(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 4 556 606 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication: **21.05.2025 Bulletin 2025/21**

(21) Application number: **23210617.9**

(22) Date of filing: **17.11.2023**

(51) International Patent Classification (IPC):
D01D 5/253 (2006.01) ***D01D 5/00*** (2006.01)
D01F 6/04 (2006.01) ***D01F 6/60*** (2006.01)
D06N 7/00 (2006.01) ***E01C 13/08*** (2006.01)

(52) Cooperative Patent Classification (CPC):
D01D 5/253; D06N 7/0068; E01C 13/08;
D01D 5/0023; D01F 6/04; D01F 6/60

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **15.11.2023 US 202318468115**

(71) Applicants:
- **Polytex Sportbeläge Produktions-GmbH**
  47929 Grefrath (DE)
- **Synthetic Turf Resources**
  Dalton, GA 30721 (US)

(72) Inventors:
- **SICK, Stephan**
  76532 Baden-Baden (DE)
- **GROCHLA, Dario**
  44869 Bochum (DE)
- **DANIELL, Anthony David**
  30720 Dalton (US)

(74) Representative: **Richardt Patentanwälte PartG mbB**
Wilhelmstraße 7
65185 Wiesbaden (DE)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) **ARTIFICIAL TURF FIBER WITH UNINTERRUPTED UNDULATIONS**

(57) Disclosed is an extruded artificial turf fiber (100, 800, 900, 1000, 1100) having an arced cross-sectional shape, the arced cross-sectional shape being defined by a boundary line consisting of uninterrupted undulations.

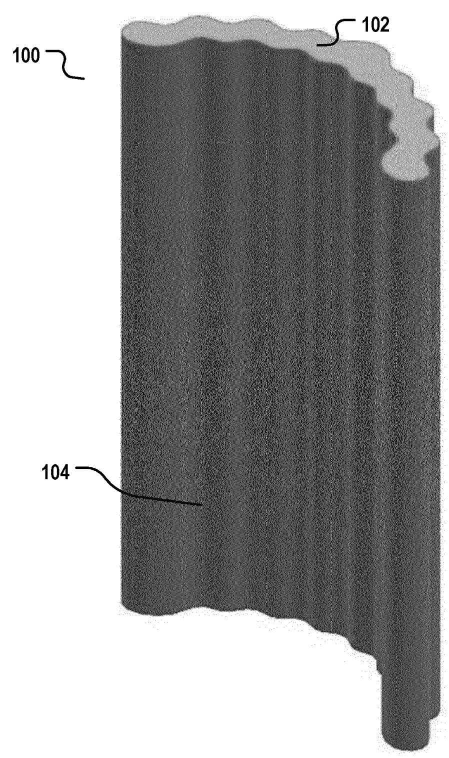

Fig. 1

EP 4 556 606 A1

Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of artificial turf, and more particular to artificial turf fibers having a natural look and feel.

BACKGROUND

[0002] Synthetic grass fields (or artificial turf) have been used for years to provide a surface that simulates natural grass. These synthetic grass fields have many benefits over natural grass and, in addition, can be installed and used in places that do not allow for natural grass fields, for example, in regions where it is particularly hot and dry.

[0003] Artificial lawns, like artificial grass sport fields, require less maintenance and can be used more intensively than lawns of natural grass. Although attempts are made to make the synthetic fibers used for the production of artificial turf look as natural as possible, for example by adding green pigments to the fibers or selecting the fiber cross-section to resemble the cross-section of certain grasses (as described e.g., in EP000003480344A1), in certain situations the artificial turf can still leave a visual impression that is clearly different from that of natural grass and appear "artificial" or "unnatural".

[0004] In addition, an exact reproduction of certain types of grass can lead to the fibers being mechanically unstable or not being able to be produced in the desired form. Thus, the production of artificial turf fibers that give an artificial turf a natural appearance for as long as possible during the entire period of use still represents a major technical challenge.

[0005] US patent US 10,793,973 B2 relates to a synthetic monofilament fiber for use in an artificial lawn which has multiple tapered elevations which are believed be associated with increased risk of skin abrasion, and an increased proneness to wear and tear and the associated generation of microplastic waste.

[0006] EP 1950 350 A1 discloses various fibers, some of which have large bulbs at the center and on the ends. These fibers have stress points at the point the bulbs are connected to the fiber. As a result, these types of fibers have a tendency to fray or split along these stress points.

[0007] A further fiber is disclosed in US006491991B2 which has a curved cross section with a series of flat, planar sections which may lead to decreased mechanical stiffness and other undesired properties.

[0008] Korean patent KR 10-1989-0002109 discloses a spinneret for manufacturing monofilamaents for artificial turf. In cross-section, the spinneret has an outer periphery formed of continuosly repeated triangles of the same size, and an inner periphery formed of continuosly repeated curved parts of the same size, for forming a monofiliment that by defintion has a cross-section that is the same as the cross-section of the spinneret. Since the triangles and the curved parts are connected to neighboring triangles and curved parts for forming the outer periphery and inner periphery, respectively, then a slope (which may also be referrred to as tangent line) is indeterminate at each connection point on each respective periphery. That is, the slope at each connection point between neighboring triangles and curved parts on each respective periphrey is indeterminate, or in other words, the slope as measured at each point along the respective peripheries has a discontinuity at each connection point. If each point on each respective periphery is defined with respect to a cartesian corrdinate system x-y to have coordinate (x,y), then the slope at each point is dy/dx.

