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(54) Title: FORECASTING OF TREATED SKIN COLORS

(57) Abstract: A method of selecting a substance for use in a cosmetic skin treatment comprises, measuring a reflectance spectrum of the skin to which said treatment is to be applied, said reflectance spectrum defining an original skin tone; modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum defining a modified skin tone; and matching such that if said modified skin tone appears to match said original skin tone then indicating said proposed substance in said cosmetic skin treatment, and otherwise repeating said modifying with a new proposed substance until a match is found.



FORECASTING OF TREATED SKIN COLORS

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a device and method for forecasting treated skin colors and, more particularly, but not exclusively to providing or modifying cosmetic treatments for the skin on the basis of the forecast.

Skin cosmetics may include liquid or cream emulsions; powders, both pressed and loose; dispersions; and anhydrous creams or sticks. Skin cosmetics are applied to the skin and may in some cases make subtle changes in tone, to accentuate features such as cheeks, make sharper changes in tone to accentuate eyes and lips, but in many cases are intended not to be visibly apparent at all.

Skin cosmetics include lipstick, lip gloss, lip liner, lip plumper, lip balm, lip conditioner and lip boosters, for the lips. Foundation is used to smooth out the face and cover spots or uneven skin coloration. Foundation is usually a liquid, cream, or powder. Powder may be used to set the foundation, giving a matte finish, and also to conceal small flaws or blemishes. Rouge, blush or blusher, is a cheek coloring used to bring out the color in the cheeks and make the cheekbones appear more defined. The cheek colorings come in powder, cream, and liquid forms. Bronzer is used to give skin a bit of color by adding a golden or bronze glow. Mascara is used to darken, lengthen, and thicken the eyelashes. It is available in natural colors such as brown and black, but also comes in bolder colors such as blue, pink, or purple. There are many different formulas, including waterproof for those users prone to allergies or sudden tears. Eye liner, eye shadow, eye shimmer, and glitter eye pencils as well as different color pencils are used to color and emphasize the eyelids, on the basis that larger eyes give a more youthful appearance. Eyebrow pencils, creams, waxes, gels and powders are used to color and define the brows. Nail polish is used to color the fingernails and toenails, and concealer is a makeup used to cover any imperfections of the skin.

In many of the above, matching of the cosmetic to the natural skin tone is essential in order to avoid grotesque effects.

U.S. Pat. No. 6437866 "System for assisting customers in selecting an optimum color cosmetic product" provides a method and system is provided for selecting a facial color cosmetic scheme. The method includes measuring via spectrophotometer a

customer's facial color, translating the color into L,a,b color coordinates and transmitting information on that color to the module for display on the model face appearing in the monitor, and allowing the customer to select at least one color for an area of the face to be covered by a cosmetic product.

5 The system reads color coordinates and fits the best makeup product to achieve the desirable target color.

 US. Pat. No. 6779686 "Point-of-sale body powder dispensing system" provides a system, for a point of sale, for custom selection, design, blending, mixing or packaging of a body powder, and more particularly a cosmetic powder color, effect or
10 both. Mixing of ingredients is carried out to accord with typical spectra of the material as obtained from a database.

 Principal component analysis of skin color and its application to colorimetric color reproduction on CRT display and hardcopy by Francisco Hideki Imai, Norimichi Tsumura, Hideaki Haneishi, and Yoichi Miyake of the department of Information and
15 Computer Sciences, Chiba University 1-33 Yayoi-cho, Inage-ku, Chiba-shi, Chiba-ken 263 JAPAN teaches a method of estimation of a spectral reflectance using tristimulus values measured by colorimeter rather than inputting the spectrum itself. The method predicts the skin color under various illuminants. It allows colorimetric reproduction without colorimetric measurement for each illuminant. The skin colors are reproduced
20 on a CRT display or for printing.

 U.S. Pat. 5,478,238 teaches a method and apparatus for determining a foundation makeup color that allows for best reproduction of a person's natural skin
25 color. A method of determining the foundation makeup color that reproduces the natural skin color of a person, is based on a database. A large data base of human skin is made. Chromatic parameters, that is color coordinates L,a,b derived from RGB,Y of the skin are measured and then the computer looks up the database to output a foundation makeup color.

30 U.S. Pat. 5,313,267 teaches a method and instrument for selecting personally compatible colors. Skin is classified into color groups by measuring its color coordinates.

U.S. Pat. 5,622,692 teaches a method and apparatus for customizing facial foundation products. Customizing is made of a facial foundation product at the point of sale to a customer based on color coordinates.

U.S. Pat. 6,293,284 concerns a method and apparatus for allowing a consumer
5 at the point-of-sale to evaluate color cosmetic products on virtual images of their faces prior to purchase.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a method of
10 selecting a substance for use in a cosmetic skin treatment comprising, in an electronic hardware processor:

measuring a reflectance spectrum of the skin to which said treatment is to be applied, said reflectance spectrum defining an original skin tone;

modifying the measured reflectance spectrum in accordance with the absorbance
15 spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum defining a modified skin tone; and

matching such that if said modified skin tone appears to match said original skin tone then indicating said proposed substance in said cosmetic skin treatment, and otherwise repeating said modifying with a new proposed substance until a match is
20 found.

In an embodiment, said matching is between said skin reflectance spectrum and said modified reflectance spectrum.

In an embodiment, said original skin tone is derived from said skin reflectance spectrum and said modified skin tone is derived from said modified reflectance
25 spectrum and said matching is between said original skin tone and said modified skin tone.

In an embodiment, modelling skin tone as a plurality of underlying spectral factors, may comprise scaling each factor by a respective coefficient to obtain the reflectance spectrum of any given individual.

30 The method may comprise storing the absorption spectra of various substances for cosmetic skin treatments as additional factors.

In an embodiment, said modified reflectance spectrum is obtained by applying the factors of the proposed substance to the coefficients obtained from said measuring to obtain said modified reflectance spectrum.

The method may comprise calculating over a distance, wherein said distance
5 represents a thickness of a layer of said substance.

In an embodiment, a plurality of said substances for skin treatment are associated with a set of functions per wavelength that relate spectral differences of the respective substance to the initial spectrum of the skin.

The method may comprise calculating the modified tone from the skin
10 reflectance spectrum and the cosmetics substance absorbance spectrum per volume unit using:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

Where:

R_f = final spectrum of treated skin;

15 R_i = illumination spectrum;

α = absorbance spectrum;

d = thickness of cosmetics material layer over treated skin; and

R_s = skin's reflectance spectrum.

The method may comprise modifying the final spectrum of treated skin for layer
20 thickness by:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

wherein:

the illumination spectrum R_i is absorbed by rate α per unit length through a
thickness d of the cosmetic substance, to illuminate the underlying skin layer with

25 spectrum $R_i \cdot e^{-\alpha \cdot d}$ wherein the reflectance spectrum of the skin R_s multiplies the

light and exhibits a spectrum $R_i \cdot e^{-\alpha \cdot d} \cdot R_s$ being reflected back and absorbed

again through the cosmetics material layer along thickness d to introduce said final spectrum as an emerging reflectance spectrum.

