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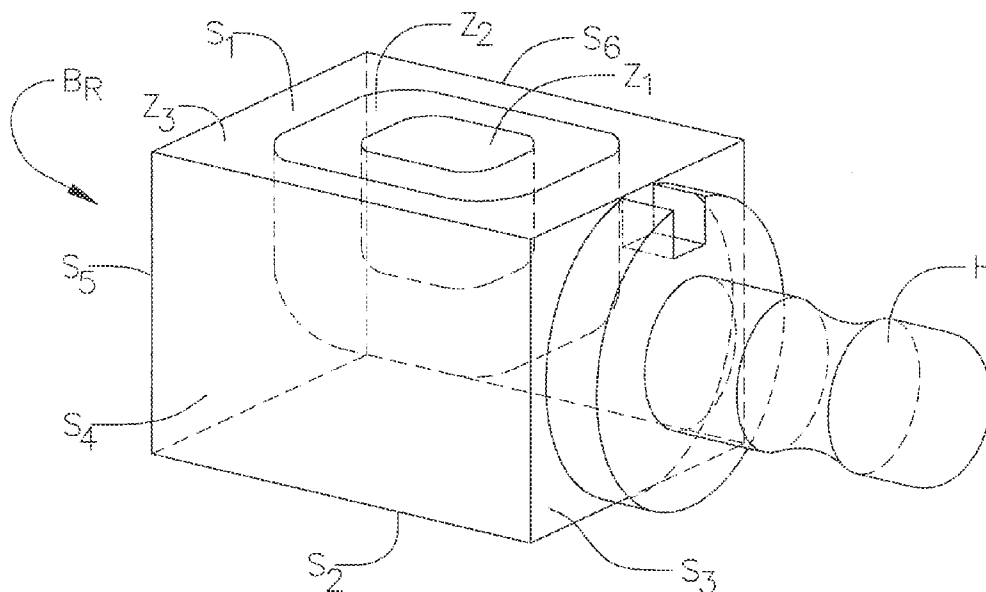
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(54) Title: MULTICOLOR DENTAL BLANKS AND RELATED METHODS



(57) Abstract: A dental blank of the present invention has at least an inner zone (or layer) of a first color and an outer zone (or layer) of a second color wherein the inner and outer zones are concentric. The inner zone can be surrounded in its entirety by the outer zone such that only the outer zone is visible on all surfaces of the blank and the inner zone is not visible on any surface of the blank. Alternatively, the inner zone and the outer zone can extend to a same single surface of the blank, such that only the outer zone covers all remaining surfaces. The dental blank may also have an intermediate zone between the inner and outer zones, wherein the intermediate zone is surrounded in its entirety by the outer zone and/or the intermediate zone surrounds the inner zone in its entirety.

MULTICOLOR DENTAL BLANKS AND RELATED METHODS

FIELD OF THE INVENTION

The invention relates to methods and materials for machinable multicolor dental blanks to fabricate polychromatic, color-graded dental devices which replicate the color gradation of natural teeth.

BACKGROUND OF THE INVENTION

Presently, dental blanks are composed of a single color, or of multiple colors layered on top of each other. The monochromatic blocks may not match the natural color gradation found in natural teeth. Furthermore, shades of these colored blocks are limited in number, and may not even match an overall base shade of a tooth.

One known type of block does have three layers of color. However, these layers extend fully to surfaces of the block, and result in restorations with sharp gradations in color, as opposed to natural teeth which have gradual changes in color. Furthermore, natural teeth have color generated internally by overlapping colors from the enamel and dentin of the tooth.

Conventional methods of fabricating dental blocks involve pressing powders into a mold or using an extrusion from which blocks are then fired to full density. These are time and labor intensive processes and do not easily allow for placement of multiple colors as desirable for dental blocks with improved color matching.

Accordingly, it would be desirable to provide a blank with color zones which correspond to colors found in natural teeth. Moreover, it would be desirable to provide a blank from which restorations with varying ratios of color thicknesses can be produced. It would also be desirable to provide a method of fabrication of dental blocks that readily allows for placement and incorporation of multiple colors.

SUMMARY OF THE INVENTION

The proposed blank has concentric zones of color which correspond to colors found in natural teeth. A restoration may be positioned in the blank to produce a milled restoration with layered overlapping colors. The resulting milled restoration more closely resembles the layering found in natural teeth. Furthermore, the restoration may be positioned in the blank to produce varying ratios of color thickness which allows for production of multiple shades from a single blank. Blocks currently on the market are a single shade, or are limited in the number of shades available. The proposed blank would allow for more shades to be produced, and thus improve the likelihood of a match to the patient's natural dentition.

In one embodiment, a dental blank of the present invention has at least an inner zone of a first color and an outer zone of a second color, wherein the inner and outer zones are

1 concentric. The inner zone can be surrounded in its entirety by the outer zone such that only the outer zone is visible on all surfaces of the blank and the inner zone is not visible on any surface of the blank. Alternatively, the inner zone and the outer zone can extend to a same single surface of the blank, such that only the outer zone covers all remaining surfaces.

5 In a more detailed embodiment, the inner zone has a first chroma and the outer zone has a second chroma, wherein the first chroma is greater than the second chroma, or the color of the inner zone is darker than the color of the second zone.

10 In another embodiment, the dental blank has an intermediate zone between the inner and outer zones. The intermediate zone can be surrounded in its entirety by the outer zone and/or the intermediate zone surrounds the inner zone in its entirety, or the intermediate zone can extend to the same single surface of the blank to which the inner and outer zones extend.

15 The dental blank may have a generally rectangular configuration or a generally cylindrical configuration. The zones may have a generally rectangular configuration or a generally cylindrical configuration, wherein the configuration of the zones is independent of the configuration of the blank. Some or all of the zones may also have the same thickness or different thicknesses.

20 In another detailed embodiment, the invention comprises a blank of concentric polychromatic (typically three or more colors) material. The blank is composed of porcelain, ceramic, glass, glass ceramic, composite resin, acrylic, or other machinable or heat-pressable material. A holder, if needed, of metal, plastic, or a combination of these materials may be glued directly on the blank, or the blank may be molded directly on the holder for placement in a milling device.

25 The present invention also includes fabrication of dental blanks through solid free form processes, such as robocasting, laser sintering and 3D printing that readily allow for placement of multiple colors in a single dental blank. A method of manufacturing a dental blank includes solid free form fabricating a dental blank having at least a first and a second concentric zones, wherein the first concentric zone has one color and the second concentric zone has another color. The solid free form fabrication can be robocasting, three dimensionally printing or laser sintering. In a more detailed embodiment, the solid free form fabricating a dental blank includes providing a depositing device adapted to deposit a material of a first color and a material of a second color, providing a platform, wherein the depositing device and the platform move in a predetermined pattern relative to each other, and controlling the depositing device to switching between depositing the material of the first color color and depositing the material of the second color. The predetermined pattern can be a spiral, a raster, or variations or combinations thereof.

35 The methods and materials for producing milled dental devices of the present invention can overcome shortcomings of prior-art devices. The methods and materials for producing dental blanks of the present invention can be applied to fabricate polychromatic,

1 color-graded dental devices which replicate the color gradation of natural teeth. The
methods and materials for producing dental blanks of the present invention can also allow for
the production of a variety of shades from a single block of material by varying the ratio of
milled outer layers to internal layers.

5 DETAILED DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will be better
understood by reference to the following detailed description when considered in conjunction
with the accompanying drawings wherein:

10 FIG. 1. is a perspective view of one embodiment of a dental blank of the present
invention.

FIG. 1A is a perspective view of the dental blank of FIG. 1 showing concentric zones.

FIG. 2 is a top view of the dental block of FIG. 1.

FIG. 2A is a cross-sectional view of the dental block of FIG. 2 taken along line A--A.

15 FIG. 3 is an end view of the dental block of FIG. 1.

FIG. 4 is a side elevational view of the dental block of FIG. 1, with restoration
contour lines C1, C2 and C3.

FIG. 5 is perspective view of another embodiment of a dental blank of the present
invention.

20 FIG. 6 is a top elevational view of the dental blank of FIG. 5.

FIG. 6A is a cross-sectional view of the dental blank of FIG. 6, taken along line A--A.

FIG. 7 is an end view of the dental blank of FIG. 6.

FIG. 8 is a top view of the dental blank of FIG. 6, showing a restoration contour
line C.

25 FIG. 9 is a side view of another embodiment of a dental blank showing concentric
zones with different configurations and/or thicknesses.

FIG. 10 is a perspective view of another embodiment of a dental blank of the present
invention, whose internal concentric zones do not extend any surface of the dental blank.

30 FIG. 10A is a perspective view of the dental blank of FIG. 10 showing concentric
zones.

FIG. 11 is a top view of the dental block of FIG. 10.