[0009] It is an objective to provide for an improved artificial turf fiber and artificial turf comprising the same. The objectives underlying the invention are solved by the features of the independent claims.

SUMMARY

[0010] In one aspect an extruded artificial turf fiber is disclosed. The artificial turf fiber has an arced cross-sectional shape. The arced cross-sectional shape is defined by a boundary line consisting of uninterrupted undulations.

[0011] This may be beneficial, because the effect of a boundary line consisting completely of uninterrupted undulations is that the entire boundary line of the fiber is free of planar areas, pointed elevations and pointed depressions.

[0012] This can provide a highly advantageous compromise between mechanical durability, wear resistance and a natural look and feel: the multiple undulations cause the fiber to scatter incident light and therefore appear dull, like most natural grass fibers.

[0013] As explained above, some prior art artificial turf fibers have a boundary line comprising a series of elevations or depressions to scatter incident light and provide a matt surface impression which is similar to the look of a natural grass fiber surface. However, some prior art fibers have fiber profile contours with multiple successive concave depressions or multiple successive convex elevations. Such an outline has several disadvantages: Series of concave depressions result in thin, pointed protrusions. These can lead to a very rough surface, especially when using relatively hard, mechanically robust polymer material, which in turn can lead to skin damage. In addition, these pointed protrusions are subject to high mechanical stress, resulting in a large amount of material being abraded in a short period of time. This abrasion can end up in the environment as unwanted microplastic waste. Series of convex bumps in turn create thin, conical depressions. Dirt and unwanted germs can accumulate in these depressions and negatively affect the appearance and hygiene of the artificial turf. In addition, such conical depressions, especially if they are large, represent a mechanical weak point where the fibers can easily tear (splice) under mechanical stress.

[0014] To the contrary, a shape with a contour consisting of uninterrupted undulations according to embodiments the invention has the advantage that the incident light is diffusely scattered, so that a matt, natural surface impression is created, without having to accept problems regarding the risk of injury, microplastics, hygiene or mechanical integrity of the fibers. In a fiber cross section of a fiber according to embodiments of the invention, all depressions and indentations of the fiber surface are rounded, or in other words, a tangent line may be formed or defined (i.e., a tangent line is determinate) at each point on boundary lines that define the fiber in cross section, thereby minimizing the risk of splicing, the risk of skin burns, the generation of microplastic and the accumulation of dirt and debris. That is, if each point on the boundary lines is defined with respect to a cartesian corrdinate system x-y to have coordinate (x,y), then the slope at each point is dy/dx, and according to an embodiment of the present invention, the boundary lines have a continuous slope as measured at each point along the boundary lines. In other words, the boundary lines have no discontinuities in slope.

[0015] A further benefit may be that the extrusion process can run true to shape. This means that the shape of the fiber cross section essentially matches the shape of the extrusion die profile opening. As the boundary line of the fiber profile is free of pointed protrusions or indentations, also the extrusion die profile is free of such pointed protrusions or elevations. As a consequence, the formation of speed differences of the extruded polymer mass during extrusion which may result in deformed fibers may be prevented.

[0016] According to some examples the fiber has ends, e.g., a first end and a second end.

[0017] The ends have a radius of curvature being at least as large as (or larger as) the smallest radius defining the undulations of the boundary line of the other parts of the cross-sectional shape.

[0018] For example, the ends may have a radius of curvature being at least 5%, e.g., at least 10%, e.g., at least 15% larger, e.g., 25% than the smallest radius defining the undulations of the boundary line of the other parts of the cross-sectional shape.

[0019] This may be beneficial as the ends will have a curvature based on a radius which is at least as large, and possible larger, than the smallest radius defining one or more of the undulations of the boundary line of other fiber parts, e.g., fiber arms or the center.

[0020] This may be beneficial as it protects the fiber against abrasion and also eases the manufacturing process: filigree fiber ends may result in a strongly reduced flow rate of the polymer matrix at the respective portions of the extrusion nozzle opening, which may result in a significant deviation of the shape of the extruded fiber from the shape of the extrusion nozzle opening. A further advantage of the above-mentioned fiber end curvature is that incident light is diffusely scattered even when it falls on the ends of the fibers. This is because a large radius of curvature at the fiber ends ensures that the incident light hits a relatively wide surface at the ends, so that the light scattering behavior of the fiber surface at its ends is similar to the scattering behavior at its wide inside and outside surfaces. With artificial turf, due to the industrial manufacturing process, there is always a risk that the synthetic lawn optics will depend on the viewing angle, as the fibers can have an unnatural-looking uniform orientation or distribution, for example. Because the ends have a comparatively large curvature radius, the light is scattered similarly at the ends as in the wide side and it is less noticeable if the majority of the fibers should have the same orientation.

[0021] According to some examples, the fiber has thickenings at the fiber ends. The ends are connected to the center of the fiber via fiber portions referred to as "fiber arms" or "arms". The diameter of each of the thickenings is thicker than the thickest part of the fiber arm that connects said end to the center of the fiber. For example, having a thickening at a fiber arm may mean having a thickening within the outermost quarter or the outermost fifth of the arm length of an arm.

