensor signal is processed by a feedforward controller (not shown) that control the LED unit L.

Fig. 2 shows a second embodiment of the invention, again in a hair curler example. The Fig. 2 embodiment differs from the Fig. 1 embodiment in that multiple LED units L1, L2 and multiple sensors S1, S2 are present. In this way, multiple sensors S1, S2 are used to better control the heating of the hairs. Also, reflective areas R1, R2 are present so that no light energy is wasted.

Figs. 3a and 3b show a third embodiment of the invention, viz. a straightener having a housing Hs. Fig. 3a illustrates the use case that hair H is guided from left to right, and Fig. 3b illustrates the opposite use case, e.g. when the straightener is used at the other side of a user's head. In this third embodiment, a first LED unit L1 provides a first flash at a reduced intensity, and based on the measurement by the sensors S1, S2, the intensity of the second LED unit L2 is controlled. In the use case of Fig. 3a, the leftmost LED unit is the first LED unit L1, while in the use case of Fig. 3b, the rightmost LED unit is the first LED unit L1. In the use case of Fig. 3a, the rightmost LED unit (the one that acts as the first LED unit L1 in the use case of Fig. 3b) can be controlled together with the second LED unit L2. Similarly, in the use case of Fig.

3b, the leftmost LED unit (the one that acts as the first LED unit L1 in the use case of Fig. 3a) can be controlled together with the second LED unit L2. Mirrors are preferably present below the hair H to re-use light that has not yet been absorbed.

Fig. 4 shows a fourth embodiment of the invention, in which a drive mechanism D regulates the speed of the hair H along the LED unit L and the reflective area R. The drive mechanism D is controlled by the feedforward controller in dependence on a signal from the sensor S.

Figs. 5a and 5b show advantageous layouts of LEDs 21 in upper and lower light units of a hair styling device 20, in a zone between parts of a heat bridge 22. Between the LEDs 21 shown by means of black squares / stripes, sensors are present in the white squares / stripes. The positions of the LEDs and sensors in the upper and lower light units of the hair styling device 20 are in anti-phase, so that a LED is facing a sensor. The heat bridge feature is described in more detail in a co-pending application entitled to the same priority date as the present application (attorney's ref.: 2017PF02405), incorporated by reference herein.

[0031] As shown above, embodiments of the invention may have one or more of the following features: One or more sensors measure the hair properties within the area of illumination. The sensors may be within the light exposure area. Multiple sensors may be used in sequential order (positioned after each other into the direction of the styling movement) to control the heating of the hair.

[0032] In an embodiment, pulsed LEDs are used to style hair. The output wavelength is preferably in the range between 400 and 900 nm, and more preferably in the range between 450 and 550 nm. The pulse width is preferably shorter than or equal to 200 ms, and more preferably shorter than or equal to 100 ms. To prevent the hair from being damaged, the output energy fluence on the hair surface is preferably in the range between 1 J/cm^2 and 10 J/cm^2, more preferably between 3 J/cm^2 and 7 J/cm^2, and most preferably between 4 and 6 J/cm^2.

[0033] As set out in more detail in a co-pending application entitled to the same priority date as the present application (attorney's ref.: 2017PF02405), incorporated by reference herein, embodiments of the present invention are related to a hair styling device comprising a heat source for heating hair, and an optical radiation source for - in combination with heat from the heat source - heating the hair to a temperature sufficiently high for hair styling, in which the heat source obtains its heat from energy provided by the optical radiation source, and in a preferred embodiment, only from the optical radiation source. Advantageously, the heat source may include a heat sink of the optical radiation source. The optical radiation source may advantageously be covered by a cover that is not fully transparent, whereby optical radiation energy is transformed into thermal energy, the heat source including the cover. The cover may advantageously be largely transparent for wavelengths effective for hair styling, while the cover is largely not transparent for wavelengths less effective for hair styling. Advantageously, the optical radiation source may be covered by a cover that is heated by the heat source.