FIG. 11A is a cross-sectional view of the dental block of FIG. 11 taken along line
A--A.

FIG. 12 is a side elevational view of the dental block of FIG. 10.

35 FIG. 13 is an end view of the dental block of FIG. 10.

FIG. 14 is a top view of the dental block of FIG. 10, showing a restoration contour
line C'.

FIG. 15 is a cross sectional view of an embodiment of a milled dental block of the present invention.

FIG. 16 is a top view of yet another embodiment of a dental block of the present invention.

FIG. 16A is a cross sectional view of the dental block of FIG. 16, taken along line A--A.

FIG. 17 shows a schematic representation on an embodiment of a system in accordance with the present invention.

FIG. 18 shows a perspective view of an embodiment of a cylindrical blank as fabricated in accordance with the present invention.

FIG. 19 shows a perspective view of an embodiment of a rectangular blank as fabricated in accordance with the present invention.

FIG. 20 shows a perspective view of an embodiment of a rectangular blank as fabricated in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A blank in accordance with the present invention is composed of porcelain, ceramic, glass, glass ceramic, acrylic, composite resin, a combination of some of these materials, or other materials with concentric colors representing natural tooth colors. Colorants may be inorganic or organic. A suitable porcelain may be composed of a variety of materials with a glass matrix such as feldspathic glasses, silica, aluminosilicates, and crystalline materials such as leucite, fluorapatite, fluoromica, with other metallic oxides as colorants or matrix/crystal components. Ceramic materials may include metallic oxides such as alumina, zirconia, spinel or other monocrystalline or polycrystalline materials. As understood by one of ordinary skill in the art, ceramics and porcelains may contain inorganic colorants to achieve the proper color gradation to match natural teeth. Moreover, acrylic and composite resins may be composed of methacrylates such as methyl methacrylate or urethane dimethacrylate, BIS-GMA, epoxies, polyacrylamide, with or without glass, ceramic, or fibers commonly used as fillers for direct or indirect resin-based restorative materials.

As illustrated in FIGs. 1-14, a blank (or block, used interchangeably herein) B of the present invention may be in the form of a cylinder of various diameters and lengths, or a rectangle of various dimensions, e.g., widths, lengths and heights. In any of these forms, the blank has at least two opposing surfaces S1 and S2. In the case of a rectangular blank BR (inclusive of a square blank) as illustrated in FIGs. 1-4, there are the opposing surfaces S1 and S2 with four additional surfaces S3-S6 extending therebetween. In the case of a cylindrical blank BC as illustrated in FIGs. 5-8, there are the opposing surfaces S1 and S2 and a tubular surface ST extending therebetween.

1 In accordance with a feature of the present invention, the blank B whether it is
cylindrical or rectangular (or any other shape) is configured with a plurality of concentric
zones (or layers) of colors Z1, Z2, ...Zn, with the plurality n ranging between about 2 to 5,
and more preferably about 3. The zones may be of varying sizes/volumes/thicknesses, and
5 varying degrees of chroma, hue and value. Typically two or three zones of color extend from
darker to lighter, and/or higher chroma to lower chroma, as one proceeds from an innermost
or internal zone Z1, to middle or intermediate zone(s) Zi and to an outermost or external
zone Zn.

10 In one embodiment of the blank, all of the concentric zones extend to one of the
surfaces S1 or S2, such that all of the concentric zones are visible on that one surface only.
In the embodiment of FIGs. 5-8, all of the concentric zones Z1-Z3 of the cylindrical blank
BC are visible on surface S1, whereas only the outermost zone Z3 is visible on the remaining
surfaces S2 and ST. In the embodiment of FIGs. 1-4, all of the concentric zones Z1-Z3 of the
rectangular blank BR are visible on surface S1, whereas only the outermost zone Z3 is visible
15 on the remaining surfaces S2, and S3-S6.

It is understood by one of ordinary skill in the art that with either the blank BC or BR,
each of the surfaces except for the surface on which the concentric zones are visible
(namely S1 in the illustrated embodiments) presents a surface underneath which the different
zones Z1-Zn are layered to advantageously simulate the layering structure found in natural
20 teeth. The concentric zones and colors are contained within the block, with outwardly
decreasing chroma, and with possible differences in shade and opacity. The change in chroma
progresses from an internal layer Z1, through an intermediate layer Zi, to an external
layer Zn. In accordance with a feature of the present invention, a resulting color and chroma
that is visible on the surfaces on which only the outermost zone Zn is visible (namely, all
25 surfaces except for the surface S1) is composed of a combination of the colors and chromas
of all the zones layered below the surfaces of the blank.

In another embodiment, only the outer zone Zn extends to the surfaces of the blank.
As illustrated in FIGS. 10-13, the innermost zone Z1 is surrounded entirely by the
intermediate zone Z2, which in turn is surrounded entirely by the outermost zone Z3.
30 Accordingly, only the outermost zone Z3 is visible on all surfaces of the blank. In
accordance with a feature of the present invention, the color and chroma visible on all of the
surfaces of the blank is a combination of all the colors and chromas of all the zones that are
layered under the surfaces of the blank.

35 In the illustrated embodiments of FIGs. 1-8 and 10-13, the zones have a cross section
or overall shape that mirrors the cross section or overall shape of their respective blank. That
is, the zones of the rectangular blank BR have a generally rectangular shape and the zones of
the cylindrical blank BC have a generally cylindrical shape. Conceivably, the zones may not
mirror the shape of their respective blank, and a cylindrical blank can have rectangular zones,

1 and a rectangular blank can have cylindrical zones, or a blank can even have a mix of rectangular or cylindrical zones as appropriate or desired.

Moreover, the zones within a blank can have the same or different thicknesses, and the thickness of any one zone can also be varied in different dimensions, for example, in the (X,Y,Z) Cartesian coordinates, or (R, Z) polar coordinates. In the illustrated embodiments, the zones Z2 and Z3 of the block BR are generally thicker than the zone Z1, and the zone Z2 of Block BC is thinner than both zones Z1 and Z3. As illustrated in FIG. 9, the block whether it is a rectangular block BR or a cylindrical block BC, a zone (such as zone Z2) can have a greater thickness in one dimension (e.g., X axis) and a lesser thickness in another dimension (e.g., Y axis).

Furthermore, the zones within a blank may be varied in whether they extend to a surface of the blank. As illustrated in FIGs. 16 and 16A, the zone Z1 may be surrounded entirely by zone Z2 and not extend to any surface of the blank, but the zone Z2 may extend to the surface S1. Indeed, any variation in the configuration or the thickness of the zones is contemplated within the present invention, as desired or appropriate. However, in accordance with a feature of the present invention, the zones remain generally concentric.

The blank may be made partially or completely opaque, and may be colored to match natural tooth colors or other colors. Additional materials may be added to the milled devices to further alter color or shape. The blank may be positioned in a milling device to alter a ratio of milled external colors to internal colors to produce multiple tooth shades from a single blank.

The blank may be used directly as a final or provisional restoration. The blank may be milled to provide a substructure for other materials layered on the milled blank to produce a final or provisional restoration.

In one embodiment, a porcelain blank is placed in a spindle of a milling device. The blank is milled to form a full-contour dental restoration, using computer design and milling. A proper blank is selected for the tooth color being matched, and is placed in the milling system. The blank is milled to provide an inner layer(s) of darker, more chromatic material, with an outer layer(s) of lighter, less chromatic material. This replicates the gradation in color found in the tooth being restored, and in the adjacent natural teeth. In the illustrated embodiments, the innermost layer Z1 provides the darker, more chromatic material and the outermost layer Zn provides the lighter, less chromatic material.

A holder H comprised of metal, plastic or a combination thereof, may be attached to the blank for placement in the milling device. The holder may be glued to the blank, or the blank may be directly processed on the holder. The holder H may be fixed to the block in order to facilitate positioning in the milling device. This may or may not be necessary, and the holder is not limited to the exact configuration as illustrated. Referring to FIG. 4, the block may be milled to produce a full-contour restoration, such as a crown C. The layers Z1,

1 Z2 and Z3 represent the natural layering of color seen in a tooth. An outline of the crown C1
is shown in FIG. 4. Notably, the surface S1 on which all zones of the blank are visible
coincides with a bottom of the crown C1, that is, a surface for which there is minimal need
for matching color with natural teeth. Correspondingly, all other surfaces of the crown C1 lie
5 in an area underneath which is a layering of the various zones of the blank. And, by
adjusting the outline of the crown C1 in FIG. 4, the thickness of the outermost zone Z3 at any
region can be varied so as to vary the resulting color/chroma in that region. For example,
where the outline is lowered to C2, the crown has a thinner layer of Z3 on its biting or
occlusal surface. And, where the outline is raised to C3, the crown has a thicker layer Z3 on
10 its occlusal surface. Similarly, a shift to the left or right in FIG. 4, can result in the crown
having a thinner or thicker layer of Z3 on its facial or lingual surface. Since a difference in
the thickness of the layer of Z3 can affect color/chroma, the crown following outline C2 has a
different color/chroma from the crowns following outlines C1 and C3. However, all crowns
C1, C2 and C3 have the benefit of a more natural looking color/chroma resulting from the
15 layering effects of zones Z1, Z2 and Z3.