[0022] For example, the diameter of each of the thickenings may be at least 5%, e.g., at least 10%, e.g., at least 15%, e.g., 25% thicker than the thickest part of the fiber arm that connects said end to the center of the fiber. For example, the diameter of the thickening may be the width of the thickening measured along a line perpendicular to the arced longitudinal axis of the fiber.

[0023] This feature may have similar beneficial effects like the use of the above-mentioned use of fiber end undulation having a radius of at least a certain size. It is possible, however, that the boundary line of the thickened ends comprises multiple undulations and hence cannot be described by the size of a single curvature radius.

[0024] Applicant has observed that thickenings at the fiber arm ends may increase the mechanical stability of the fiber and increase its ability to stand up again after the gras was trampled down. As the thickenings are rounded, the damage caused by abrasion at the fiber arm ends is reduced compared to fibers lacking a rounded thickening at the fiber arms.

[0025] According to some examples, the arced cross-sectional shape has an outer, convex boundary line and an inner, concave boundary line. At least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by first circles (508) having the same first diameter. At least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by second circles having the same second diameter.

[0026] For example, the first and second diameters can be identical or similar, wherein a similar diameter lies in a range of plus or minus 10 % of the other diameter.

[0027] The largely uniform wave shape of the bounding line may have the advantage that there are no particularly deep wave valleys where the fiber thickness is reduced to such an extent that weak points are created at which the fiber tears open under mechanical load. The risk of splicing is thereby further reduced. Likewise, there may not exist particularly high protrusions which may be particularly prone to wear and tear. This may further help to prevent the generation of microplastic waste.

[0028] According to some further examples, the fiber comprises a thickening at its center which forms a rounded protrusion to at least one side of the fiber. The curvature of the protrusion is defined by a circle having a radius selected such that a ratio of the said radius to the radius of the first circles is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

[0029] According to some further examples, the radius of curvature of the fiber ends is selected such that a ratio of the radius of curvature of the fiber ends to the radius of the first circle is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

[0030] According to a further example, the cross-section of the fiber is shaped like the arc of a segment of a circle. This circle is referred herein as the "fiber profile circle" and the radius of this circle the "fiber profile circle radius". According to some embodiments, the ratio of the width of the fiber profile and the fiber profile radius is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

[0031] Applicant has observed that this ratio provides for a particularly "natural" look of a synthetic yarn made of respective fibers. Without the intention to be bound by any theory, applicant believes that this effect may be the result of said ratio value range approximately representing the "golden ratio".

[0032] If one divides a stretch of an elongated object into two parts, of which the smaller part relates to the larger part as the larger part relates to the whole, then one speaks of the so-called 'golden ratio'. In this case, the relationship of the larger part to the smaller part is: 1.618 [...] and also the ratio of the whole to the larger part is 1.618[...]. In a circle, this "golden ratio" corresponds to an angle of 137.5 degrees. And this is exactly the most common arrangement of leaves and flowers around a plant stem in nature. For example, the golden ratio can be found in the arrangement of leaves and inflorescences of many plants. In these plants, the angle of two successive leaves divides the full circle in the ratio of the golden section. For example, the petals of the rose are arranged according to the golden ratio.

[0033] According to some examples, the fiber ends are connected to the center of the fiber via fiber arms, wherein each of the fiber arms is formed such that over a portion of at least 80% of the length of that arm, the fiber arm thickness has a thickness which is no more than 15% thicker or thinner than the average thickness of that fiber arm portion.

[0034] This may have the advantage that the fiber arms have an approximately uniform thickness. Hence, there do not exist particularly deep indentations or particularly high protrusions which may be associated with the above-mentioned problems concerning proneness to wear and tear, the generation of microplastic waste, splicing risk, etc.

[0035] According to some examples, the fiber comprises a nucleating agent.

[0036] This may have the advantage of further increasing the surface roughness, because the nucleating agent may induce or boost the formation of polymer microcrystals at the surface of the fiber during or after the extrusion process.

[0037] For example, the nucleating agent may be a substance or substance mixture selected from a group comprising: talcum; kaolin (also known as "China clay"); calcium carbonate; magnesium carbonate; silicate: aluminum silicate and; as e.g. sodium aluminosilicate (in particular zeolites of natural and synthetic origin); amorphous and partially amorphous silica and mixed morphologies hereof, e.g. fumed silica; silicic acid and silicic acid esters; e.g. tetraalkyl orthosilicate (also known as orthosilicic acid ester) aluminum trihydrate; magnesium hydroxide; meta- and/or polyphosphates; and coal fly ash (CFA); coal fly ash is a fine recovered e.g. from coal-fires of electric generation power plants; wherein the organic nucleating agent consists of one of the following items or a mixture thereof: 1,2-cyclohexane dicarbonic acid salts (also known as main component of "Hyperform®"); in particular calcium salts of the 1,2-cyclohexane dicarbonic acid; benzoic acid; benzoic acid salt; the benzoic acid salt may be, in particular, an alkaline metal salt of the benzoic acid (e.g. sodium and potassium salts of the benzoic acid); and an alkaline earth metal salt of the benzoic acid (e.g. magnesium and calcium salts of the benzoic acid); sorbic acid; and sorbic acid salt.