In an embodiment, said substance for said cosmetic treatment comprises a mixture of a plurality of cosmetic material components, each component having a known absorbance, the mixture having an overall absorbance which is the linear summation of each component's absorbance weighted by its concentration, such that a mixture made of N components of makeup dyes:

$$\alpha_{total} = \sum_{n=1}^N c_n \cdot \alpha_n$$

wherein:

α_{total} = absorbance of makeup mixture;

c_n = the concentration of the n'th component in the mixture; and

α_n = absorbance of the n'th component in the mixture.

The method may comprise making up said substance for said cosmetic treatment by providing respective concentrations of said components and mixing them together.

According to a second aspect of the present invention there is provided apparatus for selecting a substance for use in a cosmetic skin treatment comprising:

a spectrometer configured for measuring a reflectance spectrum of the skin to which said treatment is to be applied;

a skin tone calculator for receiving said reflectance spectrum from said spectrometer and determining an original skin tone;

a modifier for modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum, and from said modified skin reflectance spectrum obtaining a modified skin tone; and

a matcher for matching said original and modified skin tones, and when said modified skin tone is considered a match to said original skin tone, indicating said proposed substance for said cosmetic skin treatment.

According to a third aspect of the invention there is provided apparatus for
5 selecting a substance for use in a cosmetic skin treatment comprising:

a spectrometer configured for measuring a reflectance spectrum of the skin to which said treatment is to be applied, said reflectance spectrum defining a skin tone;

a modifier for modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to
10 provide a modified skin reflectance spectrum, said modified skin reflectance spectrum defining a modified skin tone; and

a matcher for matching said original and modified spectra, and when said modified spectrum is considered a match to said original skin spectrum, indicating said proposed substance for said cosmetic skin treatment.

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Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The materials, methods, and examples provided herein are illustrative only and not intended to be limiting.

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The word “exemplary” is used herein to mean “serving as an example, instance or illustration”. Any embodiment described as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

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The word “optionally” is used herein to mean “is provided in some embodiments and not provided in other embodiments”. Any particular embodiment of the invention may include a plurality of “optional” features unless such features conflict.

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Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. This refers in particular to tasks involving the control of the spectral measurement equipment.

Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

5 For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks
10 according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network
15 connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and
25 are presented in order to provide what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of
30 the invention may be embodied in practice.

In the drawings:

FIG. 1 is a simplified flow diagram illustrating a first method according to the present embodiments;

FIG. 2A shows two pairs of natural and modified skin spectra;

FIG. 2B shows two skin spectra prior to application of a layer of Jade Bronzer;

5 FIG. 3 shows the two skin spectra of Fig. 2B after application of the Jade Bronzer;

FIG. 4 is a simplified graph showing the spectra of two skin pairs prior to application of L'Oreal True Match N3; and

10 FIG. 5 is a simplified diagram of the two skin spectra of Fig. 4 following modification by application of L'Oreal N3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present embodiments comprise a method and apparatus to find the most appropriate substance and thickness thereof to apply on skin in order to achieve a target
15 color, texture, and other visual properties of the treated skin. Substances and treatment herein includes makeup dyes, skin lighteners, concealers, sunscreens and any cosmetics or medical material which modifies the visual properties of the skin.

The principles and operation of an apparatus and method according to the present invention may be better understood with reference to the drawings and
20 accompanying description.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other
25 embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

By way of introduction, the reflectance spectrum is the percentage of light intensity which is reflected per each wavelength from an illuminated object. Once the
30 illumination spectrum is known a color can be given as a set of coordinates which are calculated from the spectrum and related to the human sense of color vision. Therefore, any given reflectance spectrum relates to only one set of color coordinates under a given

illumination spectrum. On the other hand, the same single set of color coordinates can be calculated from a large number of substantially different reflectance spectra, for example spectra that may not provide a matching color at another wavelength in the eye sensitive range. In other words several objects may appear to the human eye to have the same color, although each one of them exhibits a different reflectance spectrum. By trying to match color as seen by the human eye, one does not deal with the underlying spectrum, and thus complex color processes involving matching colors between different substances tends not to be very successful. This is also true of human skin and hair where underlying factors contribute to the overall color in a relatively complex way, and thus is a problem for cosmetics.

In particular, where cosmetic applications to skin are concerned, exact color matching is essential, otherwise the result is aesthetically displeasing. That is to say if the skin color does not match then an affect is produced which appears to verge on the grotesque.

In general, the process of dyeing an object comprises making deliberate changes to the reflectance spectrum of the object. Therefore, in the art of color prediction it is more accurate to forecast a final color by analyzing the modifications that the spectrum undergoes during the coloring process and deriving the color from the evolution of the final spectrum.

Reference is now made to Fig. 1A, which is a simplified diagram illustrating a method of selecting a substance for use in a cosmetic skin treatment that is carried out in an electronic hardware processor, which may in one embodiment operate a substance preparation and/or dispensing device.

The method comprises measuring a reflectance spectrum of the skin to which said treatment is to be applied. The reflectance spectrum defines an original skin tone, which may or may not be calculated.

The measured reflectance spectrum is then modified in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum.

From the modified skin reflectance spectrum a modified skin tone is defined, and again may or may not actually be calculated. A matching stage then follows, in

10

which the two spectra or the two skin tones may be matched. If there is a match then the proposed substance is recommended, otherwise a new proposed substance is tested.

In the above, skin tone may be modeled as a plurality of underlying spectral factors, wherein each factor is scaled by a corresponding coefficient to obtain the
5 reflectance spectrum of any given individual.

The method may comprise prestoring the absorption spectra of various substances for cosmetic skin treatments as additional factors. The prestored data may be held in a database.

10 The modified reflectance spectrum may be obtained by applying the factors of the proposed substance to the coefficients obtained from the measuring to obtain the modified reflectance spectrum. That is to say, the modified reflectance spectrum may be obtained by adding the factors of the proposed substance to those obtained from measuring, then predicting new coefficients for all factors and receiving the modified
15 reflectance spectrum.

The method may further comprise calculating over a distance, the distance representing a thickness of a layer of the substance spread on the skin, or more precisely twice the distance, as will be discussed in greater detail below.

Different substances for skin treatment may individually be associated with a set
20 of functions per wavelength that relate spectral differences of the respective substance to the initial spectrum of the skin.

As will be discussed in greater detail below, calculating the modified tone from the skin reflectance spectrum and the cosmetics substance absorbance spectrum per volume unit may be carried out using:

$$25 \quad R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

Where:

R_f = final spectrum of treated skin;

R_i = illumination spectrum;

α = absorbance spectrum;

30 d = thickness of cosmetics material layer over treated skin; and

R_s = skin's reflectance spectrum.

The method may comprise modifying the final spectrum of treated skin for layer thickness by:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

wherein:

the illumination spectrum R_i is absorbed by rate α per unit length through a thickness d of the cosmetic substance, to illuminate the underlying skin layer with spectrum $R_i \cdot e^{-\alpha \cdot d}$ wherein the reflectance spectrum of the skin R_s multiplies the light and exhibits a spectrum $R_i \cdot e^{-\alpha \cdot d} \cdot R_s$ being reflected back and absorbed again through the cosmetics material layer along thickness d to introduce said final spectrum as an emerging reflectance spectrum.