FIGs. 10-13 illustrate another embodiment of a multicolor rectangular bank BR'
(although it is understood that the following description applies to a cylindrical blank). In
this embodiment, the inner zones or layers are surrounded in their entirety by the outer zones
or layers so that only the outermost zone Zn (in this instance Z3) is visible on the surface S1.
20 Also in this embodiment, the chroma decreases from an internal layer Z1, to an intermediate
layer Z2, and then is lowest at an outer layer Z3. Furthermore, as with the previous
embodiments, the opacity and color may also change. FIG. 14 illustrates a full-contour
crown fabricated using this block embodiment block. An outline C' of the crown is depicted.
Again, it is understood that by adjusting the placement of the outline C', the thickness of the
25 layer of Z3 can be increased or decreased in all three dimensions of X, Y and Z.

FIG. 15 illustrates one embodiment of a milled full-contour crown in which three
layers of increasing chroma have been used. As illustrated, each zone Z1-Z3 has a similar
configuration resembling that of the crown or the resulting dental device/prosthesis. A lower-
central area 23 contains no material, and fits on a mating portion of a prepared tooth. Chroma
30 outwardly decreases from an inner layer or zone Z1 (highest chroma) through a middle layer
or zone Z2, to an outer layer or zone Z3 (lowest chroma). Shade and opacity may also be
varied across these layers. Furthermore, varying the thickness ratio of the three layers) may
allow fabrication of a variety of tooth shades from a single block.

Regardless of the specific embodiment of a blank, a method of milling a dental
35 prosthesis from the blank can include using a blank with concentric zones of different colors,
including an outermost zone, and positioning a form of the dental prosthesis on the blank
wherein an occlusal surface of the prosthesis is contained in the outermost zone, so that the
occlusal surface provides a resulting color/chroma that results from the combination of

1 colors/chromas of the underlying zones. And, by adjusting the positioning of the form on the blank, the resulting color/chroma can be adjusted.

Advantageously, position of the block may be altered in the milling system to allow for improved color replication and production of multiple tooth shades from a single block.

5 Alternatively, the blank may be milled to provide a substructure upon which additional colored layers may be applied to produce the final dental restoration.

Alternatively, the above procedures may be followed to produce a provisional restoration.

10 Alternatively, the blank may be milled to produce a superstructure, which is then joined to a substructure by gluing or firing, using an intermediary glass, porcelain or ceramic material.

Alternatively, the blank may be milled to produce a denture tooth.

Alternatively, the blank may be heated until flowable, and pressed or molded into a tooth pattern to fabricate the dental restoration.

15 The multicolor layered blank may be fabricated by sequential pressing, injection molding, or three-dimensional rapid manufacturing techniques. These include selective laser sintering, three-dimensional printing, or Robocasting/Direct slurry deposition, or deposition of a suspension of the component materials.

20 Selective Laser Sintering is an additive rapid manufacturing technique that uses a high power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal, or ceramic powders into a mass representing a desired 3-dimensional object. The laser selectively fuses powdered material by scanning cross-sections generated from a 3-D digital description of the part (e.g. from a CAD file or scan data) on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed.

25 Three-dimensional printing is a method of converting a virtual 3D model into a physical object. 3D printing is a category of rapid prototyping technology. 3D printers typically work by printing successive layers on top of the previous to build up a three dimensional object.

30 Robocasting is a method of fabricating ceramics that requires no molds or machining, by generally relying on robotics for computer-controlled deposition of ceramic slurries -- mixtures of ceramic powder, water, and trace amounts of chemical modifiers -- through a syringe. The material, which flows like a milkshake even though the water content is only about 15 percent, is deposited in thin sequential layers onto a heated base. The product manufactured is fabricated layer by layer by a robot that squeezes a slurry out of the syringe, following a pattern prescribed by computer software. A suitable robocasting method is described in U.S. Patent No. 6,027,326, and 6,401,795, the entire disclosures of which are hereby incorporated by reference.

35

1 The foregoing techniques and other types of solid free form fabrication allow for
placement of multiple colors. As illustrated in FIG. 17, an embodiment of a system S for
freeforming a dental blank includes a moveable platform 100 and a material depositing
device 120 having a nozzle or printer head 124 through which material (e.g., a slurry 1) 130
5 is controllably deposited. Conventional means are provided for controllably moving
depositing device 120 with respect to platform 110 in at least X, Y, and Z directions. As
illustrated, platform 110 may be an X-Y table which is moveable in the X-Y plane by a
platform controller 132, and device 120 may be driven by conventional means, such as a
threaded rod in the Z direction. Alternatively, platform 110 may be fixed and device 120 may
10 be affixed to a robotic arm moveable in any direction. In addition, both platform 110 and
device 120 may be moveable with respect to one another.

 Depositing device 120 may be a syringe or a printer head. The movement of
device 120 with respect to platform 110, and actuation of the depositing device 120, is
controlled by a programmed processor or computer 140.

15 To provide the different zones of colors in the blank B, the S system in the illustrated
embodiment includes a color or pigment source 160 that is also connected to the
processor 140 which controls the amount of color or pigment to be mixed with the slurry 1.
Alternatively, the system can include a second material 130' (e.g., slurry 2 with a different
color, shade or chroma,) which the processor 140 can select as an alternate source of material
20 for the depositing device 120.

 With further reference to FIG. 18, in fabricating a cylindrical blank BC, the relative
movement between the platform and the depositing device 120 may be a spiral pattern
(illustrated in broken lines) that is generally circular. The spiral can be inwardly and/or
outwardly, creating layer upon layer of material with each pass over the same location on the
blank. In one embodiment, where the blank BC has an inner zone Z1 and an outer zone Z2,
25 the computer 140 starts a deposition process by positioning the depositing device at
location A and depositing the slurry II from the material source 130' in an inwardly spiral
counterclockwise pattern to begin creating the zone Z2. When the depositing device reaches
a boundary or border 200 between the zones Z1 and Z2, the computer 140 changes the
amount of color or pigment from the source 160 to be added to the slurry II to begin creating
30 the zone Z1. The deposition process in the zone Z1 continues until the depositing device
reaches location B (e.g., a center of the blank), at which stage the computer 140 can reverse
the deposition pattern to an outwardly spiral clockwise pattern to add another layer to the
zone Z1. When the depositing device again reaches the boundary 200, the computer 140
35 changes the amount of color back to that used for the zone Z2. Alternatively, when the
deposition device reaches the boundary 200, the computer 140 can switch the source of the
slurry for the deposition device between materials 130 and 130' for building the zones Z1 and
Z2, respectively. It is understood that while the embodiment of FIG. 18 shows the relative

1 movement between the nozzle and the platform as a spiral pattern, the pattern can also be a
raster (see FIG. 20), although the frequency in changing the amount of color/pigment input
from the color source 160, or in switching between the material sources 130 and 130' would
be greater. With reference to FIG. 19, a generally rectangular blank BR can be fabricated
5 with a relative pattern that is generally rectangular. Indeed, the relative pattern can also
correspond with or be dependent on the configurations of the zones.

The preceding description has been presented with reference to presently preferred
embodiments of the invention. Workers skilled in the art and technology to which this
invention pertains will appreciate that alterations and changes in the described structure may
10 be practiced without meaningfully departing from the principal, spirit and scope of this
invention.

Accordingly, the foregoing description should not be read as pertaining only to the
precise structures described and illustrated in the accompanying drawings, but rather should
be read consistent with and as support to the following claims which are to have their fullest
15 and fair scope.

1 WHAT IS CLAIMED IS:

1. A dental blank comprising at least an inner zone of a first color and an outer zone of a second color, wherein the inner and outer zones are concentric.

5 2. A dental blank of claim 1, wherein the inner zone is surrounded in its entirety by the outer zone.

3. A dental blank of claim 1, wherein only the outer zone is visible on all surfaces of the blank.

10 4. A dental blank of claim 1, wherein the inner zone is not visible on any surface of the blank.

5. A dental blank of claim 1, wherein the inner zone and the outer zone extend to a same single surface of the blank.

15 6. A dental block of claim 5, wherein only the outer zone covers all remaining surfaces.

7. A dental block of claim 1, wherein the inner zone and the outer zone are visible on a same single surface of the blank.

20 8. A dental block of claim 7, wherein only the outer zone is visible on all remaining surfaces.