[0038] According to some examples, 0.01 % - 3.0 % by weight of the artificial turf fiber consists of the nucleating agent. preferably, 0.2 %- 0.4 % by weight of the artificial turf fiber consists of the nucleating agent. This is a comparatively low amount. Nevertheless, applicant has observed that this small amount is sufficient to achieve a diffuse light scattering that is almost indistinguishable from the light scattering on natural grass. It is possible to use only very small amounts of the nucleating agent, because the diffuse scattering is not only caused by the crystals on the fiber surface, but also by the undulations of the fiber profile. Using only very small amounts of the nucleating agent (or none at all) may be beneficial as the crystalline portions induced by the nucleating agent at the surface and within a fiber may increase the brittleness of the fiber, thereby increasing the tendency to break or splice.

[0039] According to some examples, the cross-section of the fiber is shaped like the arc of a segment of a circle or an ellipse.

[0040] The use of fiber profiles with a boundary line that is curved like a circular segment arc can have the advantage that light falling from different directions is scattered homogeneously because the curvature of the fiber profile is the same when viewed from all directions. This also means that the light reflected by the artificial turf looks the same when viewed from different angles. As a result, even a synthetic turf that has a too uniform orientation of the fibers due to the manufacturing process does not have any artificial dependence of the optical impression on the viewing angle.

[0041] According to some other examples, the cross-section of the fiber is shaped like a catenary. The catenary is a particular type of arced curve which is particularly robust against mechanical stress.

[0042] Using an artificial turf fiber having a cross-section shaped like a catenary may strengthen the ability of a downed fiber to straighten up quickly. With artificial turf, the problem exists that synthetic fibers that have been depressed by the ball or the players need several minutes or even hours to straighten up again. In some cases, the fibers do not straighten at all. This has the disadvantage that the footprints of the players are visible on the turf for a longer period of time, because the bent-down, essentially horizontally oriented fibers reflect the light differently. The footprints in artificial turf are therefore visible for a certain time as highly reflective, bright, shiny areas. This not only looks unnatural and unattractive; it can even lead to spectators and players being dazzled in strong sunlight. By using a fiber profile having a cross-section shaped like a catenary, the fiber becomes particularly mechanically stable. The tendency of the fiber to buckle under low loads is reduced, and the ability of the fiber to quickly straighten up again after a temporary load-induced buckling increases. Thus, this special shape not only supports the mechanical robustness of the fibers, but also has the particular effect of giving the turf a more natural-looking overall appearance, as footprints are no longer as strong or visible for as long.

[0043] According to some examples, the fiber comprises a thickening at its center.

[0044] This may help increasing the mechanical strength of the fiber and to increase the ability of the fiber to quickly straighten up again after a temporary load-induced buckling.

[0045] For example, the thickening at its center can be formed such that a round bulge is formed towards the outer surface of the fiber, wherein the thickening does not lead to a bulge towards the inner surface of the fiber.

[0046] According to some examples, the fiber has a width (w) measured as a straight line connecting the first and second ends of 0.7 to 2.5 mm, in particular of 0.9 to 1.5 mm.

[0047] According to some examples, the undulations are formed such that the fiber has at least 6, in particular at least 7, in particular 7-11, e.g., 9 round bulges on its outer surface, and/or such that the fiber has at least 6, in particular 6-10, e.g., 8 round bulges on its inner surface.

[0048] According to some examples, the majority of undulations form consecutive pairs of a round bulge and a round indentation, wherein each pair has a length of 0.10 mm to 0.30 mm, e.g. 0.10 to 0.20 mm.

[0049] According to some examples, at least 70% of the undulations of the inner surface and at least 70% of the outer surface have the same or a similar undulation length, wherein an undulation length is similar to a given length if it differs no more than plus or minus 10% from said given length.

[0050] The above-mentioned dimension and ranges have been observed to provide for artificial turf fibers capable to form a synthetic lawn that faithfully reproduces the look of natural grass.

[0051] In a further aspect, disclosed herein is an artificial turf comprising: a carrier; and a plurality of the artificial turf fibers described herein in various embodiments and examples integrated into the carrier and protruding therefrom to form an artificial turf.

[0052] In a further aspect, disclosed herein is the use of artificial turf fibers described herein in various embodiments and examples for providing artificial grass that looks like natural grass.

[0053] An "undulation" as used herein is a curve having a continuous up and down shape. Hence, a boundary line consisting of uninterrupted undulations may be described as a boundary line not having a vertical tangent. A boundary line consisting of uninterrupted undulations may also be described as a mathematically differentiable curve.

[0054] It is understood that one or more of the aforementioned embodiments and examples may be combined as long as the combined embodiments are not mutually exclusive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0055] In the following, examples are described in greater detail making reference to the drawings in which:

Fig. 1 is a perspective 3D view of the inside of a section of the fiber;

Fig. 2 is a perspective 3D view of the outside of a section of the fiber;

Fig. 3 shows the cross-section of a fiber;

Fig. 4 shows the fiber cross-section of Fig. 3 with height and width annotated

Fig. 5 shows the fiber cross-section of Fig. 3 with the circles defining the curvature of the corrugations and the ends annotated;

Fig. 6 shows the fiber cross-section, where the fiber thicknesses at different cross-sectional areas are annotated;

Figs. 7A and B show an example of a fiber cross-section annotated with concrete dimensions;

Fig. 8 shows an example of a cross-section of a further fiber having more undulations;

Fig. 9 shows an example of a cross-section of a further fiber having more undulations and an extended curvature;

Fig. 10 shows an example of a cross-section of a further fiber having a central thickening which leads to a visible bulge on both the outer and inner surface of the fiber;

Fig. 11 shows an example of a cross-section of a further fiber, the cross section having the shape of a catenary;

DETAILED DESCRIPTION

[0056] In the following, similar elements may be denoted by the same reference numerals.

