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METHOD OF COLORING A CONTACT LENS

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Background of the Invention(1) Field of the Invention

15 This invention relates to colored contact lenses and methods of making colored contact lenses.

(2) General Background

20 Pad printed processes are often utilized to mass produce colored cosmetic corrective and non-corrective contact lenses. Pad-printing generally comprises the use of printing plates or clichés that have one or more depressions that collectively form a pattern that is transferable to a contact lens. During a pad-printing process, the fluent colorant is introduced into the depressions of the cliché. After the fluent colorant is

introduced into the depressions of the cliché, a doctor blade or an ink cup is then wiped across the surface of the cliché surrounding the depression(s) to remove excess ink from the cliché. A printing pad is then pressed against the cliché to transfer at least some of the colorant from the depressions to the printing pad. Finally, the printing pad is pressed against the contact lens to transfer the colorant from the printing pad to the contact lens.

A disadvantage of using pad-printing techniques is that the clichés wear as a result of the wiping process and generally must be replaced after approximately one-hundred thousand cycles, thereafter being no longer suitable for use. In addition to costs associated with forming new clichés, the replacement process requires halting production, dismounting the worn cliché or cliché set, and then mounting and aligning new cliché(s). Aligning new clichés is often time consuming and tedious. When printing detailed image patterns comprising multiple layers of individual colorants, each new cliché for a particular colorant layer must not only be properly aligned to the contact lenses, but also to each of the other clichés. As a result, numerous iterations of resuming then halting the lens production line to verify the cliché alignment accuracy are

often required. As images for coloring contact lenses become more intricate with higher resolutions and increasing numbers of color layers, the difficulty of aligning clichés and the time spent to do so increases.

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Summary of the Invention

The pad-printing methods of the present invention are an improvement over prior art pad-printing methods of coloring contact lenses. In general, the present invention increases the
10 useful life of clichés and improves the image resolution achievable using printing pad techniques.

In a first aspect of the invention, a method comprises a step of forming a cliché. The cliché comprises a piece of material having at least one depression formed therein using an
15 electrical discharge machining process. This method also comprises a step of introducing a fluent colorant into the depression of the cliché. Still further, this method comprises a step of transferring at least some of the colorant from the depression to a contact lens.

20 In a second aspect of the invention, a method comprises a step of forming a cliché. The cliché comprises a piece of material having a hardness rating in excess of Rockwell 64 (measured on the "C" Scale). The cliché also comprises a

depression formed into the piece of material. The method also comprises a step of introducing a fluent colorant into the depression of the cliché. Furthermore, the method comprises a step of transferring at least some of the colorant from the
5 depression to a contact lens.

In another aspect of the invention, a method comprises a step of providing a cliché. The cliché comprises a piece of material having a flat surface portion and a depression. The flat surface portion defines a plane and the depression extends
10 through the plane and into the piece of material a maximum depth perpendicular to and beyond the plane. The method further comprises a step of introducing a fluent colorant into the depression of the cliché. Additionally, the method comprises a step of wiping excess fluent colorant from the flat surface
15 portion surrounding the depression, the wiping causing the piece of material to wear in a manner such that the maximum depth of the depression is reduced. Still further, the method comprises a step of transferring at least some of the colorant from the depression to a contact lens. The steps of introducing a fluent
20 colorant into the depression of the cliché, wiping excess fluent colorant from the flat surface portion surrounding the depression, and transferring at least some of the colorant from

the depression to a contact lens occur in a manner such that these steps could be repeated in excess of one million times without the maximum depth of the depression being reduced by more than five micrometers.

5 In yet another aspect of the invention, a method comprises a step of forming a cliché. The cliché comprises a piece of cemented carbide material having at least one depression formed thereinto. The method further comprises steps of introducing a
10 fluent colorant into the depression of the cliché, and transferring at least some of the colorant from the depression to a contact lens.

While the principal advantages and features of the invention have been described above, a more complete and thorough understanding of the invention may be obtained by
15 referring to the drawings and the detailed description of the preferred embodiment, which follow.