9. A dental blank of claim 1, wherein the inner zone has a first chroma and the outer zone has a second chroma.

25 10. A dental block of claim 9, wherein the first chroma is greater than the second chroma.

11. A dental blank of claim 1, wherein the first color is darker than the second color.

30 12. A dental blank of claim 1, further comprising an intermediate zone between the inner and outer zones.

13. A dental blank of claim 1, further comprising an intermediate zone surrounded in its entirety by the outer zone.

35 14. A dental blank of claim 1, further comprising an intermediate zone, wherein the inner zone is surrounded in its entirety by the intermediate zone.

1 15. A dental blank of claim 1, further comprising an intermediate zone between and concentric with the inner and outer zones.

5 16. A dental blank of claim 1, wherein the blank has a generally rectangular configuration.

 17. A dental blank of claim 1, wherein the blank has a generally cylindrical configuration

10 18. A dental blank of claim 1, wherein the blank has a generally cylindrical configuration having two opposing generally circular surfaces, and the inner and outer zones extend to one of the opposing generally circular surface.

 19. A dental blank of claim 1, further comprising a holder.

15 20. A dental blank of claim 1, wherein the zones have an equal thickness along at least one dimension.

20 21. A dental blank comprising at least an inner layer of a first color and an outer layer of a second color, wherein the blank has at least one outer surface whose resulting color is a combination of at least the first and second colors of the inner and outer layers.

 22. A method of milling a dental prosthesis from a blank, comprising:
 providing a blank with concentric zones, including an outermost zone, wherein each of the zones has a different color;

25 positioning a form of the dental prosthesis on the blank wherein an occlusal surface of the prosthesis is contained in the outermost zone.

 23. A method of claim 22, further comprising adjusting a position of the form on the blank to adjust a resulting color or chroma of the prosthesis.

30 24. A method of claim 23, wherein the adjusting a position results in changing an amount of the outermost zone to be contained in the prosthesis.

35 25. A method of manufacturing a dental blank, comprising solid free form fabricating a dental blank having at least a first and a second concentric zones, wherein the first concentric zone has one color and the second concentric zone has another color.

 26. A method of claim 25, wherein the solid free form fabricating comprises robocasting.

1 27. A method of claim 25, wherein the solid free form fabricating comprises three dimensionally printing.

 28. A method of claim 25, wherein the solid free form fabricating comprises laser
5 sintering.

 29. A method of claim 25, wherein the solid free form fabricating a dental blank comprises:

 providing a depositing device adapted to deposit a material of a first color and a
10 material of a second color;

 providing a platform, wherein the depositing device and the platform move in a predetermined pattern relative to each other;

 controlling the depositing device to switching between depositing the material of the
15 first color and depositing the material of the second color.