[0057] **Figure 1** is a perspective 3D view of the inside of a section of an artificial turf fiber 100. For example, the fiber may be made of polyethylene or polypropylene or polyamide or a mixture of two or more of these polymers. The fiber may be generated in an extrusion process and the cross-sectional area 102 of the fiber may have essentially the same shape along the entire length of the fiber. Figure 1 shows the inner surface 104 of the fiber defined by the concave part of the boundary line of the shape of the fiber profile. Depending on the type of artificial turf, the length of the fiber (measured from the upper surface of a carrier to the free ends of the fibers) may be different. For example, the fiber length may be in the range of e.g., 2.0 cm to 9.0 cm, preferably 3.0 cm to 7.0 cm.

[0058] **Figure 2** is a perspective 3D view of the outside of a section of the fiber 100 shown already in figure 1. Figure 2 shows the outer surface 202 of the fiber defined by the outer, convex part of the boundary line of the shape of the fiber profile.

[0059] **Figure 3** shows the cross-section of the fiber 100 depicted already in figures 1 and 2. The fiber comprises a first end 302 connected to the center 306 of the fiber via a first fiber arm and comprises a second end 304 connected to the center of the fiber via a second arm.

[0060] As can be inferred from figures 1-3, the fiber has an arced cross-sectional shape, in this case the shape of a circle segment arc. The arced cross-sectional shape is defined by a boundary line consisting of uninterrupted undulations. This means that there are therefore no tapering elevations or recesses and no planar surface areas. In more mathematical terms, the boundary profile may be described as a curve being free of "spinodes" or "cusps", i.e., a point on a curve where a moving point must reverse direction, or as a curve having no discontinuities in slope (i.e., having continuous values of slope) as measured at points along the curve, where slope may be defined as dy/dx at each point (x,y) on the curve, where points (x,y) that define the curve are points defined with respect to a cartesian coordinate system x-y that may be placed anywhere in the plane of Fig. 3, for example. The particular form of the boundary line consisting of uninterrupted undulations may imply that - apart from the cross-sectional area of the fiber at the upper and lower fiber ends where the fiber is cut during or after integration into a carrier - the fiber surface is basically free of any planar areas. This may be highly beneficial, because planar areas reflect the incident light directionally, not diffusely, so that the artificial turf is at least partially highly reflective and can even dazzle the observer. This creates a visual impression that is clearly different from that of a natural lawn, which is undesirable.

[0061] In the example shown, the undulations comprise alternating depressions 308 and elevations 312 on the outer fiber surface and alternating depressions 310 and elevations 314 on the inner fiber surface.

[0062] The thickness of the fiber at the thickenings 318 at the two ends is slightly greater than the thickness of the thickest portions of the fiber arms connecting the ends 302, 304 with the center 306. Moreover, there is a further thickening at the center of the fiber resulting in a protrusion/undulation 316 from the outer surface 312. In the depicted example, the central thickening does not result in a protrusion from the inner surface 102 of the fiber.

[0063] **Figure 4** shows the fiber cross-section of Fig. 3 with height h and width w annotated. For example, the width w can be measured as straight line indicating the distance of the most outer points of the two fiber ends. The height h of the fiber may be measured as the distance of the "lowest" points of the fiber ends to the "highest" point at the fiber center. As can be inferred from figure 4, the height h may be significantly smaller than the radius defining the curvature of the arced shape of the fiber profile, meaning that in case the arced shape is defined by a circle, the fiber profile may cover a segment that is significantly smaller than the 180° segment. In other words, the radius of this circle may be significantly longer than h.

[0064] **Figure 5** shows the fiber cross-section of Fig. 3 with the circles defining the curvature of the corrugations and the ends annotated. As illustrated in figure 5, the undulations of the boundary line defining the shape of the outer surface of the fiber are defined by multiple circles 508 sharing the same radius/diameter D3. The undulations of the boundary line defining the shape of the inner surface of the fiber are defined by multiple circles 510 sharing the same radius/diameter D4. The fiber has thickenings at the center and at the two ends to increase the mechanical stability. The curvature of the ends is defined by the radius/diameter D1 of the circles 502. The curvature of the protrusion 316 induced by the thickening at the center is defined by the radius/diameter D2 of circle 506. As can be inferred from figure 5, D1 and D2 are significantly larger than D3 and D4. D3 and D4 are identical. D1 is slightly larger than D2.

[0065] In other embodiments (not shown), D3 and D4 may be similar, but not identical.

[0066] In addition, or alternatively, D1 and D2 may be identical. For example, both D1 and D2 may represent a diameter which is chosen such that the ratio of D1 (or D2) to D3 (or D4) approximately is the golden ratio.