[0034] As set out in more detail in a co-pending application entitled to the same priority date as the present application (attorney's ref.: 2017PF02406), incorporated by reference herein, embodiments of the present invention are related to a hair styling device comprising a light engine to deliver optical energy to hair, in which the hair styling device is arranged to allow moist escaping from the hair in response to optical energy being applied to the hair, to escape from the hair styling device. Preferably, the light engine is the sole energy source for hair styling. A ventilator may move the moist away from the light engine. A processor may control the light engine, in which case the ventilator may also serve to cool the processor and/or the light engine. The hair styling device may comprise clamping members arranged for allowing hair to be guided between and styled by the clamping members, at least one of the clamping members being provided with the light engine. At least one of the clamping members may be provided with openings for allowing moist to escape, or with openings for allowing air to enter so as to convey the moist out of the hair styling device. The clamping members may have non-conforming shapes to allow the moist to escape from the hair styling device. A hair treatment area comprising the light engine may have a gap through which the hair can be guided, the gap being sufficiently wide to allow the moist to escape. A width of the gap may be between 0.3 and 5 mm, and preferably between 1 and 2 mm.

[0035] As set out in more detail in a co-pending application entitled to the same priority date as the present application (attorney's ref.: 2017PF02408), incorporated by reference herein, embodiments of the present invention are related to a hair styling device having a two-dimensional array of elements to bring hair at a styling temperature, in which the elements produce optical radiation energy. The elements may include one or more LEDs, and preferably a plurality of LEDs, in which case the LEDS are driven in clusters that may be of mutually different shapes and sizes. The hair styling device may comprise sensors to obtain an areal light absorption measurement opposed to the two-dimensional array of elements, and a control unit for individually controlling the elements in dependence of the measurement. The hair styling device may radiate hair from two sides, both of which includes an areal light absorption measurement. The sensors may include LEDs that momentarily do not produce light.

[0036] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements, and the singular may cover a plurality unless otherwise indicated. The feedforward control device of the invention may be implemented by means of hardware comprising several distinct elements, and/or by means of a suitably programmed processor. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims that do not refer to one another does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. A hair styling device comprising:

   an optical radiation source (L) for radiating hair (H),
   a sensor unit (S) for measuring effects from radiating hair (H); and
   a feedforward control device for controlling the optical radiation source (L) in dependence on a signal from the sensor unit (S).

2. A hair styling device as claimed in claim 1, wherein the optical radiation source (L1, L2) is controlled to produce a first flash having a lower energy density than required for photo-thermal hair reshaping, the optical radiation source being controlled to produce a subsequent flash in dependence on a sensor signal obtained in response to the first flash.

3. A hair styling device as claimed in claim 1 or 2, wherein the optical radiation source (L1, L2) is controlled to produce a first flash having a first energy density, the optical radiation source being controlled to produce a subsequent flash in dependence on a sensor signal obtained in response to the first flash, the subsequent flash having at least the first energy density.

4. A hair styling device as claimed in any of the preceding claims, wherein the sensor unit (S) includes a sensor arranged before the optical radiation source in a hair flow direction.

5. A hair styling device as claimed in any of the preceding claims, comprising, along a direction in which the hair (H) is guided, a first sensor (S1), a first LED unit (L1) being controlled in dependence on a signal from the first sensor (S1), a second sensor (S2), and a second LED unit (L2) being controlled in dependence on a signal from the second sensor (S2).

6. A hair styling device as claimed in claim 5, wherein the direction in which hair is guided through the hair styling device determines which part of the optical radiation source will act as the first LED unit (L1).

7. A hair styling device as claimed in any of the preceding claims, wherein the sensor unit (S) includes LEDs that momentarily do not produce light.

8. A hair styling device as claimed in any of the preceding claims, comprising a drive mechanism (D) to move the hair (H) along the optical radiation source (L) at a speed controlled by the feedforward control device in dependence on the signal from the sensor unit (S).