 30. A method of claim 29, wherein the predetermined pattern is a spiral.

 31. A method of claim 29, wherein the predetermined pattern is a raster.

1/11

FIG.1

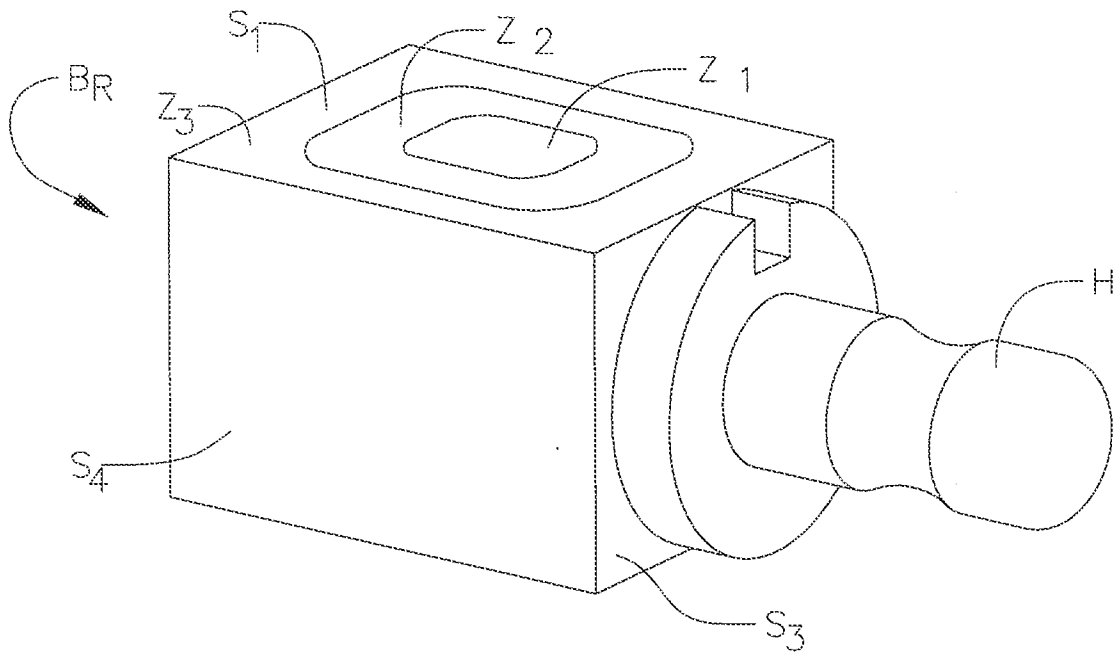


FIG.1A

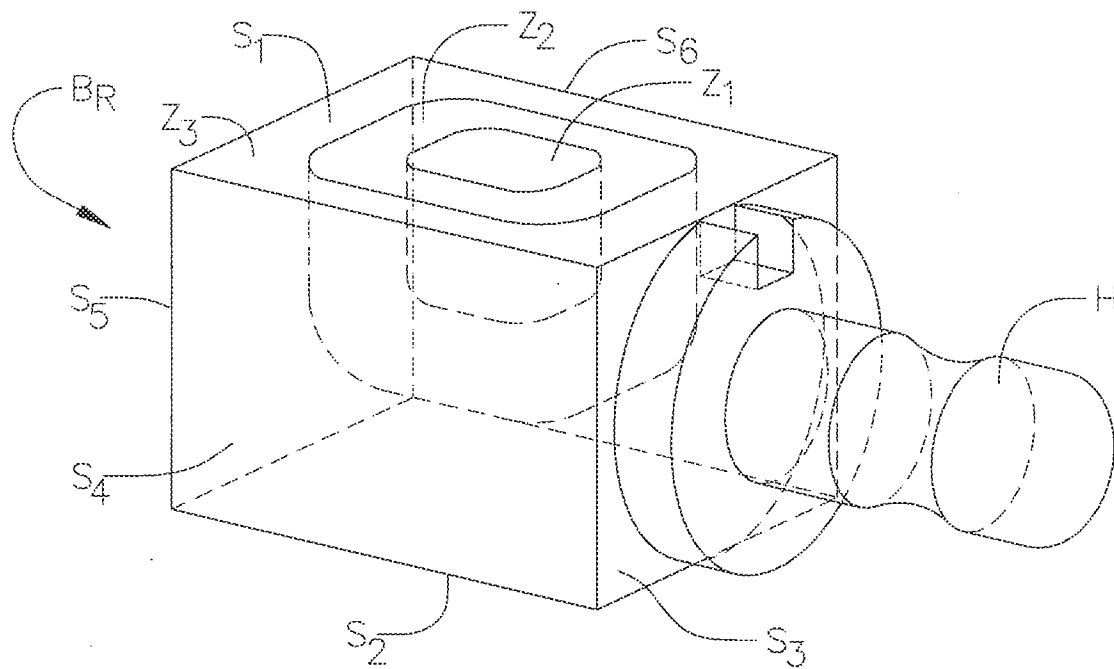


FIG. 2A

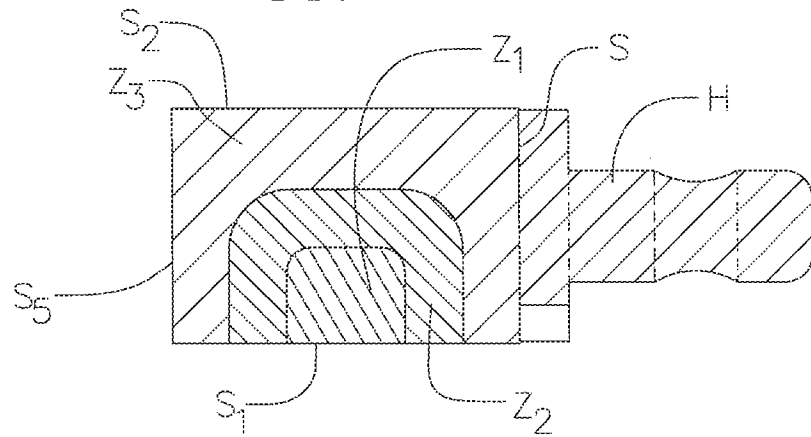


FIG. 3

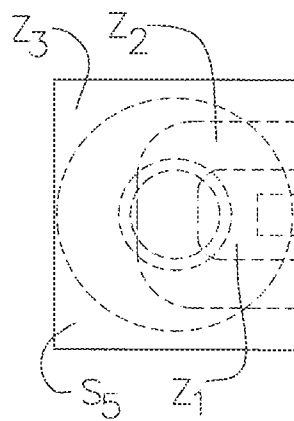


FIG. 2

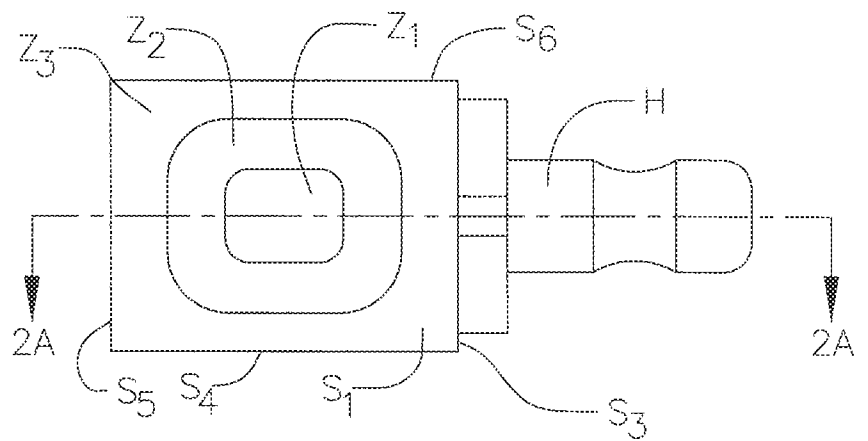


FIG. 4

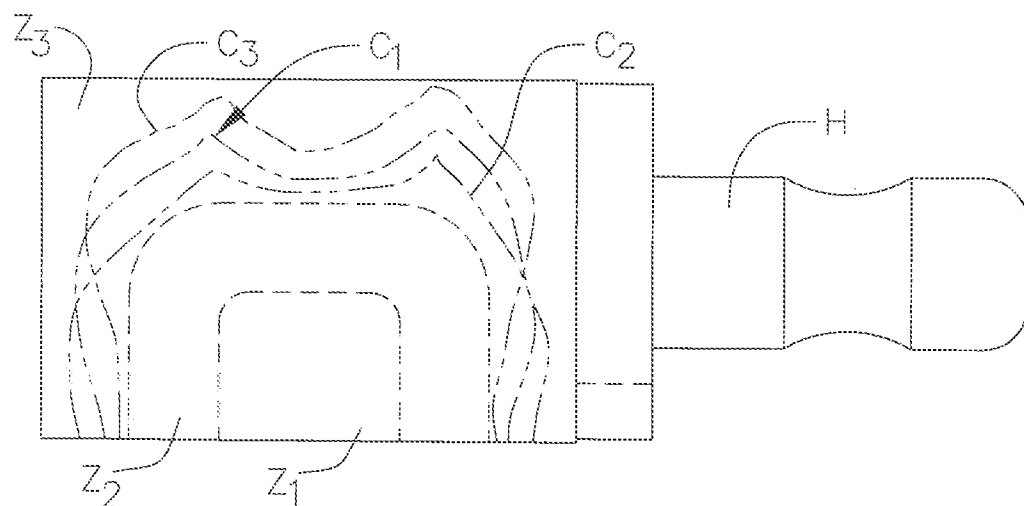


FIG. 5

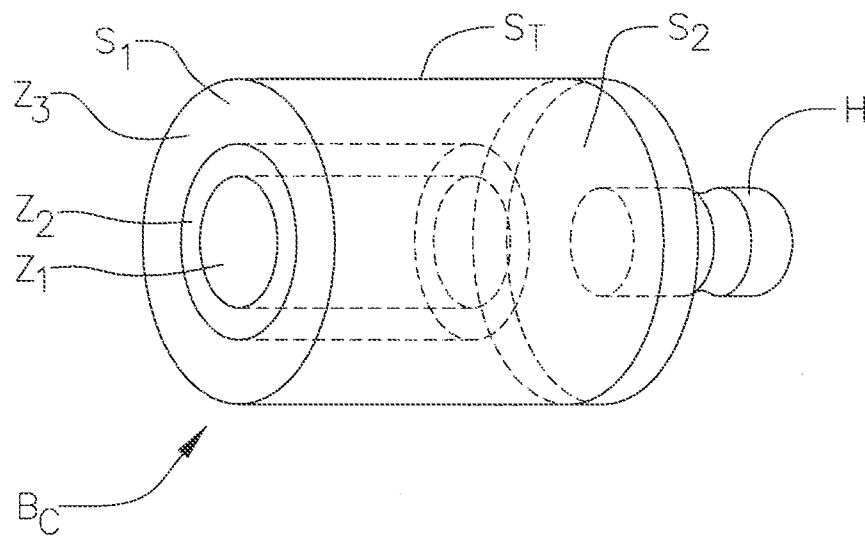


FIG. 7