[0067] **Figure 6** shows the fiber cross-section, where the fiber thicknesses at different cross-sectional areas are annotated. As can be inferred from figure 6, the thickness of the fiber cross section is not constant but varies only slightly: the thickness w1 602 is slightly greater than the thickness w2 604 at the two points in the fiber arms equidistant from the ends, because in the depicted example, the fiber ends comprise a thickening. The thickness w3 606 at two other points in the fiber arms equidistant from the ends is slightly greater than the thickness w2. The fiber center represents the thickest and hence stiffest portion of the fiber having a thickness w4 608 being greater than w1, w2 and w3.

[0068] In the depicted example, w2 is the smallest with in the fiber arm and w3 is the largest width of the fiber arm.

[0069] In other examples, w1 and w2 may be identical, but preferably w1 is greater than the smallest width w2 of the fiber arms, and preferably also greater than the largest width w3 of the fiber arm.

[0070] According to some examples, the fiber profile is axisymmetric with respect to a vertical axis through the center of the fiber profile as shown in figures 3-6. According to other embodiments, the undulations may be shifted such that the fiber profile is not axisymmetric with respect to the vertical axis.

[0071] **Figures 7A and 7B** show an example of a fiber cross-section annotated with concrete dimensions. The fiber cross section corresponds to the cross section of the fibers depicted in figures 1-6. The dimensions of the fiber 100 shown in figures 7A and 7B correspond to a 1100 dtex fiber. The numbers are given in cm. For example, the width of the fiber profile measured from the outermost points of the two ends is 1.0 cm, or 0.9 cm if the distance between the centers of the two fiber ends is measured.

[0072] The fiber profile can be scaled to provide fibers of different fiber weights. For example, by scaling the outer width of the fiber profile from 1.0 cm to 1.351 cm, and scaling all other dimensions given in figure 7 proportionally, a fiber of 2000 dtex can be obtained. By using a different scaling factor, many different versions of the artificial turf fiber having different fiber weights can be obtained.

[0073] As can be inferred from Figures 7A and B, the cross-section of the fiber is shaped like the arc of a segment of a circle having a radius referred to as "fiber profile circle radius".

[0074] According to figure 7A, the radius to the topmost point of the outer surface is 0.59 cm. The width of the fiber profile when the outmost points of the fiber ends are considered is 1.0 cm. Hence, the ratio of the width of the fiber profile and the fiber profile radius is 1.0/0.59, i.e., 1.694. This value is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, and hence approximately the golden ratio.

[0075] According to figure 7B, the radius of the circle 506 defining the undulation at the center of the fiber is 0.081 cm. The shared radius of the multiple smaller circles defining the undulation at the outer surface of the fiber 100 is 0.05 cm. In the depicted example, the shared radius of the multiple smaller circles defining the undulation at the inner surface of the fiber 100 is also 0.05 cm. Hence, the ratio of the radius defining the curvature of the protrusion 316 at the fiber center to the radius of the circles defining the undulations at the outer (and/or inner) surface of the fiber is 0.081/0.05, i.e., 1.62. This value is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, and hence approximately the golden ratio.

[0076] Figure 8 shows an example of a cross-section of a further fiber 800 having more undulations than the fiber cross section depicted in figures 1-7. The curvature of the whole fiber profile is the same as the profile curvature of the fibers depicted in figures 1-7.

[0077] Figure 9 shows an example of a cross-section of a further fiber 900 having more undulations than the fiber cross section depicted in figures 1-7and having an extended curvature compared to the fiber cross sections depicted in figures 1-7. Extended curvature means that the fiber profile corresponds to the arc of a circular segment having a larger angle than the circular segment whose arc corresponds to the fiber profile curvature of the fibers shown in Figures 1-7.

[0078] Figure 10 shows the cross-section of an example of a further fiber 1000. The depicted fiber has a thickening at its center which leads to a bulge on both the outer and inner surface of the fiber.

[0079] Figure 11 shows the cross-section of an example of a further fiber 1100. The cross-section of the depicted fiber has the shape of a catenary.

[0080] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

REFERENCE SIGNS LIST

[0081]

100	artificial turf fiber
102	cross section area
104	inner surface
202	outer surface
302	first fiber end
304	second fiber end
306	center of the fiber
308	undulation of outer surface in the form of an indentation
310	undulation of inner surface in the form of an indentation
312	undulation of outer surface in the form of an protrusion

314 undulation of the inner surface in the form of a protrusion
316 protrusion caused by a central thickening
318 thickenings at the fiber ends
502 circle defining the curvature of an undulation of the first fiber end
504 circle defining the curvature of an undulation of the second fiber end
506 circle defining the curvature of an undulation at the thickened fiber center
508 circles defining the curvature of undulations at the outer surface
510 circles defining the curvature of undulations at the inner surface
602 fiber width at the fiber ends
604 fiber width at one position of the fiber arms
606 fiber width at another position of the fiber arms
608 fiber width at the fiber center
800 artificial turf fiber
900 artificial turf fiber
1000 artificial turf fiber
1100 artificial turf fiber

Claims

1. An extruded artificial turf fiber (100, 800, 900, 1000, 1100) having an arced cross-sectional shape, the arced cross-sectional shape being defined by a boundary line consisting of uninterrupted undulations.

2. The fiber of claim 1, wherein the fiber has ends, the ends having a radius of curvature at least as large as the smallest radius defining the undulations of the boundary line of the other parts of the cross-sectional shape.