Brief Description of the Drawings

Figure 1 is an example of an iris simulating image
20 comprising a plurality of distinct colorant layers overlaying each other.

Figures 2a through 2d are the individual colorant layers that, in combination, form the iris simulating image shown in Figure 1.

Figures 3a through 3e depict steps of a standard pad-printing process for transferring colorant from a cliché to a contact lens.

Figure 4 is a detail perspective view of a cliché depicting an example of two individual depressions of a larger depression pattern formed into the cliché.

Reference characters in the written specification indicate corresponding items shown throughout the drawing figures.

Detailed Description of the Preferred Embodiments of the Invention

An example of an iris simulating image for use in coloring contact lenses via a pad-printing process is shown in Figure 1. The iris simulating image 20 comprises the plurality of individual colorant layers shown in Figures 2a through 2d. Using a pad-printing process, the individual colorant layers are each separately applied to a contact lens.

The process of printing a colorant layer on a contact lens using a pad-printing process is schematically shown in Figures

3a through 3e. As depicted in Figure 3a, a cliché 30 having a flat surface 32 is flooded with a fluent colorant 34. The cliché 30 has at least one depression 36 that extends into the material forming the cliché through the flat surface 32. The depression 30 or set of depressions is configured such that when viewed from directly above the flat surface 32, the depression or set of depressions create a pattern identical to the particular colorant layer sought to be applied to a contact lens (i.e., a pattern such as shown in Figures 2a through 2d). A doctor blade 38, or in some cases a portion of an ink cup, is engaged with and swept across the flat surface 32 of the cliché 30 to wipe excess fluent colorant 34 from the portion of the flat surface surrounding the depression(s) 36, leaving fluent colorant in the depression(s). Following these steps and as shown in Figure 3b, a conventional pad-printing pad 40 is then vertically aligned with the depression 36 and pressed downward against the cliché 30 to transfer at least some of the fluent colorant 34 in the depression(s) to the pad. The pad 40 is thereafter brought into registration (Figure 3c) with a contact lens substrate 42 held on a lens holder 44 and then pressed (Figure 3d) against the lens substrate to deposit the colorant on the substrate. When the pad 40 is raised from the contact

lens substrate 42, at least some of the colorant layer 46 remains on the substrate in the desired pattern for the particular colorant layer, and is allowed to dry. Although not shown, additional colorant layers are thereafter serially
5 printed on the lens substrate 42 by transferring fluent colorant from other clichés (or other portions of the same cliché) that have distinct patterns or arrangement of depressions. Preferably, different fluent colorants are used for each distinct pattern. Once transferred to the contact lens
10 substrate 42, the individual colorant layers combine to form the complete iris-simulating image (such as shown in Figure 1).

The number of colorant layers making up the overall image sought to be printed on contact lenses can vary, and in some cases may be only one. However, the present invention is
15 particularly advantageous when the image sought to be printed is an iris simulating image comprising multiple colorant layers.

Typically the images sought to be printed on contact lenses are created or edited using computers. For example, a computer having a processor such as an Intel Pentium-4[®] processor and that
20 is equipped with a vector graphics design program such as Adobe Illustrator[®] is well suited for editing such images. In situations where the image to be printed is an iris simulating

image, an initial digitized image pattern may be obtained by scanning a photograph or rendering of a iris simulating pattern the computer, via a digital camera, or any other means of obtaining an digitized image of an iris pattern. Alternatively, the iris simulating patterns can be created from scratch using computer software. When using a pad-printing process, several sub-images, each representing a separate colorant layer, may be generated. Depressions are then formed into clichés to match the images or sub-images as described below.