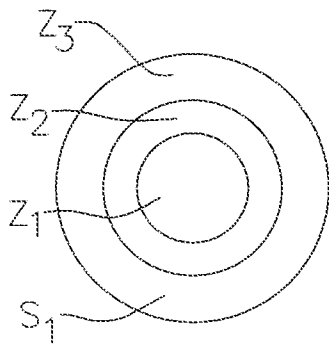


FIG. 6

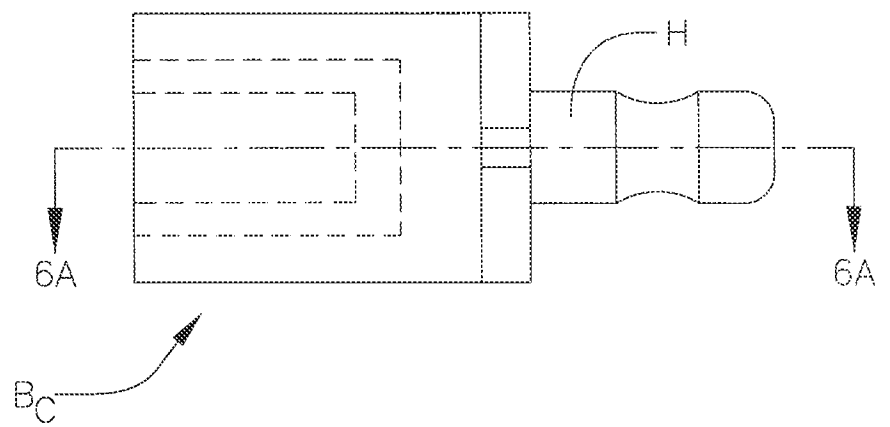


FIG. 6 A

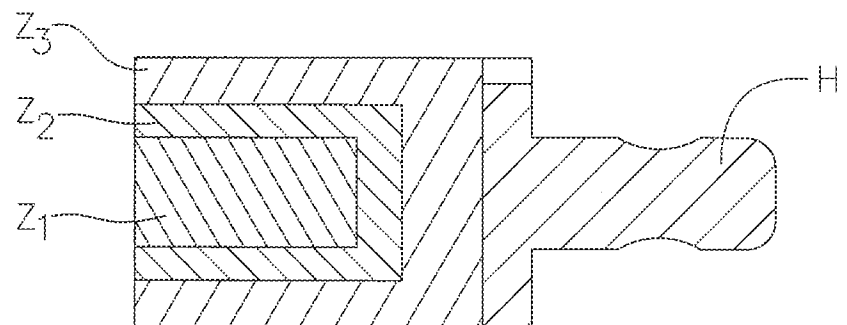


FIG. 8

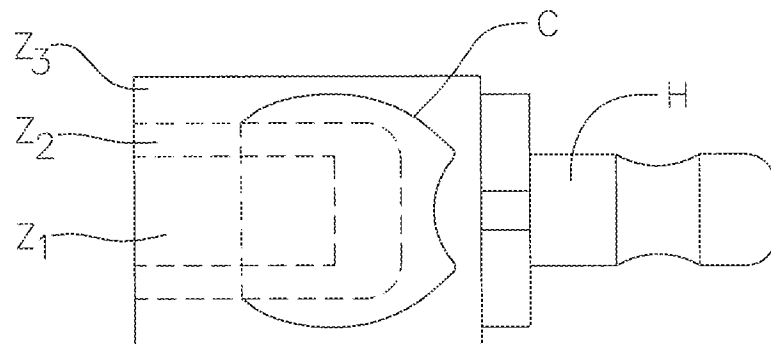


FIG. 9

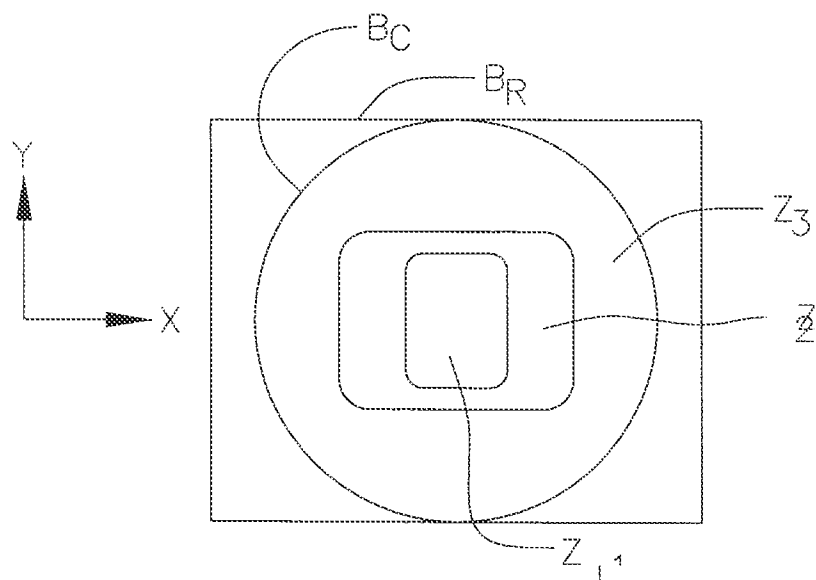


FIG. 10

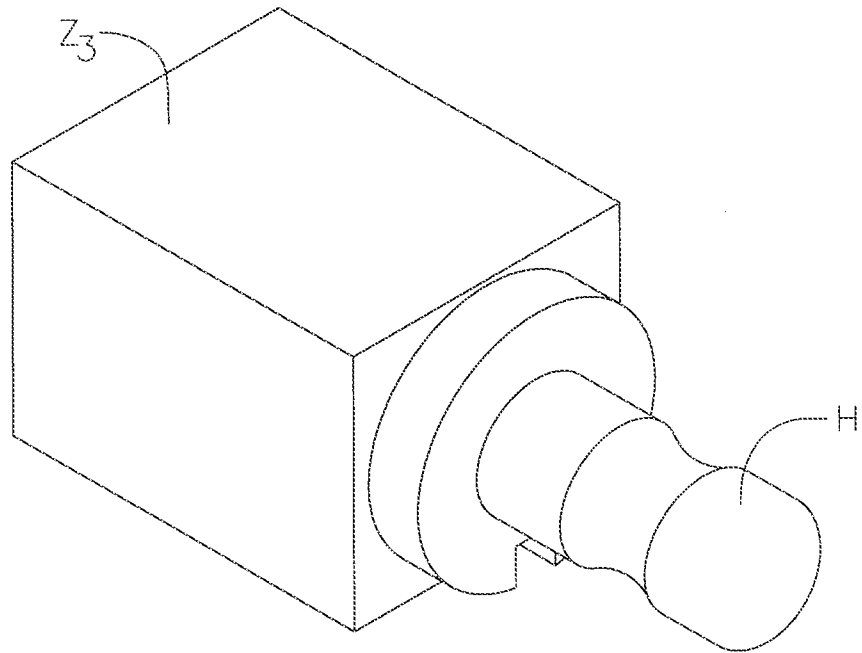
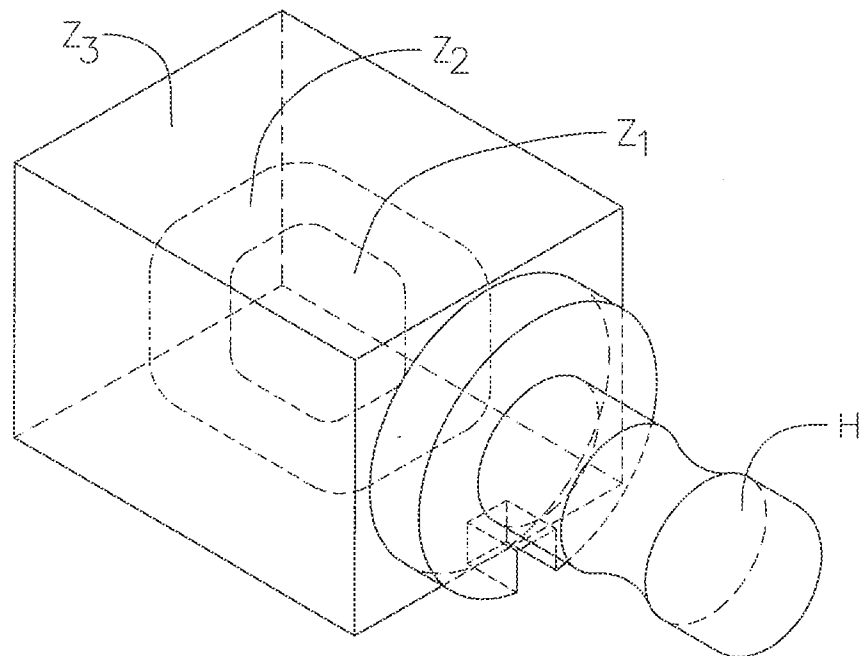


FIG. 10 A



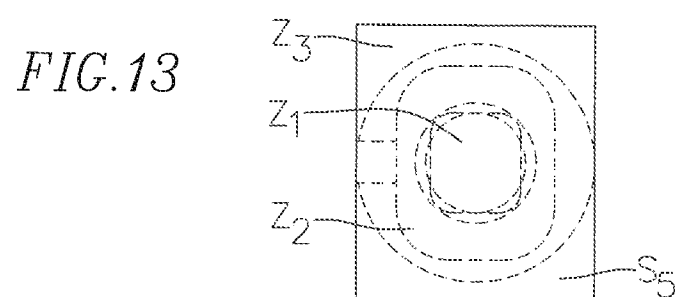
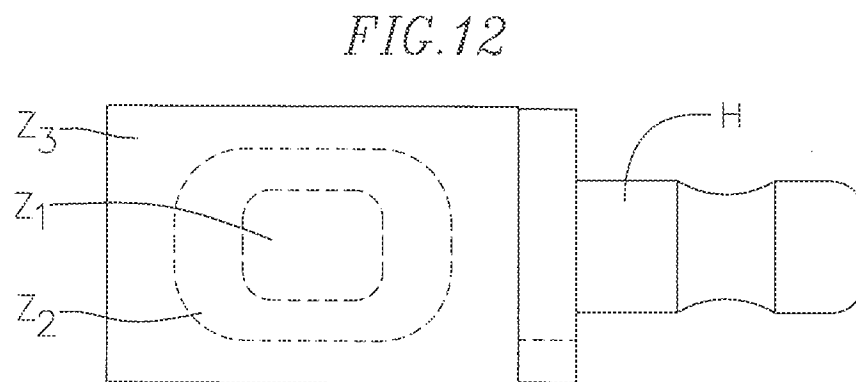
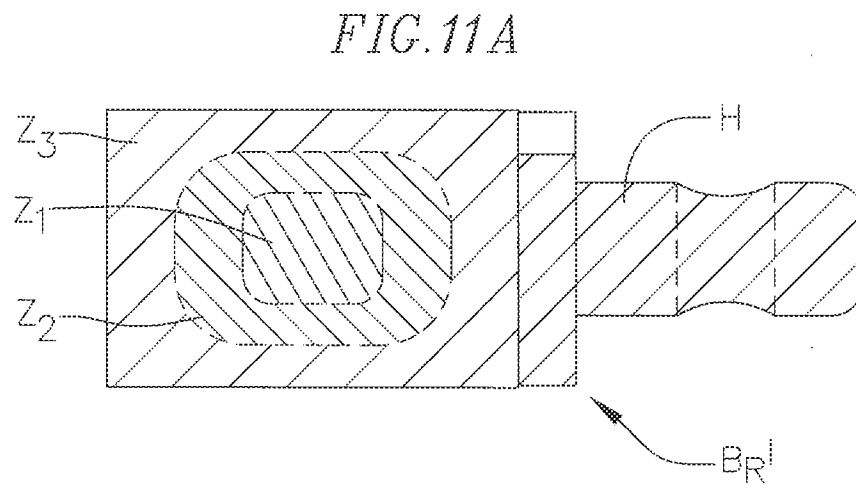
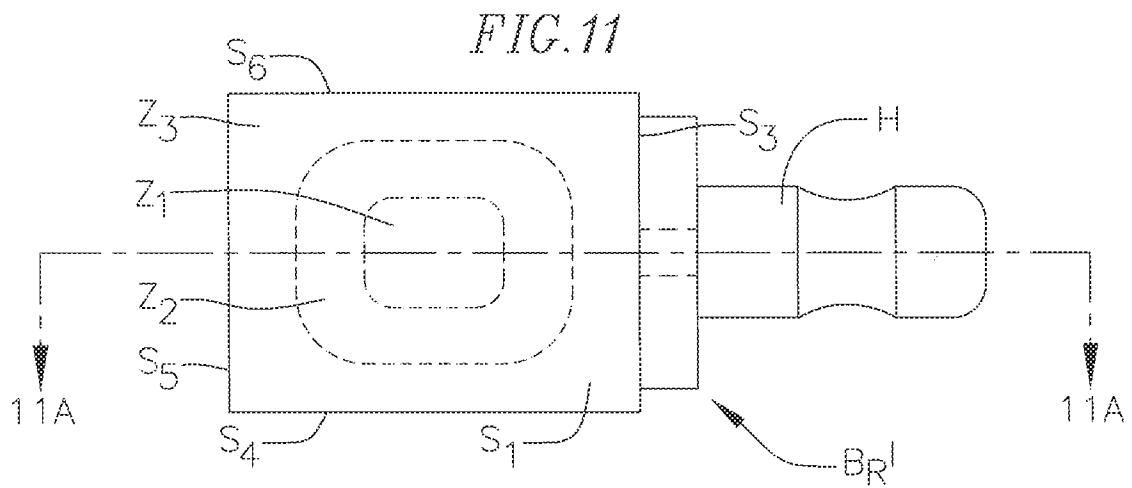