The proposed substance for cosmetic treatment may comprise a mixture of different cosmetic material components, each component having a known absorbance, the mixture having an overall absorbance which is the linear summation of each component's absorbance weighted by its concentration, such that a mixture made of N components of makeup dyes may give an absorption rate according to:

$$\alpha_{total} = \sum_{n=1}^N c_n \cdot \alpha_n$$

wherein:

α_{total} = absorbance of makeup mixture;

c_n = the concentration of the n'th component in the mixture; and

α_n = absorbance of the n'th component in the mixture.

A further stage of making up the substance for the cosmetic treatment may comprise providing respective concentrations of the components and mixing them together.

The following is a series of experiments involving color measurement of the human skin in accordance with the above embodiments.

Human skin color measurements

All the reflectance measurements were made with Avamouse (Avantes) scanning spectrometer having 45° viewing geometry. Four reflectance spectra over the wavelength range 380-750 nm, each requiring about 3 seconds for measurement, were obtained for the same region and computer averaged.

The L,a,b calculations using the reflectance data and data processing were obtained using MATLAB software. The software goal was to detect pairs of skin measurements according to desired thresholds of ΔE and spectral differences given by ΔR . The subscripts refer to respective first and second skins in each pair tested.

$$\Delta R = \sqrt{\sum_{\lambda} (R_1(\lambda) - R_2(\lambda))^2}$$

$$\Delta E = \sqrt{(L_2 - L_1)^2 + (a_1 - a_2)^2 + (b_2 - b_1)^2}$$

Experiment1- Natural Skin Measurement

Goal – Finding cases, where skin spectra have similar $L_{a,b}$, but different ΔR

The first sample was composed of 14 volunteers, 5 male and 9 female. The age range was from 23 to 45 years old. The observations were taken at the forehead, cheek, neck, the inner and outer parts of the palm of the hand, and the inner and outer parts of the arm, not in any particular order. In the case of some of the male volunteers the arms were too hairy for taking measurements.

The cheeks and forehead of males and females were all free from cosmetics. The regions measured had no visible blood veins or any abnormal pigmentation.

Fig. 2A shows examples for two different skin pairs. In each case dE is low while ΔR is high, meaning that the color is different but the $L_{a,b}$ scheme is unable to show the difference.

Experiment2 – Make up application to natural skin

Goal – Observing the spectral change of the skin after cosmetic products' application.

A second sample was composed of 11 volunteers: 10 female and one male. The age range was from 23 to 45 years old. The inner part of the arm was used for the experiment. Seven different cosmetic products were applied: four liquid make-ups (L'Oreal C1, N2, W3, W5), two powder mineral make-ups (L'Oreal N3,N6) and one liquid Bronzer (Jade). An approximate equal quantity of each product was applied every time.

All the cosmetic products were tried on every volunteer. The skin region was measured before and after product application. The skin measurements before make up were also added to the database of natural skin of Experiment 1.

The results are shown between Figs 2B and 5. Fig. 2B shows a pair of skins with fairly similar color but different underlying spectrum, before application of the Jade Bronzer. Although the skins have similar spectra at 535 – 590nm where the eye is highly sensitive and may therefore appear similar, there are substantial differences at 450 – 490nm and above 600nm. These differences may lead to significantly different reflectance at different times of the day due to changes in the solar spectrum over the course of the daylight period. Fig. 3 shows the same pair of skins after application of the jade bronzer. The resulting colors are quite different, and this is due to the different initial spectra of the skins. Table 1 shows the results in terms of dE and ΔR .

dE before	ΔR before
1.17	12.78
dE after	ΔR after
8.18	28.65

Table 1: At the beginning the color similarity is high (small dE) although quite big spectral differences (big ΔR). The final result shows bigger color differences (big dE).

Figures 4 and 5 are graphs showing spectra before and after the application of "N3" L'Oreal makeup to almost identical visual colored skins with different spectra.

Table 2 shows the results of Figures 4 and 5 in terms of dE and ΔR .

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dE before	ΔR before
1.51	21.75
dE after	ΔR after
3.12	27.76

Table 2: At the beginning the color similarity is high (small dE) although there are quite large spectral differences (big ΔR). The final result shows bigger color differences (big dE).

5 The experiments show that the L,a,b system, which is sensitive mainly to the 490-550nm range and much less at below and above, loses much detail of the spectrum as being out of the effective range. Thus unpredictable effects occur when the incident light spectrum changes, for example causing unsatisfying results under afternoon lighting when there is more light in the red/near-infra-red end of the spectrum to which
10 the L,a,b system is not sensitive.

A system acquired with spectrophotometer and processor can choose best fitted cosmetics material treatment for achieving target skin's color whenever a prediction of final spectrum after treatment is available per each cosmetics product. The customer's skin spectrum is measured and the computer runs hypothetical treatments, searching for
15 the one that provides a closest end result color coordinates to that of the target.

Predicting final colors by spectrum prediction

Factor analysis

20 Reference is made to U.S. Patent No. 7,110,117 "Hair color measurement and treatment". The patent considers dealing with prediction of hair spectra by way of factor analysis. Hair consists of two pigmentation factors, each of which contributes to the overall hair color, but whose individual contributions are only apparent from the overall spectrum and not from the final color. In the case of hair the general intention is to dye
25 the hair to a different color. Spectral prediction, given the present hair spectrum and a proposed treatment, allows the end user to obtain the intended hair color rather than an approximation.

With skin treatment the issue is different. Generally skin applications are intended to match the underlying skin color rather than change it, or where the color is to be changed, then often the changes are to be subtle. Furthermore the skin preparations themselves are of varying thicknesses and are rubbed manually into the skin, in a process whose chemistry is very different from the dyeing of hair. Furthermore, the skin coloration factors, mainly based on melanin, work differently from hair.

Spectral prediction can be used as a method of predicting the spectrum of treated skin with a cosmetics product. Base spectra are calculated by a procedure using factor analysis to introduce the natural factors of the skin, while every cosmetics product substance is associated with its own spectrum which serves as an additional factor. The factor of the cosmetics product dye can be obtained in several ways according to the nature of the model. The factor can be obtained via direct spectrum measurement, or a calculation thereof within a Factor Analysis process.

The spectrum of Natural skin is made up of a linear summation of a series of natural factors, multiplied by corresponding coefficients. Treated skin is a linear combination of the natural factors plus the factors of the cosmetics substance over the treated skin. The coefficients for each natural or colored skin's spectrum can be obtained by using a least squares process.