Unlike prior art techniques used to create clichés for pad-printing contact lenses, the present invention utilizes different materials and different methods of creating depressions in the clichés. Preferably each cliché is formed from a piece of cemented carbide material. As used herein, cemented carbide is meant to include Tungsten Carbide, Molybdenum Carbide, Tantalum Carbide, Rhenium Carbide, Columbium Carbide, Alumon Carbide, Barium Carbide, Boron Carbide, Calcium Carbide, Cerium Carbide, Hafnium Carbide, Iron Carbide, Itrion Carbide, Lantion Carbide, Litium Carbide, Mangese Carbide, Molibion Carbide, Niobium Carbide, Neodymium Carbide, Nigel Carbide, Nitron Carbide, Praseon Carbide, Samarium Carbide, Sodium Carbide, Selenium Carbide, Silicon

Carbide, Tantalum Carbide, Torion Carbide, Titanium Carbide, Uranium Carbide, Vanadium Carbide, Zircon Carbide, and any other cemented carbide belonging to the class of hard, wear-resistant, refractory materials in which the hard carbide particles are
5 bound together, or cemented, by a binder and binderless carbides such as Cerbide™, Hardide™, and any heterogeneous combination of metal(s) or alloy(s) with one or more ceramic phases in which the latter constitutes approximately fifteen to eighty-five percent by volume and in which there is relatively
10 little solubility between metallic and ceramic phases at the preparation temperature.

A perspective view of a portion of an exemplary cliché 30 is shown in Figure 4. The piece of cemented carbide material used to form the cliché 30 preferably comprises a flat surface
15 32 having surface finish of six micro-inches centre line average (CLA). Pieces of cemented carbide material meeting these specifications can be purchased through various cemented carbide material suppliers such as Philadelphia Carbide Company located in Oreland, Pennsylvania. The piece of material used to create
20 the cliché 30 is preferably plate material having overall dimensions similar to prior art pad-printing plates or clichés.

Preferably a plurality of depressions 36 corresponding to

the image or image colorant layer sought to be reproduced using the cliché 30 are formed into the piece of material though the flat surface 32. Unlike prior art techniques of forming depressions in clichés, the present invention preferably
5 utilizes an electrical discharge machining (EDM) process to create the depressions 36. This is preferably done by saving the desired image in a digitized format such as IGES (Initial Graphics Exchange Specification) format and exporting it to computer aided machining software (CAM software) (available
10 through SmalTec International of Naperville, Illinois). Preferably, the CAM software, in turn, drives a CNC Controller and an electrical pulse controller used to run a wire electrical discharge grinding (WEDG) EDM device, such as a Panasonic model MG-ED72W (also available through SmalTec International), to thereby
15 form the depressions into the piece of material. Alternatively, a Die-Sinking EDM (also known as Sinker, Ram-Type, Conventional, Plunge or Vertical EDM) can be used to form the depressions into the piece of material. When using a Die-Sinking EDM, a raised reciprocal pattern of the image is preferably formed on the
20 electrode of the EDM machine using known lasing processes. For example, positive image or reciprocal relief of the depressions from a colorant layer can be etched into an electrode comprised

of a tungsten-copper alloy (such as is available through Saturn Industries of Hudson, New York) via a yttrium aluminum garnet (YAG) laser (such as an Electrox[®] Scriba II, commercially available from Electrox USA, Indianapolis, Indiana). It should
5 be appreciated that a cliché can comprises a single set of depressions forming a single color layer or that a cliché may comprise a plurality of sets of depressions, with each set forming a separate image pattern.

Using the forgoing methods to create the depressions of a
10 color contact pad-printing cliché provides several advantages over prior art methods of forming depressions. In particular, using a WEDG EDM process allows for the formation of very small and precise depressions that are not achievable using prior art techniques of forming color contact pad-printing clichés. To
15 illustrate this point, a detail perspective view depicting a pair of depression formed into the flat surface 32 of a cliché 30 is shown in Figure 4. A first depression 50 is shown extending into the piece of material through the plane of the flat surface 32 of the cliché 30. The first depression 50
20 extends into the material of the cliché 30 a constant depth 52 perpendicular to and beyond the plane of the flat surface 32. The second depression 54 comprises a first portion 56 that

extends into the material of the cliché 30 a first depth 58 perpendicular to and beyond the plane of the flat surface 32, and a second portion 60 that extends into the material of the cliché a second depth 62 perpendicular to and beyond the plane
5 of the flat surface.