FIG. 14

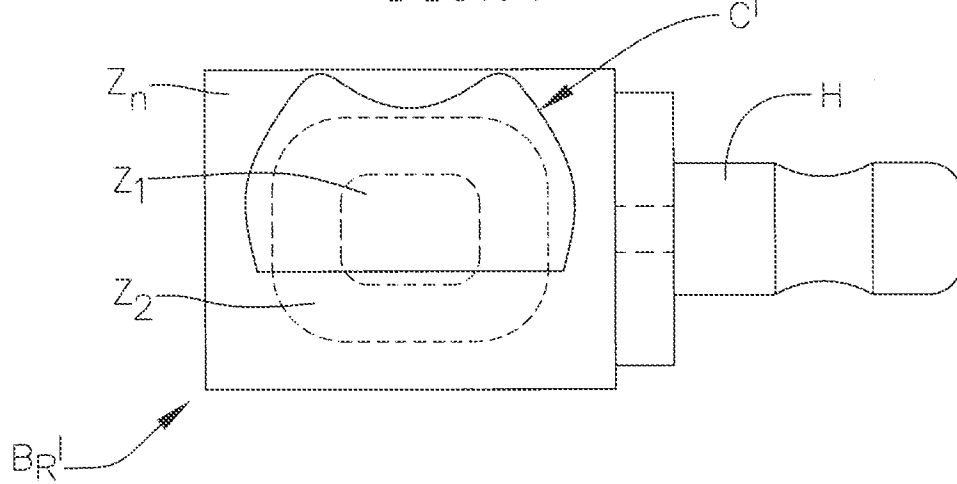


FIG. 16

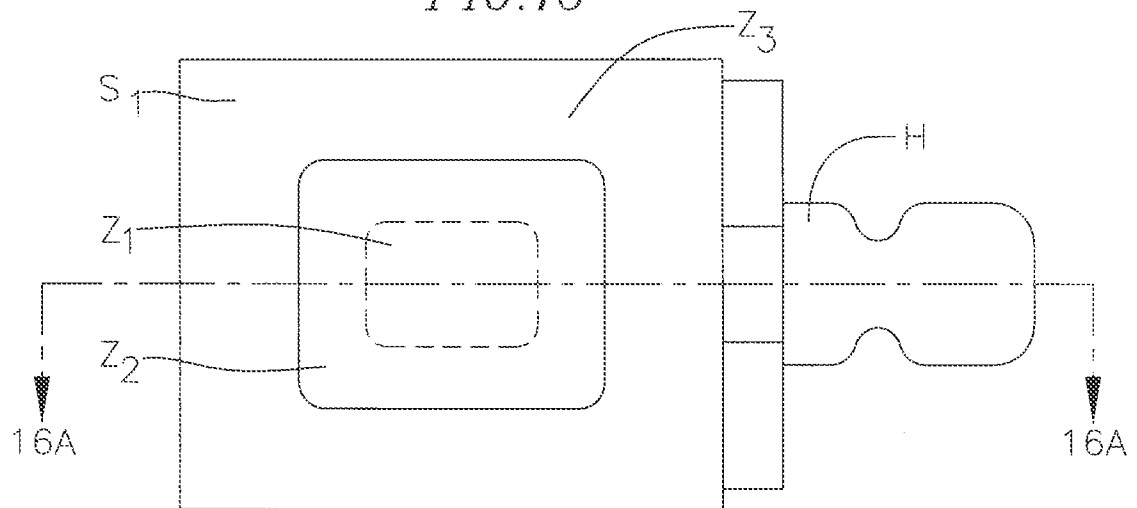


FIG. 16A

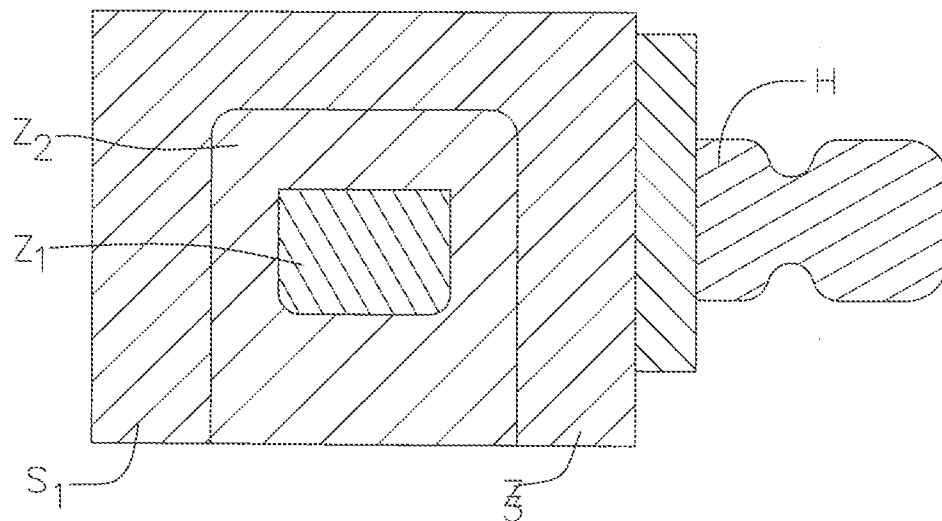
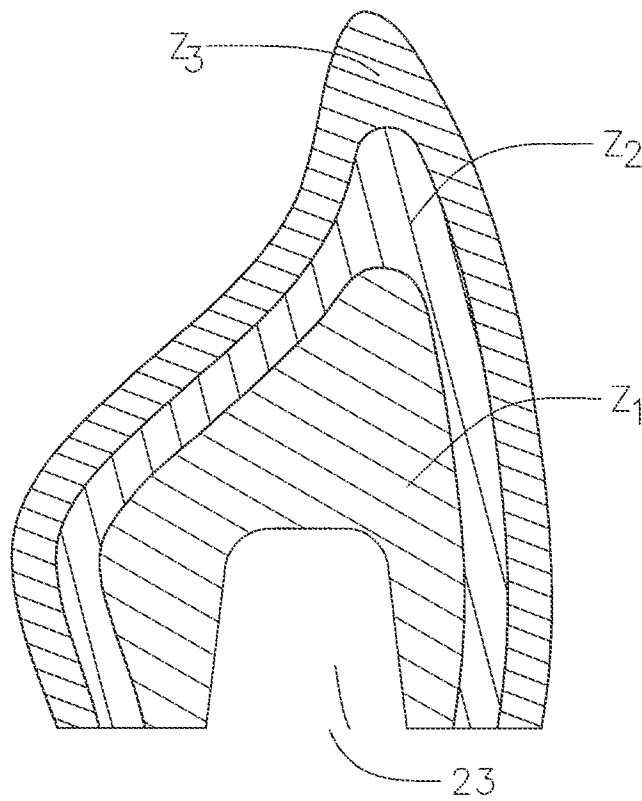