The model introduces transformation functions that give the final coefficients of the natural factors + dye factors as a function of the initial natural functions. For instance, once a skin spectrum is measured, the natural coefficients are calculated to best fit the following relation:

$$R_s(\lambda) = c_{initial_1} \cdot f_1(\lambda) + c_{initial_2} \cdot f_2(\lambda) + c_{initial_3} \cdot f_3(\lambda) + c_{initial_4} \cdot f_4(\lambda)$$

When:

λ = wavelength

$c_{initial_1}, \dots, c_{initial_4}$ = coefficients of natural factors

$f_1, \dots, f_4$ = natural factors which are four independent spectrums

The spectrum of the treated skin with cosmetics material A is:

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$$R_f(\lambda) = c_{final_1} \cdot f_1(\lambda) + c_{final_2} \cdot f_2(\lambda) + c_{final_3} \cdot f_3(\lambda) + c_{final_4} \cdot f_4(\lambda) + c_A \cdot f_A(\lambda)$$

When:

5 C_A = coefficient of cosmetics material A factor

f_A = factor of cosmetics material A substance (dye).

R_f = final spectrum

The final coefficients were calculated by:

$$c_{final_1} = F_1(c_{initial_1}, c_{initial_2}, c_{initial_3}, c_{initial_4})$$

10 $c_{final_2} = F_2(c_{initial_1}, c_{initial_2}, c_{initial_3}, c_{initial_4})$

$$c_{final_3} = F_3(c_{initial_1}, c_{initial_2}, c_{initial_3}, c_{initial_4})$$

$$c_{final_4} = F_4(c_{initial_1}, c_{initial_2}, c_{initial_3}, c_{initial_4})$$

$$c_A = F_5(c_{initial_1}, c_{initial_2}, c_{initial_3}, c_{initial_4})$$

15 The functions $F_1, \dots, F_5$ were found empirically by dyeing different skins with the same cosmetics substance "A" while measuring all initial spectrums and final spectrums and calculating all initial coefficients and final coefficients. The functions were established to best fit initial coefficients to final coefficients by transformations.

20 The same conceptual principal might be exerted on mathematically manipulated spectrum data, such as logarithms or other functions in order to provide better correlation between factors and the real nature of ingredients. For example, exerting formulas on absorbance rather than direct reflectance and associating each factor to a real component in skin or dye, such as carotene absorbance, haemoglobin absorbance in the blood, natural pigment absorbance (eumelanin and pheomelanin pigments), etc'.

Function per wavelength

Every cosmetics material product is associated with a set of functions per wavelength that relate the spectral differences to the initial spectrum of the skin. The following formula illustrates that:

$$\Delta R(\lambda) = F_{\lambda}(R_s(\lambda))$$

When:

$\Delta R(\lambda)$ = the spectral difference between the final reflectance spectrum and the initial reflectance spectrum.

F_{λ} = Function per wavelength λ .

$R_s(\lambda)$ = Skin's reflectance spectrum.

For example, F_{λ} are second order polynomials whose coefficients a, b, c are calculated by a least squares procedure that best fit $\Delta R(\lambda)$ to $R_s(\lambda)$ where N magnitudes of $\Delta R(\lambda)$ and $R_s(\lambda)$ are measured per each wavelength by coloring N different skins.

Kubelka Munk

In the Kubelka Munk method the medium in which the light is propagated both scatters the light and absorbs it at different rates per length unit. The equation per each wavelength is given by:

$$\begin{cases} R_f = \frac{1 - R_s \cdot (a - b \cdot \text{ctgh}(b \cdot s \cdot d))}{a - R_s + b \cdot \text{ctgh}(b \cdot s \cdot d)} \\ a = 1 + \frac{k}{s} \\ b = \sqrt{a^2 - 1} \end{cases}$$

When:

R_f = final spectrum of treated skin

R_s = skin reflectance spectrum

k = absorbance constant of cosmetics substance

5 S = scattering constant of cosmetics substance

d = thickness of cosmetics material layer

The magnitudes of the abovementioned parameters are calculated per each wavelength per every cosmetic substance by empirical experiments on known skin spectra with known thicknesses of cosmetic material layers.

10 One can calculate the absorbance and scattering rates of a mixture by using the following equation:

$$k_{total} = \sum_{n=1}^N c_n \cdot k_n$$

$$S_{total} = \sum_{n=1}^N c_n \cdot S_n$$

When:

15 C_n = the concentration of the n'th component among the mixture.

When the cosmetics substance penetrates inside the skin, rather than lying over it, another version of Kubelka Munk equation may be used. Approximating integration from an infinite depth of treated or untreated skin with a spectrum reflectance R we get:

$$\frac{k_{total}}{S_{total}} = \frac{(1 - R)^2}{2 \cdot R}$$

20

Beer's law

This approach is most fitted to the cases where the cosmetics substance tends to be a colorful translucent layer over the skin.

Once the skin's reflectance spectrum and the cosmetics substance absorbance spectrum per volume unit are given, the predicted color is calculated by way of multiplication:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

5 When:

R_f = final spectrum of treated skin

R_i = illumination spectrum

α = absorbance spectrum

d = thickness of cosmetics material layer over treated skin.

10 R_s = skin's reflectance spectrum

The illumination spectrum R_i is absorbed by rate α per unit length through the thickness d of the cosmetic substance. Thus the underlying skin layer is illuminated with spectrum $R_i \cdot e^{-\alpha \cdot d}$. The reflectance spectrum of the skin R_s multiplies the light and exhibits a spectrum $R_i \cdot e^{-\alpha \cdot d} \cdot R_s$ being reflected back and
15 absorbed again through the cosmetics material layer along thickness d to introduce a final emerging reflectance spectrum $R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$

When cosmetic material comprises from several cosmetic material components with known absorbance the mixture has an overall absorbance which is the linear summation of each component's absorbance weighted by its concentration. For
20 example, a mixture made of N components of makeup dyes:

$$\alpha_{total} = \sum_{n=1}^N c_n \cdot \alpha_n$$

When:

α_{total} = absorbance of makeup mixture

C_n = the concentration of the n'th component in the mixture

α_n = absorbance of the n'th component in the mixture.

It is appreciated that certain features of the invention, which are, for clarity,
5 described in the context of separate embodiments, may also be provided in combination
in a single embodiment. Conversely, various features of the invention, which are, for
brevity, described in the context of a single embodiment, may also be provided
separately or in any suitable subcombination.

Although the invention has been described in conjunction with specific
10 embodiments thereof, it is evident that many alternatives, modifications and variations
will be apparent to those skilled in the art. Accordingly, it is intended to embrace all
such alternatives, modifications and variations that fall within the spirit and broad scope
of the appended claims. All publications, patents, and patent applications mentioned in
this specification are herein incorporated in their entirety by reference into the
15 specification, to the same extent as if each individual publication, patent or patent
application was specifically and individually indicated to be incorporated herein by
reference. In addition, citation or identification of any reference in this application shall
not be construed as an admission that such reference is available as prior art to the
present invention.

What is claimed is:

1. A method of selecting a substance for use in a cosmetic skin treatment comprising, in an electronic hardware processor:
 - measuring a reflectance spectrum of the skin to which said treatment is to be applied, said reflectance spectrum defining an original skin tone;
 - modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum defining a modified skin tone; and
 - matching such that if said modified skin tone appears to match said original skin tone then indicating said proposed substance in said cosmetic skin treatment, and otherwise repeating said modifying with a new proposed substance until a match is found.
2. The method of claim 1, wherein said matching is between said skin reflectance spectrum and said modified reflectance spectrum.
3. The method of claim 1, wherein said original skin tone is derived from said skin reflectance spectrum and said modified skin tone is derived from said modified reflectance spectrum and said matching is between said original skin tone and said modified skin tone.
4. The method of claim 1, comprising:
 - modelling skin tone as a plurality of underlying spectral factors, wherein each factor is scaled by a respective coefficient to obtain the reflectance spectrum of any given individual.
5. The method of claim 4, further comprising storing the absorption spectra of various substances for cosmetic skin treatments as additional factors.