For purposes of explaining resolution details of the depressions, it should be appreciated that a projected surface area can be determined for each of the first and second depressions 50, 54 by projecting the depressions perpendicularly
10 onto the plane of the flat surface 32. Using a EDM process to form the depressions allows very precise placement of the depressions. For example, at least a portion of the projected surface area of the first depression 50 can be within 50 micrometers, 25 micrometers, 10 micrometer, 5 micrometers, and
15 even 2.5 micrometers of a portion of the second depression 54. This spacing is represented by the numeral 62 in Figure 4. Additionally, the projected surface areas of the depressions can be rather small. For example, the projected surface area of an individual depression can be less than 6000 square micrometers,
20 or if desired, less than 4000 square micrometers, 2000 square micrometers, 1000 square micrometers, or even 800 square micrometers. Still further, using EDM processes to create the

depressions, the depth of any depression can vary by more than six micrometers from one portion to another portion of the depression. Although the variance in the depth of a depression is preferably gradual, the depth variance can also be abrupt.

5 For example the first depth 58 of the first portion 56 of the second depression 54 shown in Figure 4 could be seven micrometers while the second depth 62 of its second portion 60 may be in excess of twenty micrometers.

By allowing high resolution depressions to be formed the
10 clichés, very intricate patterns of depressions can be formed to collectively create a colorant layer of an image to be transferred to a contact lens. Additionally, by allowing the depth of depression to be varied and allowing the depths of separate depressions to be distinct, different thicknesses of a
15 colorant can be simultaneously transferred to a contact lens using a pad-printing process. In situation where the colorant is not fully opaque, this allows control over the shade of the color resulting from the colorant throughout different portions of the image. Thus, using the methods described herein, a pad-
20 printing process can achieve image resolutions and quality near those achievable via inject processes.

By forming the clichés out of cemented carbide material, the hardness of the clichés is in excess of the industry standard Rockwell 62-64 ("C" Scale) steel currently employed in the art. Additionally, the wear resistance of clichés is nearly
5 100 times greater than that of the material currently employed in the art. As discussed above, the wiping step of a pad-printing process invariably wears a cliché in a manner such that the depth of the depressions is gradually reduced. By increasing the wear resistance of the clichés, such wear can be
10 reduced to less than six micrometers per million pad-printing cycles. Moreover, in some cases, the wear may be reduced to less than six micrometers per ten million cycles. This allows clichés formed using methods of this invention to have a useful life many time greater than the useful life of clichés presently
15 used in the art of coloring contact lenses. By increasing the useful life of the clichés, the frequency of replacing the clichés can be reduced by a factor of more than one hundred. This greatly increases productivity and efficiency by reducing the undesirable downtime resulting from the alignment process
20 each time the clichés are replaced.

While the present invention has been described in reference to a specific embodiment, in light of the foregoing, it should

be understood that all matter contained in the above description or shown in the accompanying drawings is intended to be interpreted as illustrative and not in a limiting sense and that various modifications and variations of the invention may be
5 constructed without departing from the scope of the invention defined by the following claims. Thus, other possible variations and modifications should be appreciated.

Furthermore, it should be understood that when introducing elements of the present invention in the claims or in the above
10 description of the preferred embodiment of the invention, the terms "comprising," "including," and "having" are intended to be open-ended and mean that there may be additional elements other than the listed elements. Similarly, the term "portion" should be construed as meaning some or all of the item or element that
15 it qualifies.

What Is Claimed Is:

1. A method comprising:

forming a cliché, the cliché comprising a piece of material having at least one depression formed thereinto, the forming of
5 the cliché comprising using an electrical discharge machining process to create the at least one depression;

introducing a fluent colorant into the depression of the cliché; and

transferring at least some of the colorant from the
10 depression to a contact lens.