3. The fiber of any one of claims, wherein the fiber has thickenings (318) at the fiber ends.

4. The fiber of claim 3, wherein the ends are connected to the center of the fiber via fiber arms, wherein the diameter of each of the thickenings is thicker than the thickest part of the fiber arm that connects said end to the center (306) of the fiber.

5. The fiber of claim 4, wherein the diameter of each of the thickenings is at least 5% thicker than the thickest part of the fiber arm that connects said end to the center of the fiber.

6. The fiber of any one of the previous claims,

- wherein the arced cross-sectional shape has an outer, convex boundary line and an inner, concave boundary line,
- wherein at least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by first circles (508) having the same first diameter (D3); and
- wherein at least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by second circles (510) having the same second diameter (D4).

7. The fiber of claim 6, wherein the first and second diameter are identical or similar, wherein a similar diameter lies in a range of plus or minus 10 % of the other diameter.

8. The fiber of claim 6 or 7, wherein the fiber comprises a thickening at its center which forms a rounded protrusion (316) to at least one side of the fiber, the curvature of the protrusion being defined by a circle (506) having a radius selected such that a ratio of the said radius to the radius of the first circles (508) is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

9. The fiber of any one of the previous claims,

- wherein the cross-sectional shape of the fiber being like an arc of a segment of a circle having a radius referred to as "fiber profile circle radius",
- wherein the ratio of the width of the fiber profile and the fiber profile radius is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

10. The fiber of any one of the previous claims, wherein the fiber has ends, the ends being connected to the center of the fiber via fiber arms, wherein each of the fiber arms is formed such that over a portion of at least 80% of the length of that arm, the fiber arm thickness has a thickness which is no more than 15% thicker or thinner than the average thickness of that fiber arm portion.

11. The fiber of any one of the previous claims, wherein the fiber comprises a nucleating agent.

12. The fiber according to any one of the previous claims, wherein the cross-sectional shape of the fiber being like an arc of a segment of a circle or an ellipse.

13. The fiber according to any one of the previous claims, wherein the cross-sectional shape of the fiber being like a catenary.

14. The fiber of any one of the previous claims, wherein the fiber comprises a thickening at its center (306).

15. The fiber of claim 14,

- wherein the thickening at its center is formed such that a round bulge is formed towards the

outer surface of the fiber,
- wherein the thickening does not lead to a bulge towards the inner surface of the fiber.

16. The fiber of any one of the previous claims, wherein the fiber has a width (w) measured as a straight line connecting the first and second ends of 0.7 to 2.5 mm, in particular of 0.9 to 1.5 mm.

17. The fiber of any one of the previous claims, wherein the undulations are formed such that the fiber has at least 6, in particular at least 7, in particular 7-11, e.g., 9 round bulges on its outer surface, and/or such that the fiber has at least 6, in particular 6-10, e.g., 8 round bulges on its inner surface.

18. The fiber of any one of the previous claims, wherein the majority of undulations form consecutive, pairs of a round bulge and a round indentation, wherein each pair has a length of 0.10 mm to 0.30 mm, e.g. 0.10 to 0.20 mm.

19. The fiber of any one of the previous claims, wherein at least 70% of the undulations of the inner surface and at least 70% of the outer surface have the same or a similar undulation length, wherein an undulation length is similar to a given length if it differs no more than plus or minus 10% from said given length.

20. The fiber of any one of the previous claims, wherein the boundary line consisting of uninterrupted undulations comprises a continuous slope.

21. An artificial turf comprising:

- a carrier; and
- a plurality of the artificial turf fibers (100, 800, 900, 1000, 1100) of any one of the previous claims integrated into the carrier and protruding therefrom to form an artificial turf.

Amended claims in accordance with Rule 137(2) EPC.

1. An extruded artificial turf fiber (100, 800, 900, 1000, 1100) having an arced cross-sectional shape, the arced cross-sectional shape being defined by a boundary line consisting of uninterrupted undulations, wherein the boundary line of the fiber is free of planar areas, pointed elevations and pointed depressions.

2. The fiber of claim 1, wherein the fiber has ends, the ends having a radius of curvature at least as large as the smallest radius defining the undulations of the boundary line of the other parts of the cross-sectional shape.

3. The fiber of any one of claims, wherein the fiber has thickenings (318) at the fiber ends.

4. The fiber of claim 3, wherein the ends are connected to the center of the fiber via fiber arms, wherein the diameter of each of the thickenings is thicker than the thickest part of the fiber arm that connects said end to the center (306) of the fiber.

5. The fiber of claim 4, wherein the diameter of each of the thickenings is at least 5% thicker than the thickest part of the fiber arm that connects said end to the center of the fiber.

6. The fiber of any one of the previous claims,

- wherein the arced cross-sectional shape has an outer, convex boundary line and an inner, concave boundary line,
- wherein at least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by first circles (508) having the same first diameter (D3); and
- wherein at least 70%, in particular at least 80%, e.g., 100% of the undulations of the outer boundary line are defined by second circles (510) having the same second diameter (D4).

7. The fiber of claim 6, wherein the first and second diameter are identical or similar, wherein a similar diameter lies in a range of plus or minus 10 % of the other diameter.