6. The method of claim 5, wherein said modified reflectance spectrum is obtained by applying the factors of the proposed substance to the coefficients obtained from said measuring to obtain said modified reflectance spectrum.

7. The method of claim 5, further comprising calculating over a distance, wherein said distance represents a thickness of a layer of said substance.

8. The method of claim 1, wherein a plurality of said substances for skin treatment are associated with a set of functions per wavelength that relate spectral differences of the respective substance to the initial spectrum of the skin.

9. The method of claim 1, comprising calculating the modified tone from the skin reflectance spectrum and the cosmetics substance absorbance spectrum per volume unit using:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

Where:

R_f = final spectrum of treated skin;

R_i = illumination spectrum;

α = absorbance spectrum;

d = thickness of cosmetics material layer over treated skin; and

R_s = skin's reflectance spectrum.

10. The method of claim 9, comprising modifying the final spectrum of treated skin for layer thickness by:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

wherein:

the illumination spectrum R_i is absorbed by rate α per unit length through a thickness d of the cosmetic substance, to illuminate the underlying skin layer with spectrum $R_i \cdot e^{-\alpha \cdot d}$ wherein the reflectance spectrum of the skin R_s multiplies the light and exhibits a spectrum $R_i \cdot e^{-\alpha \cdot d} \cdot R_s$ being reflected back and absorbed again through the cosmetics material layer along thickness d to introduce said final spectrum as an emerging reflectance spectrum.

11. The method of claim 8, wherein said substance for said cosmetic treatment comprises a mixture of a plurality of cosmetic material components, each component having a known absorbance, the mixture having an overall absorbance which is the linear summation of each component's absorbance weighted by its concentration, such that a mixture made of N components of makeup dyes:

$$\alpha_{total} = \sum_{n=1}^N c_n \cdot \alpha_n$$

wherein:

α_{total} = absorbance of makeup mixture;

c_n = the concentration of the n'th component in the mixture; and

α_n = absorbance of the n'th component in the mixture.

12. The method of claim 11, comprising making up said substance for said cosmetic treatment by providing respective concentrations of said components and mixing them together.

13. Apparatus for selecting a substance for use in a cosmetic skin treatment comprising:

a spectrometer configured for measuring a reflectance spectrum of the skin to which said treatment is to be applied;

a skin tone calculator for receiving said reflectance spectrum from said spectrometer and determining an original skin tone;

a modifier for modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum, and from said modified skin reflectance spectrum obtaining a modified skin tone; and

a matcher for matching said original and modified skin tones, and when said modified skin tone is considered a match to said original skin tone, indicating said proposed substance for said cosmetic skin treatment.

14. The apparatus of claim 13, further comprising a preparing unit for preparing said proposed substance for dispensing.

15. The apparatus of claim 13, comprising:

a modeler for modelling skin tone as a plurality of underlying spectral factors, wherein each factor is scaled by a respective coefficient to obtain the reflectance spectrum of any given individual.

16. The apparatus of claim 15, further comprising a database for storing the absorption spectra of various substances for cosmetic skin treatments as additional factors.

17. The apparatus of claim 16, wherein said modified reflectance spectrum is obtained by applying the factors of the proposed substance to the coefficients obtained from said measuring then predicting new coefficients for factors of both the original spectrum and of the proposed substance to obtain said modified reflectance spectrum.

18. The apparatus of claim 16, further comprising a calculator for calculating over a distance, wherein said distance represents a thickness of a layer of said substance.

19. The apparatus of claim 13, wherein a plurality of said substances for skin treatment are associated with a set of functions per wavelength that relate spectral differences of the respective substance to the initial spectrum of the skin.

20. The apparatus of claim 13, wherein said modifier is further configured for calculating the modified tone from the skin reflectance spectrum and the cosmetics substance absorbance spectrum per volume unit using:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

Where:

R_f = final spectrum of treated skin;

R_i = illumination spectrum;

α = absorbance spectrum;

d = thickness of cosmetics material layer over treated skin; and

R_s = skin's reflectance spectrum.

21. The apparatus of claim 20, further configured to modify the final spectrum of treated skin for layer thickness by:

$$R_f = R_i \cdot e^{-\alpha \cdot d} \cdot R_s \cdot e^{-\alpha \cdot d}$$

wherein:

the illumination spectrum R_i is absorbed by rate α per unit length through a thickness d of the cosmetic substance, to illuminate the underlying skin layer with spectrum $R_i \cdot e^{-\alpha \cdot d}$ wherein the reflectance spectrum of the skin R_s multiplies the

light and exhibits a spectrum $R_i \cdot e^{-\alpha \cdot d} \cdot R_s$ being reflected back and absorbed again through the cosmetics material layer along thickness d to introduce said final spectrum as an emerging reflectance spectrum.

22. The apparatus of claim 19, wherein said substance for said cosmetic treatment comprises a mixture of a plurality of cosmetic material components, each component having a known absorbance, the mixture having an overall absorbance which is the linear summation of each component's absorbance weighted by its concentration, such that a mixture made of N components of makeup dyes:

$$\alpha_{total} = \sum_{n=1}^N C_n \cdot \alpha_n$$

wherein:

α_{total} = absorbance of makeup mixture;

C_n = the concentration of the n'th component in the mixture; and

α_n = absorbance of the n'th component in the mixture.

23. Apparatus for selecting a substance for use in a cosmetic skin treatment comprising:

a spectrometer configured for measuring a reflectance spectrum of the skin to which said treatment is to be applied, said reflectance spectrum defining a skin tone;

a modifier for modifying the measured reflectance spectrum in accordance with the absorbance spectrum of a substance proposed for said cosmetic skin treatment to provide a modified skin reflectance spectrum, said modified skin reflectance spectrum defining a modified skin tone; and

a matcher for matching said original and modified spectra, and when said modified spectrum is considered a match to said original skin spectrum, indicating said proposed substance for said cosmetic skin treatment.