2. A method in accordance with claim 1 wherein the electrical discharge machining process utilized in the step of forming the cliché is a wire electrical discharge grinding process.

3. A method in accordance with claim 1 wherein the step of
15 forming the cliché occurs in a manner such that the piece of material has a flat surface portion that defines a plane and such that the depression extends through the plane and into the piece of material a maximum depth perpendicular to and beyond the plane, and further comprising the steps of:

20 wiping excess fluent colorant from the flat surface surrounding the depression, the wiping causing the piece of material to wear in a manner such that the maximum depth of the

depression is reduced; and

repeating each of the steps of introducing a fluent
colorant into the depression of the cliché, wiping excess fluent
colorant from the flat surface surrounding the depression, and
5 transferring at least some of the colorant from the depression
to a contact lens in excess of one million times without
reducing the maximum depth of the depression by more than five
micrometers.

4. A method in accordance with claim 1 wherein the step of
10 forming the cliché occurs in a manner such that the piece of
material is formed from a cemented carbide material.

5. A method in accordance claim 1 wherein the step of forming
the cliché occurs in a manner such that the piece of material
has a flat surface portion that defines a plane and such that
15 the piece of material comprises a plurality of spaced-apart
depressions that extend through the plane and into the piece of
material and that are formed into the piece of material using
the electrical discharge machining process, each of the
depressions having a projected surface area defined by
20 projecting such depression perpendicularly onto the plane, each
of the projected surface areas of at least twenty-five percent
of the depressions being less than one-thousand square

micrometers, and wherein the step introducing the fluent
colorant comprises introducing the fluent colorant into each of
the plurality of depressions and the step of transferring at
least some of the colorant comprises simultaneously transferring
5 at least some of the colorant from each of the depressions to
the contact lens.

6. A method in accordance claim 1 wherein the step of forming
the cliché occurs in a manner such that the piece of material
has a flat surface portion that defines a plane and such that
10 the piece of material comprises a plurality of spaced-apart
depressions that extend through the plane and into the piece of
material and that are formed into the piece of material using
the electrical discharge machining process, each of the
depressions having a projected surface area defined by
15 projecting such depression perpendicularly onto the plane, at
least a portion of the projected surface area of each of at
least twenty percent of the depressions each being within
twenty-five micrometers of another portion of another one of the
depressions, and wherein the step introducing the fluent
20 colorant comprises introducing the fluent colorant into each of
the plurality of depressions and the step of transferring at
least some of the colorant comprises simultaneously transferring

at least some of the colorant from each of the depressions to the contact lens.

7. A method in accordance with claim 6 wherein the step of forming the cliché occurs in a manner such that each of the
5 projected surface areas of at least twenty-five percent of the depressions is less than one-thousand square micrometers.

8. A method in accordance with claim 1 wherein the step of forming the cliché occurs in a manner such that the piece of material has a flat surface portion that defines a plane and
10 such that the depression comprises a first portion that extends through the plane and into the piece of material a first maximum depth perpendicular to and beyond the plane and such that the depression comprises a second portion that extends through the plane and into the piece of material a second maximum depth
15 perpendicular to and beyond the plane, the first maximum depth being in excess of six micrometers greater than the second maximum depth.

9. A method comprising:

forming a cliché, the cliché comprising a piece of material
20 having a hardness rating in excess of ("C" Scale) Rockwell 64, the cliché also comprising a depression formed into the piece of

material;

introducing a fluent colorant into the depression of the cliché; and

transferring at least some of the colorant from the
5 depression to a contact lens.

10. A method in accordance with claim 9 wherein the step of forming the cliché occurs in a manner such that the piece of material in a cemented carbide material.

11. A method in accordance with claim 9 wherein the step of
10 forming of the cliché comprises using an electrical discharge machining process to create the depression.

12. A method in accordance with claim 11 wherein the electrical discharge machining process utilized in the step of forming the cliché is a wire electrical discharge grinding process.