FIG. 15



10/11

FIG. 17

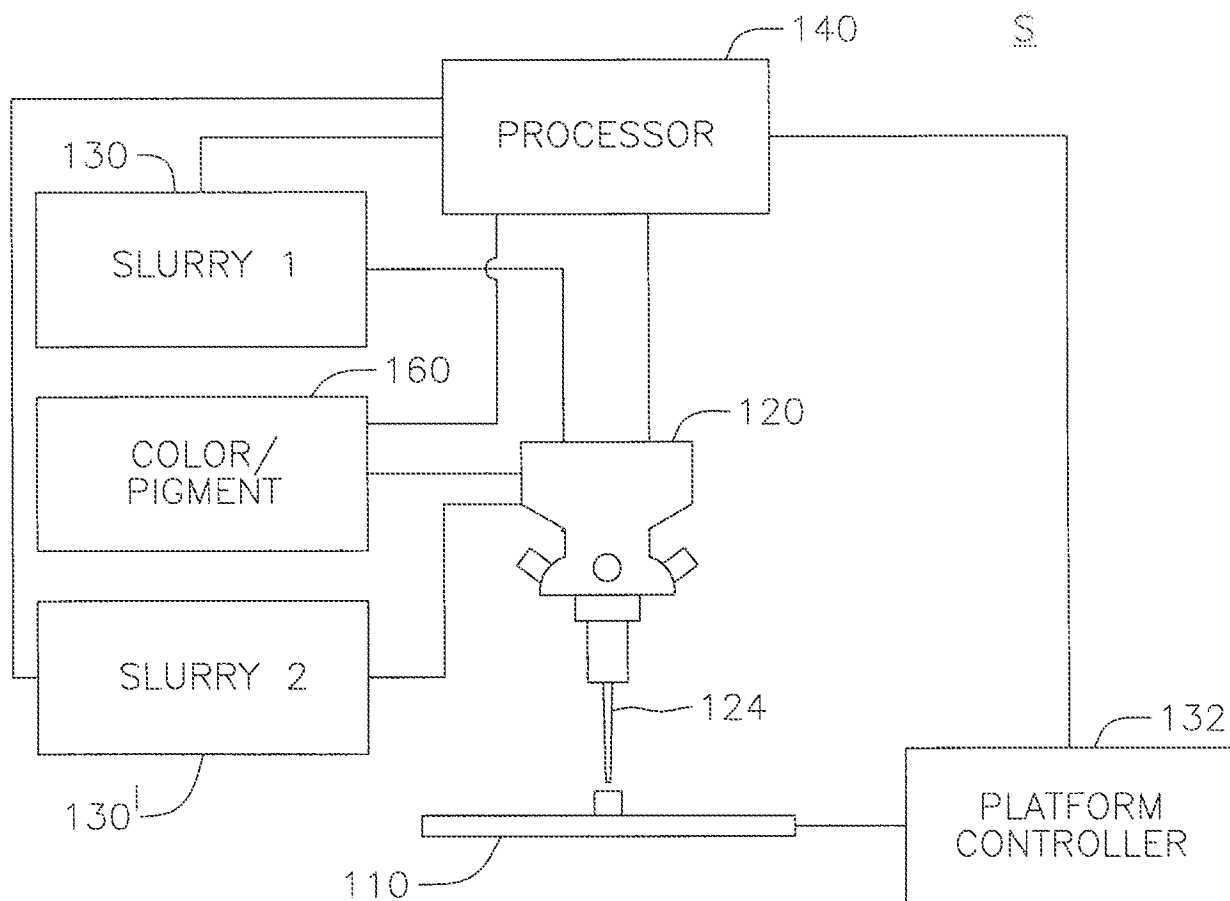
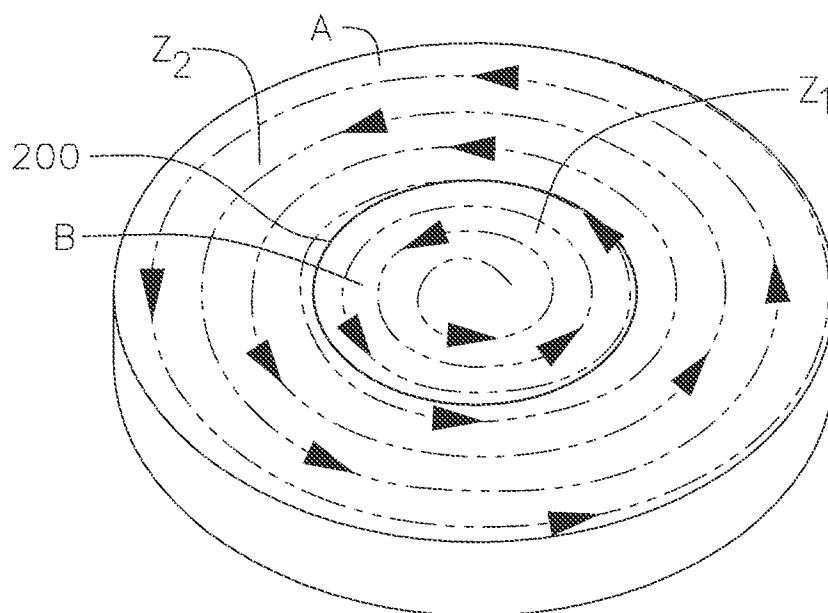


FIG. 18



11/11

FIG. 19

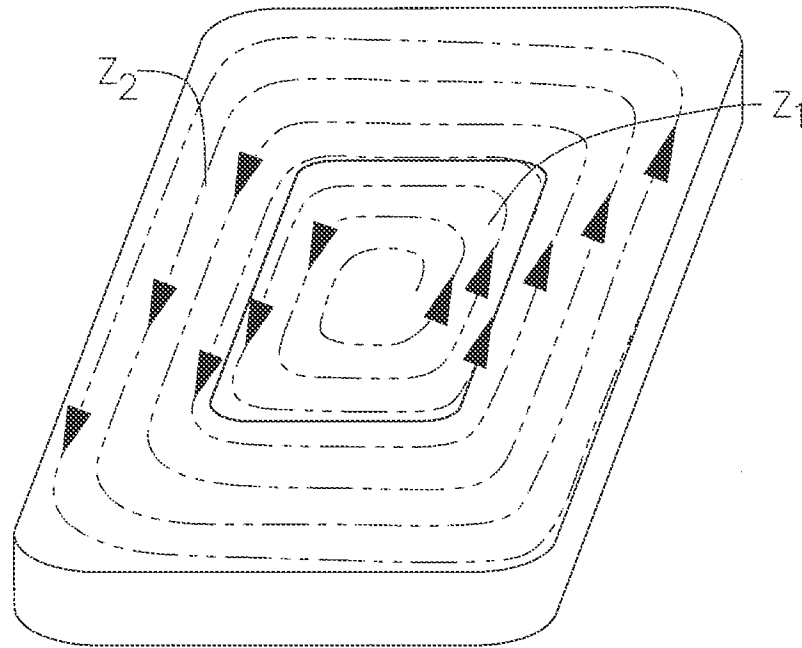
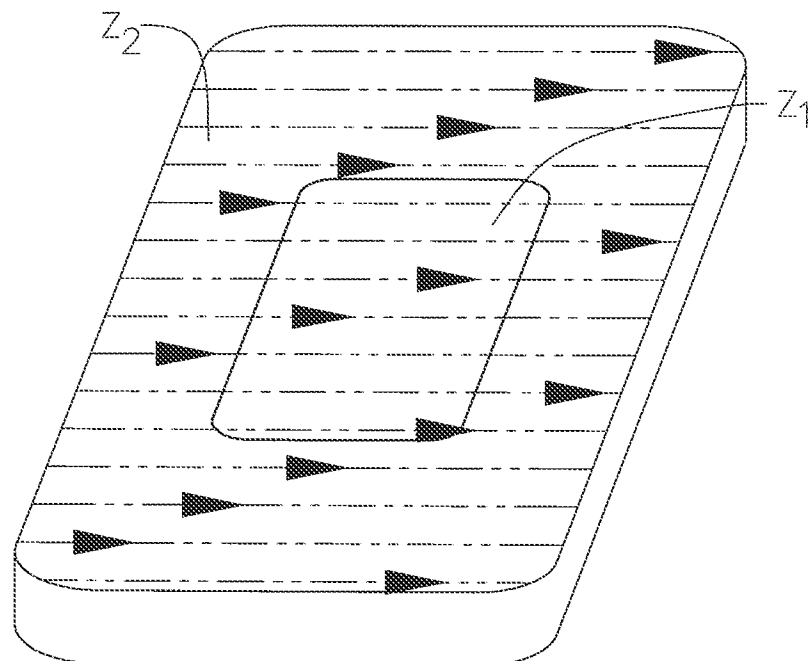


FIG. 20



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2007/089157

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61C 13/08 (2008.01)

USPC - 433/203.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A61C 13/08 (2008.01)

USPC - 433/203.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO EAST System (US, USPG-PUB, EPO, DERWENT), PatBase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,151,044 A (ROTSAERT) 29 September 1992 (29.09.1992) entire document	1-24
Y		25-31
Y	US 2003/0207235 A1 (DER ZEL) 06 November 2003 (06.11.2003) entire document	25-31

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 April 2008

Date of mailing of the international search report

16 MAY 2008

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