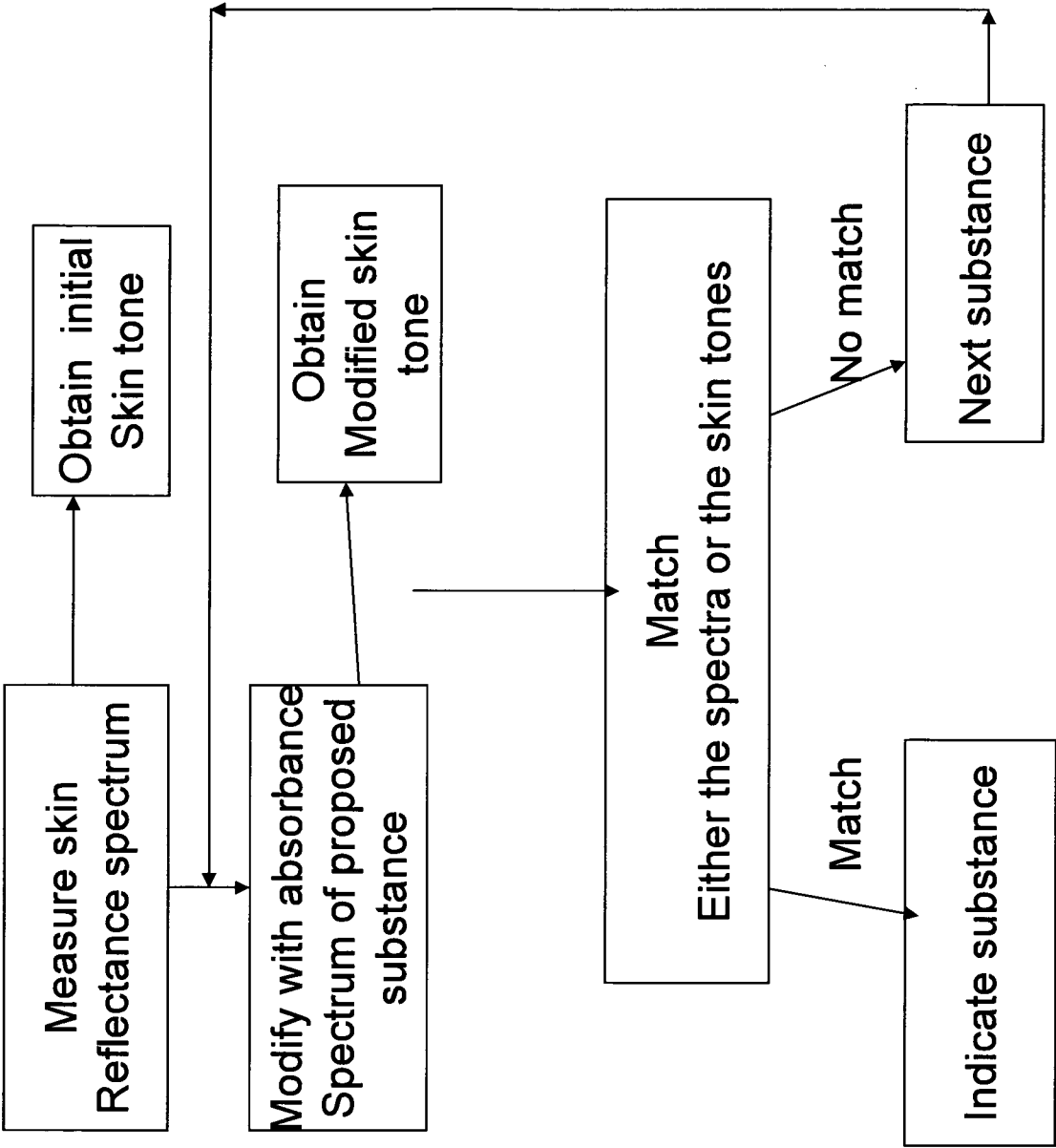


FIG. 1

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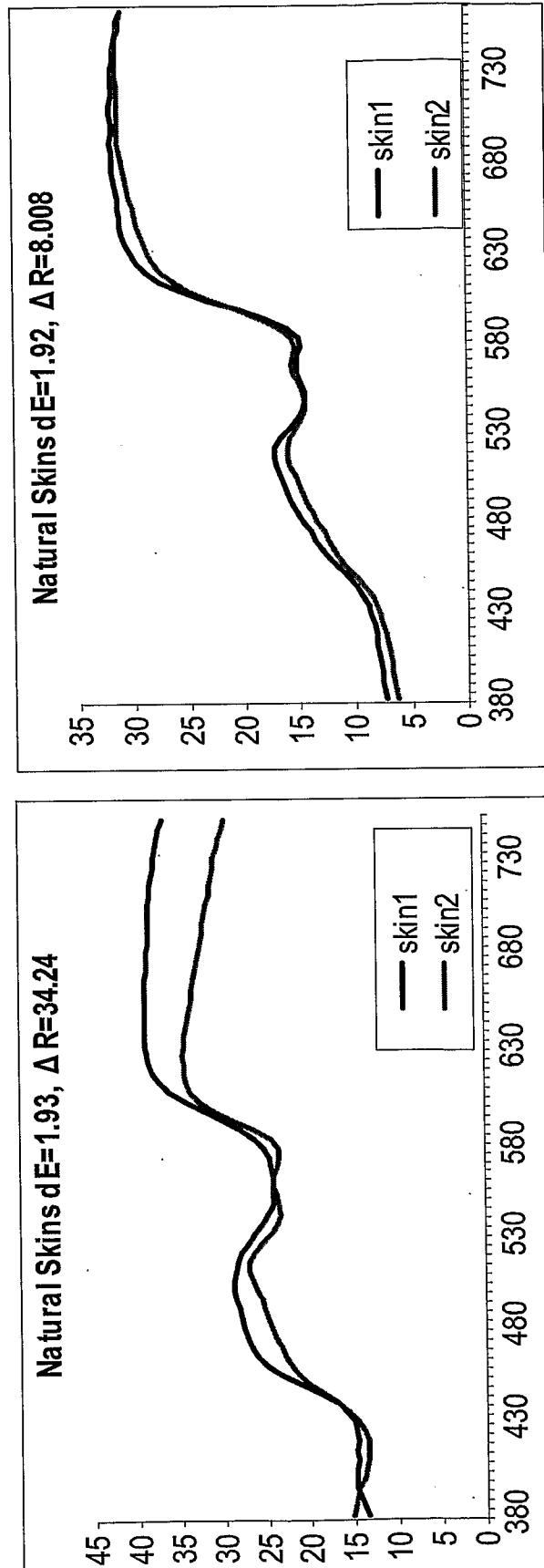