15 13. A method comprising:

providing a cliché, the cliché comprising a piece of material having a flat surface portion and a depression, the flat surface portion defining a plane, the depression extending through the plane and into the piece of material a maximum depth
20 perpendicular to and beyond the plane;

introducing a fluent colorant into the depression of the

cliché;

wiping excess fluent colorant from the flat surface portion surrounding the depression, the wiping causing the piece of material to wear in a manner such that the maximum depth of the
5 depression is reduced;

transferring at least some of the colorant from the depression to a contact lens;

the steps of introducing a fluent colorant into the depression of the cliché, wiping excess fluent colorant from the
10 flat surface portion surrounding the depression, and
transferring at least some of the colorant from the depression to a contact lens occurring in a manner such that the steps of introducing a fluent colorant into the depression of the cliché, wiping excess fluent colorant from the flat surface portion
15 surrounding the depression, and transferring at least some of the colorant from the depression to a contact lens could be repeated in excess of one million times without the maximum depth of the depression being reduced by more than five micrometers.

20 14. A method in accordance with claim 13 wherein the steps of introducing a fluent colorant into the depression of the cliché, wiping excess fluent colorant from the flat surface portion

surrounding the depression, and transferring at least some of the colorant from the depression to a contact lens are repeated in excess of one million times without the maximum depth of the depression being reduced by more than five micrometers.

5 15. A method in accordance with claim 13 wherein the steps of introducing a fluent colorant into the depression of the cliché, wiping excess fluent colorant from the flat surface portion surrounding the depression, and transferring at least some of the colorant from the depression to a contact lens occur in a
10 manner such that the steps of introducing a fluent colorant into the depression of the cliché, wiping excess fluent colorant from the flat surface portion surrounding the depression, and transferring at least some of the colorant from the depression to a contact lens could be repeated in excess of five million
15 times without the maximum depth of the depression being reduced by more than five micrometers.

16. A method in accordance with claim 13 wherein the step of forming of the cliché comprises using a wire electrical discharge grinding machining process to create the depression.

20 17. A method in accordance with claim 13 wherein the step of forming the cliché occurs in a manner such that the depression

comprises a first portion that extends through the plane and into the piece of material a first maximum depth perpendicular to and beyond the plane and such that the depression comprises a second portion that extends through the plane and into the piece
5 of material a second maximum depth perpendicular to and beyond the plane, the first maximum depth being in excess of six micrometers greater than the second maximum depth.

18. A method in accordance with claim 13 wherein the step of forming the cliché occurs in a manner such that the piece of
10 material comprises a plurality of spaced-apart depressions that extend through the plane and into the piece of material, each of the depressions having a projected surface area defined by projecting such depression perpendicularly onto the plane, at least a portion of the projected surface area of at least twenty
15 percent of the depressions each being within twenty-five micrometers of another portion of another one of the depressions, and wherein the step introducing the fluent colorant comprises introducing the fluent colorant into each of the plurality of depressions and the step of transferring at
20 least some of the colorant comprises simultaneously transferring at least some of the colorant from each of the depressions to the contact lens.

19. A method in accordance with claim 18 wherein the step of forming the cliché occurs in a manner such that each of the projected surface areas of at least twenty-five percent of the depressions is less than one-thousand square micrometers.

5 20. A method in accordance with claim 18 wherein the step of forming the cliché occurs in a manner such that at least one of the depressions comprises a first portion that extends through the plane and into the piece of material a first maximum depth perpendicular to and beyond the plane and a second portion that
10 extends through the plane and into the piece of material a second maximum depth perpendicular to and beyond the plane, the first maximum depth being in excess of six micrometers greater than the second maximum depth.

21. A method in accordance with claim 13 wherein the step of
15 forming the cliché occurs in a manner such that the piece of material is a cemented carbide material.

22. A method comprising:

forming a cliché comprising a piece of cemented carbide material having at least one depression formed thereinto;

20 introducing a fluent colorant into the depression of the cliché; and

transferring at least some of the colorant from the depression to a contact lens.