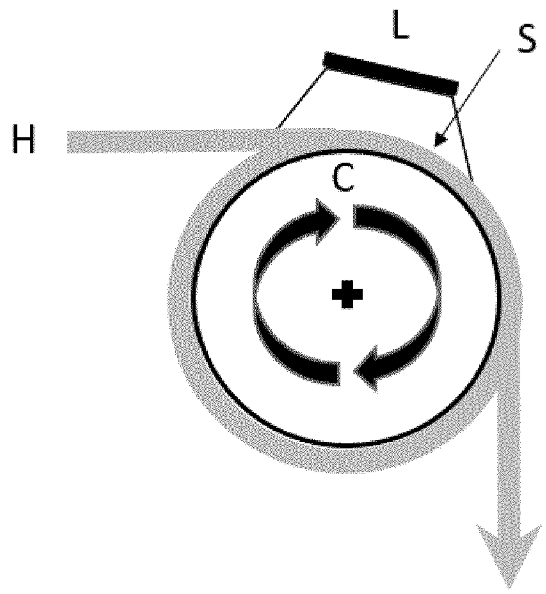

Fig. 1

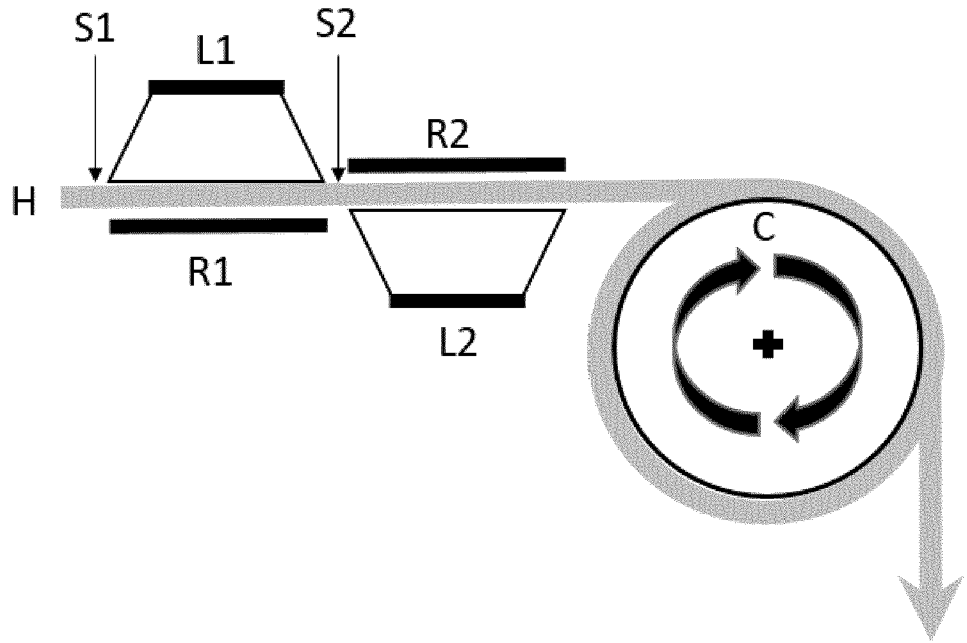

Fig. 2

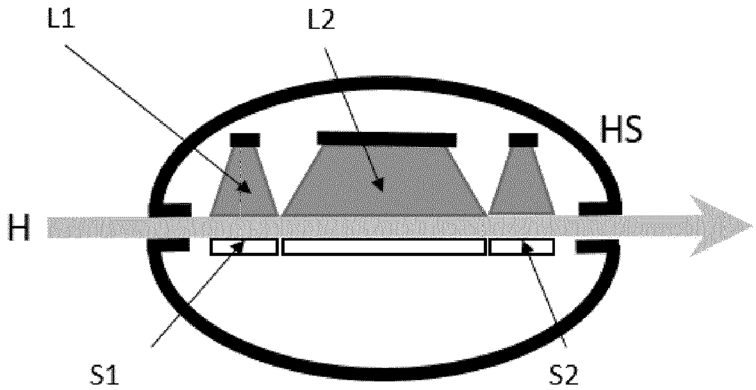

Fig. 3a

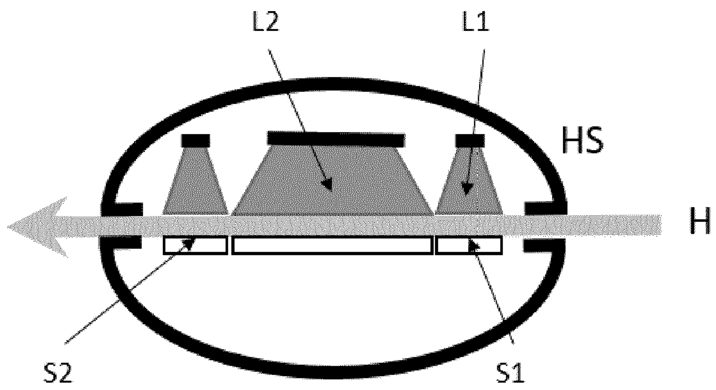

Fig. 3b

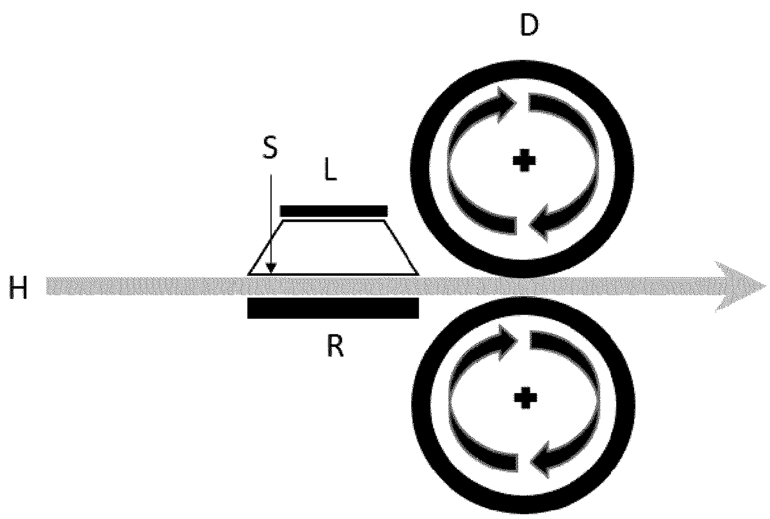

Fig. 4

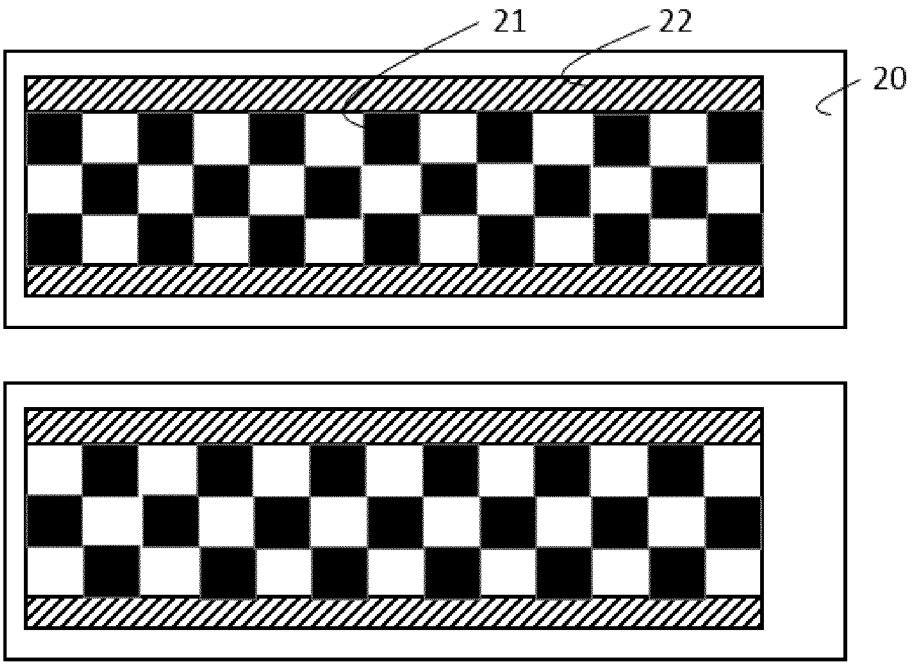

Fig. 5a

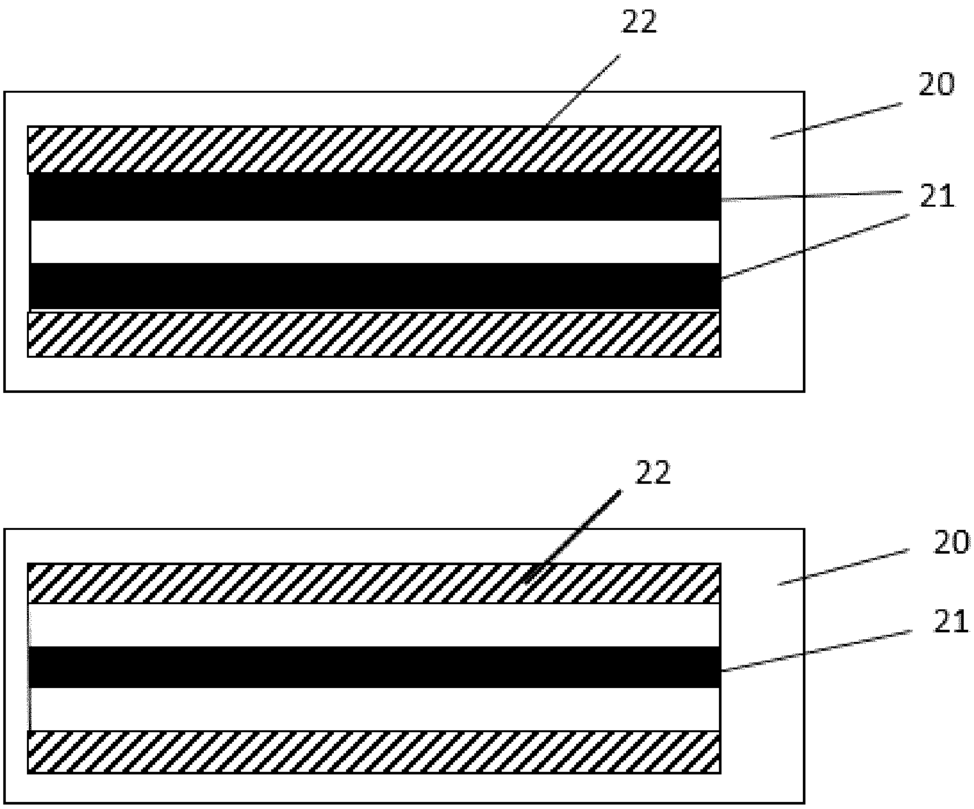

Fig. 5b

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 19 0268

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2012/175734 A1 (OREAL [FR]; PARRIS ERIC [FR]; VIC GABIN [FR]) 27 December 2012 (2012-12-27) * page 35, lines 21-29 * * figures 1,2 *	1-8	INV. A45D1/04 A45D2/00
A	WO 2013/189786 A1 (BSH BOSCH SIEMENS HAUSGERAETE [DE]) 27 December 2013 (2013-12-27) * page 2, line 11 - page 19, line 27 * * figures 1-5 *	1-8	
A	FR 2 939 285 A1 (OREAL [FR]) 11 June 2010 (2010-06-11) * page 3, lines 1-7 * * page 4, lines 5- 16 * * page 7, lines 8-15 * * page 14, line 18 - page 15, line 23 * * page 21, lines 16-18 * * figures 1-10 *	1-8	

TECHNICAL FIELDS SEARCHED (IPC)

A45D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 February 2018	Witkowska-Piela, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 19 0268

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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15-02-2018

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