FIG. 2A

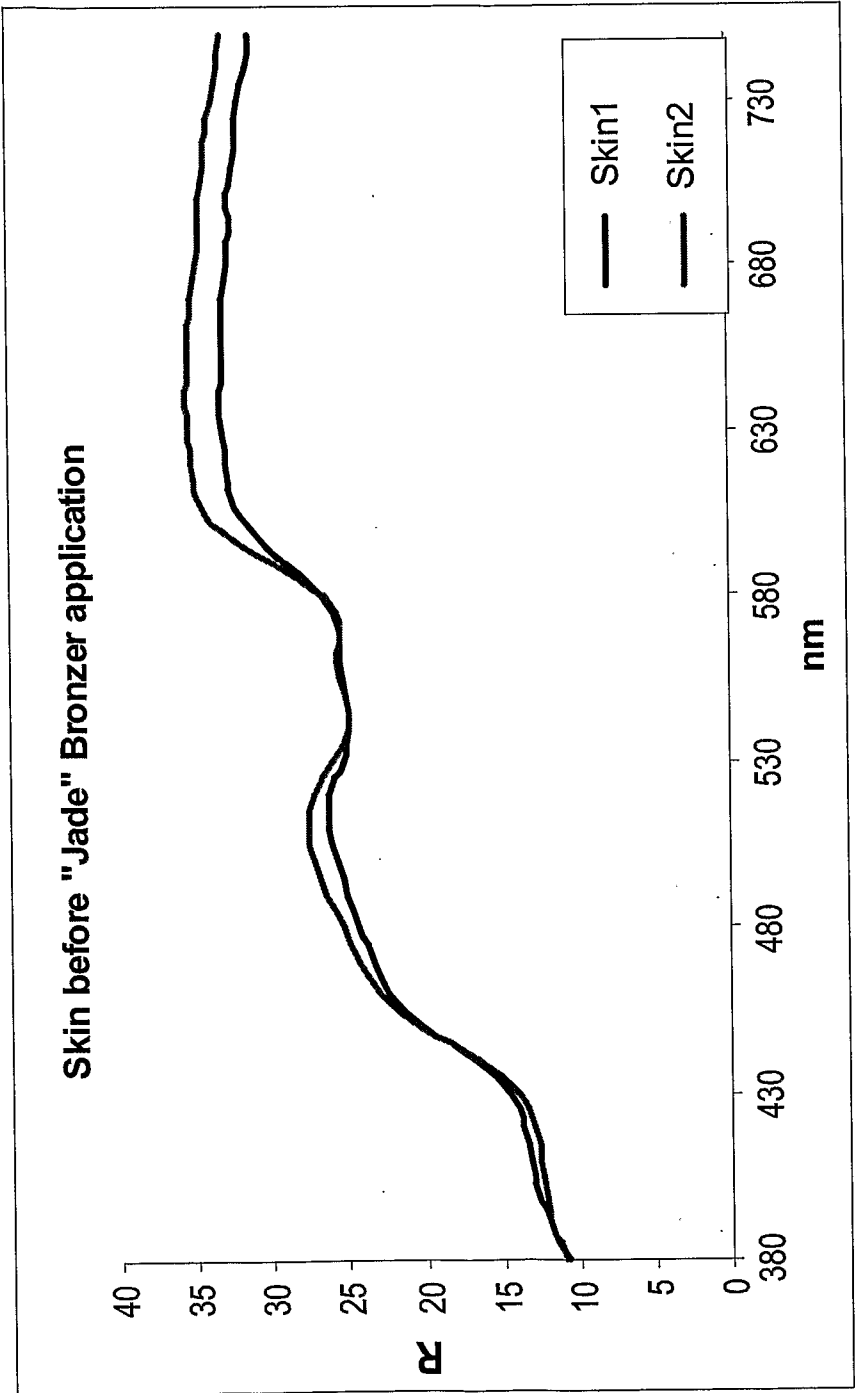


FIG. 2B

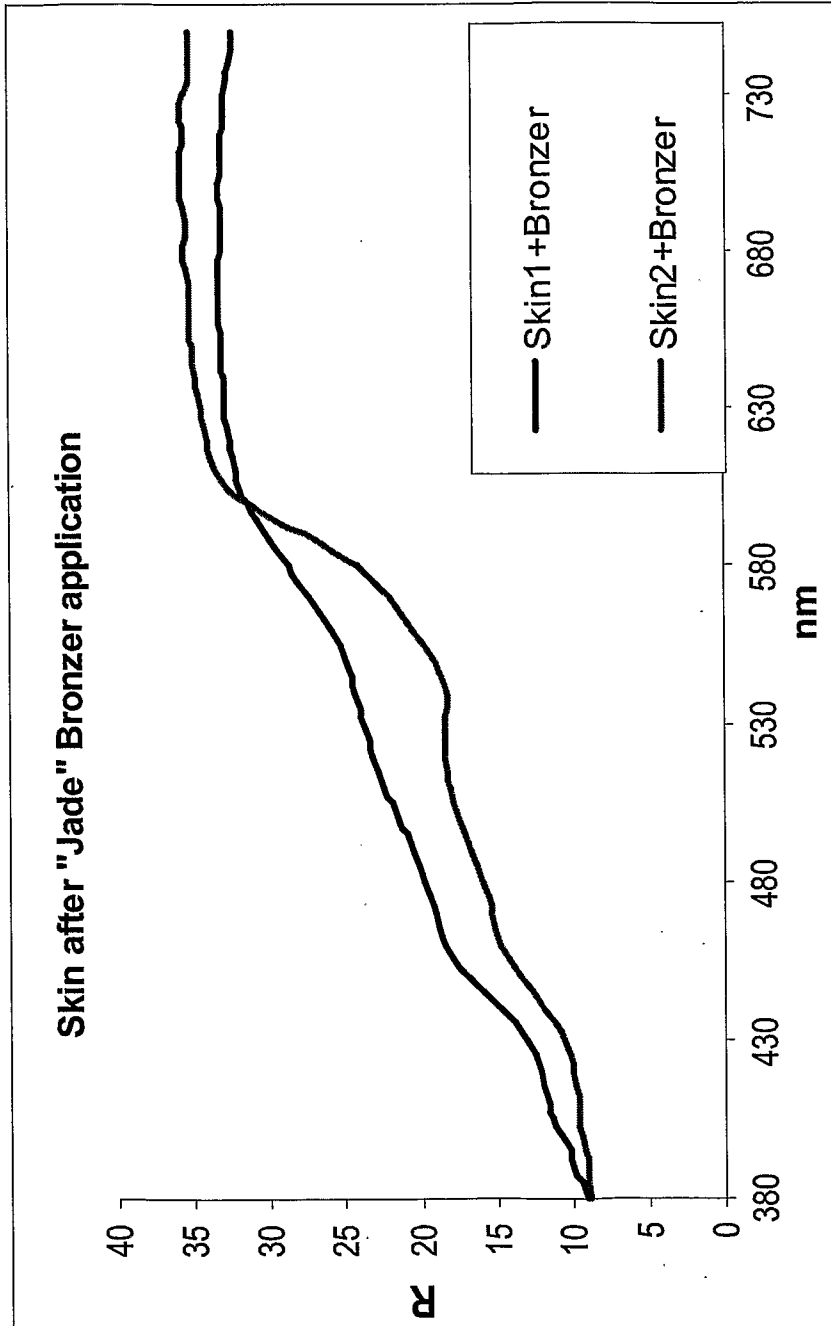


FIG. 3

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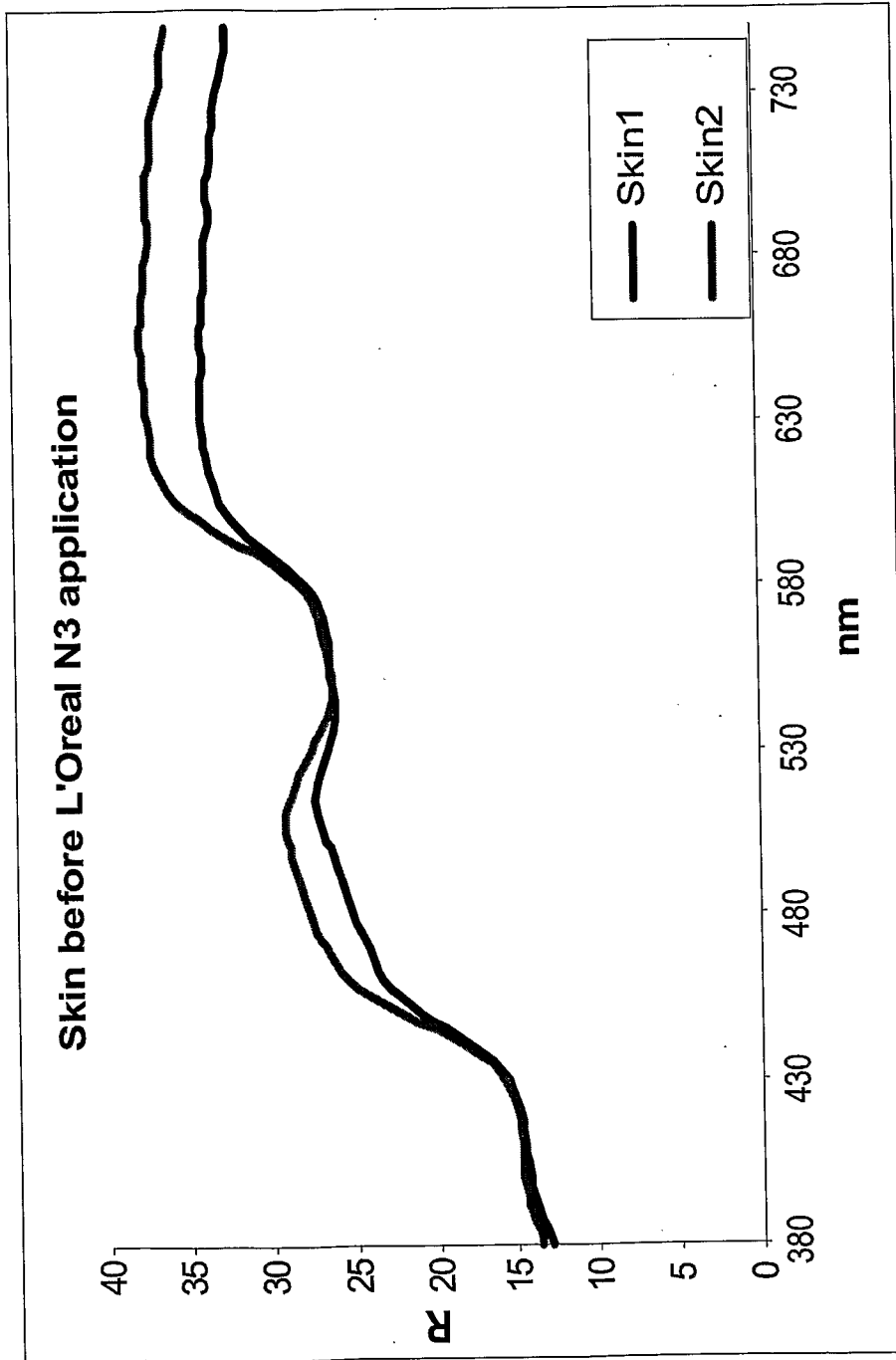


FIG. 4

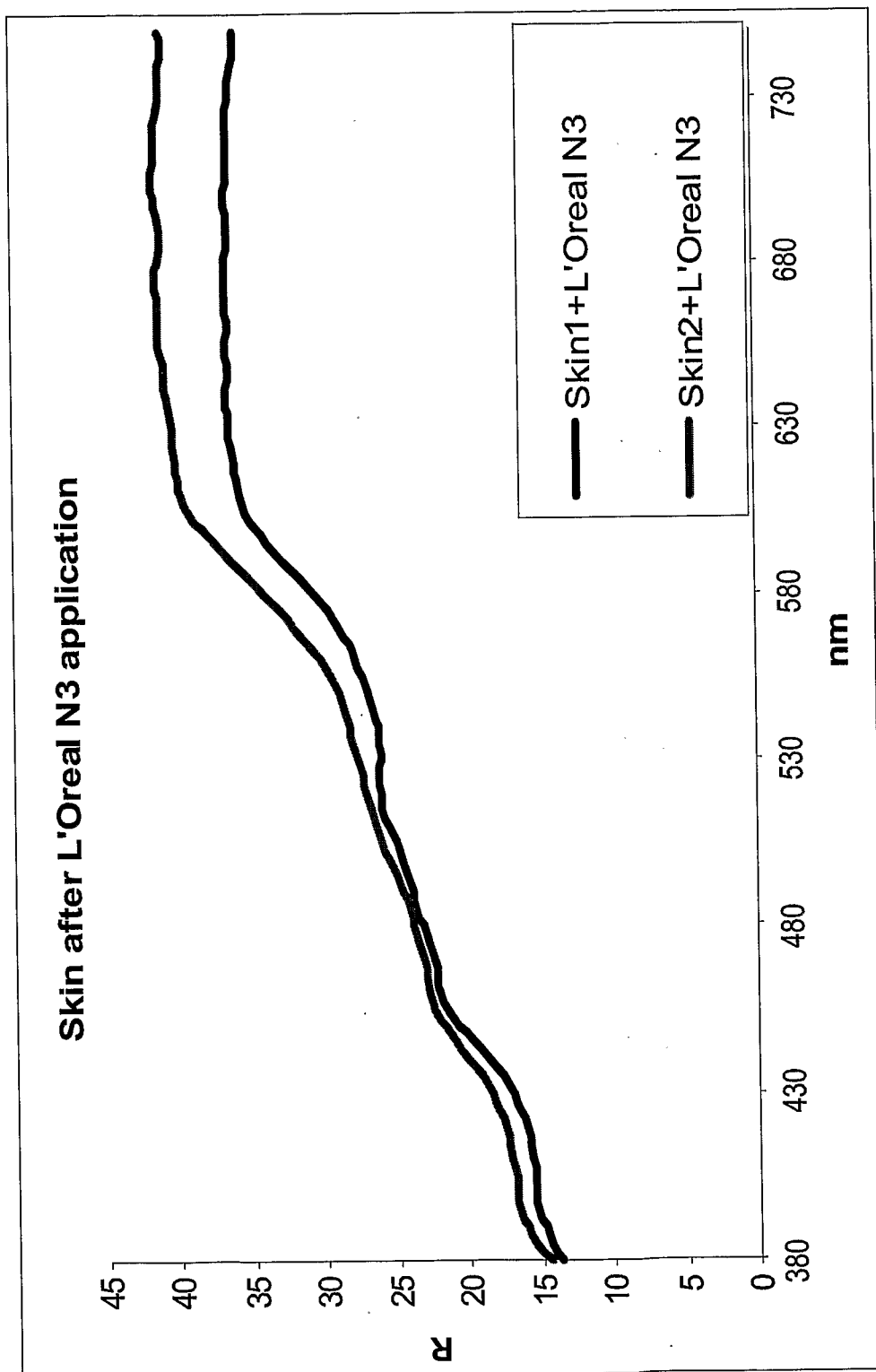


FIG. 5