8. The fiber of claim 6 or 7, wherein the fiber comprises a thickening at its center which forms a rounded protrusion (316) to at least one side of the fiber, the curvature of the protrusion being defined by a circle (506) having a radius selected such that a ratio of the said radius to the radius of the first circles (508) is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

9. The fiber of any one of the previous claims,

- wherein the cross-sectional shape of the fiber being like an arc of a segment of a circle having a radius referred to as "fiber profile circle radius",
- wherein the ratio of the width of the fiber profile and the fiber profile radius is in the range of 1.40 to 1.80, in particular 1.50 to 1.70, in particular 1.55 to 1.68.

10. The fiber of any one of the previous claims, wherein the fiber has ends, the ends being connected to the center of the fiber via fiber arms, wherein each of the fiber arms is formed such that over a portion of at least 80% of the length of that arm, the fiber arm thickness has a thickness which is no more than 15%

thicker or thinner than the average thickness of that fiber arm portion.

11. The fiber of any one of the previous claims, wherein the fiber comprises a nucleating agent.

12. The fiber according to any one of the previous claims, wherein the cross-sectional shape of the fiber being like an arc of a segment of a circle or an ellipse.

13. The fiber according to any one of the previous claims, wherein the cross-sectional shape of the fiber being like a catenary.

14. The fiber of any one of the previous claims, wherein the fiber comprises a thickening at its center (306).

15. The fiber of claim 14,

- wherein the thickening at its center is formed such that a round bulge is formed towards the outer surface of the fiber,
- wherein the thickening does not lead to a bulge towards the inner surface of the fiber.

16. The fiber of any one of the previous claims, wherein the fiber has a width (w) measured as a straight line connecting the first and second ends of 0.7 to 2.5 mm, in particular of 0.9 to 1.5 mm.

17. The fiber of any one of the previous claims, wherein the undulations are formed such that the fiber has at least 6, in particular at least 7, in particular 7-11, e.g., 9 round bulges on its outer surface, and/or such that the fiber has at least 6, in particular 6-10, e.g., 8 round bulges on its inner surface.

18. The fiber of any one of the previous claims, wherein the majority of undulations form consecutive, pairs of a round bulge and a round indentation, wherein each pair has a length of 0.10 mm to 0.30 mm, e.g. 0.10 to 0.20 mm.

19. The fiber of any one of the previous claims, wherein at least 70% of the undulations of the inner surface and at least 70% of the outer surface have the same or a similar undulation length, wherein an undulation length is similar to a given length if it differs no more than plus or minus 10% from said given length.

20. The fiber of any one of the previous claims, wherein the boundary line consisting of uninterrupted undulations comprises a continuous slope.

21. An artificial turf comprising:

- a carrier; and
- a plurality of the artificial turf fibers (100, 800, 900, 1000, 1100) of any one of the previous claims integrated into the carrier and protruding therefrom to form an artificial turf.

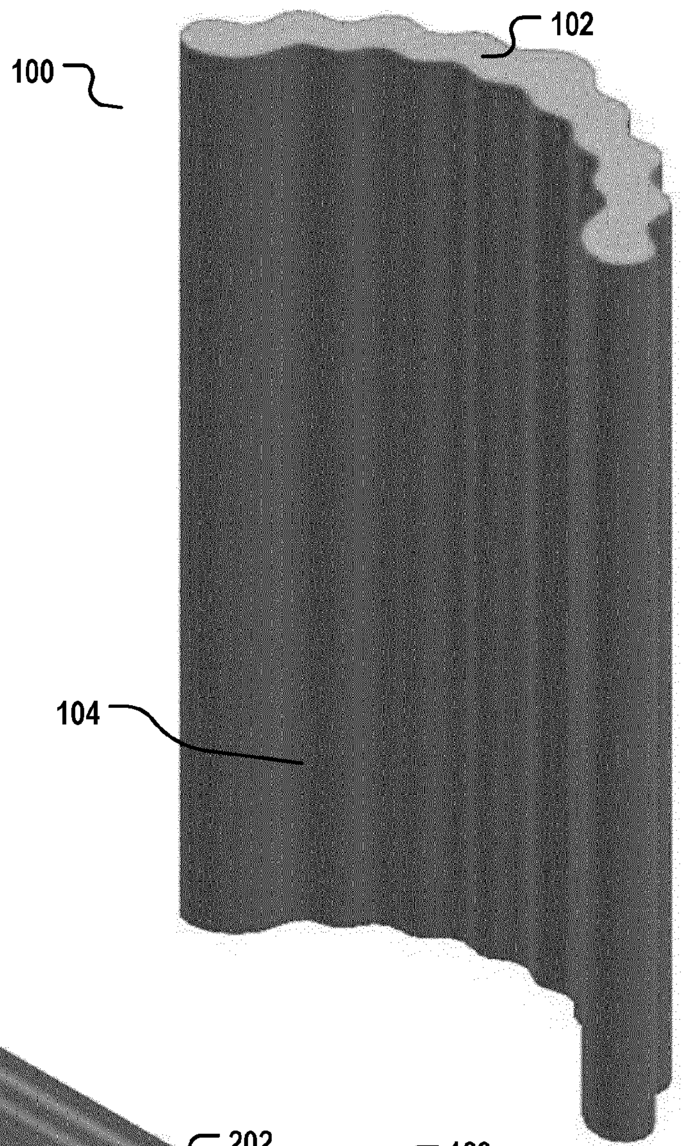

Fig. 1

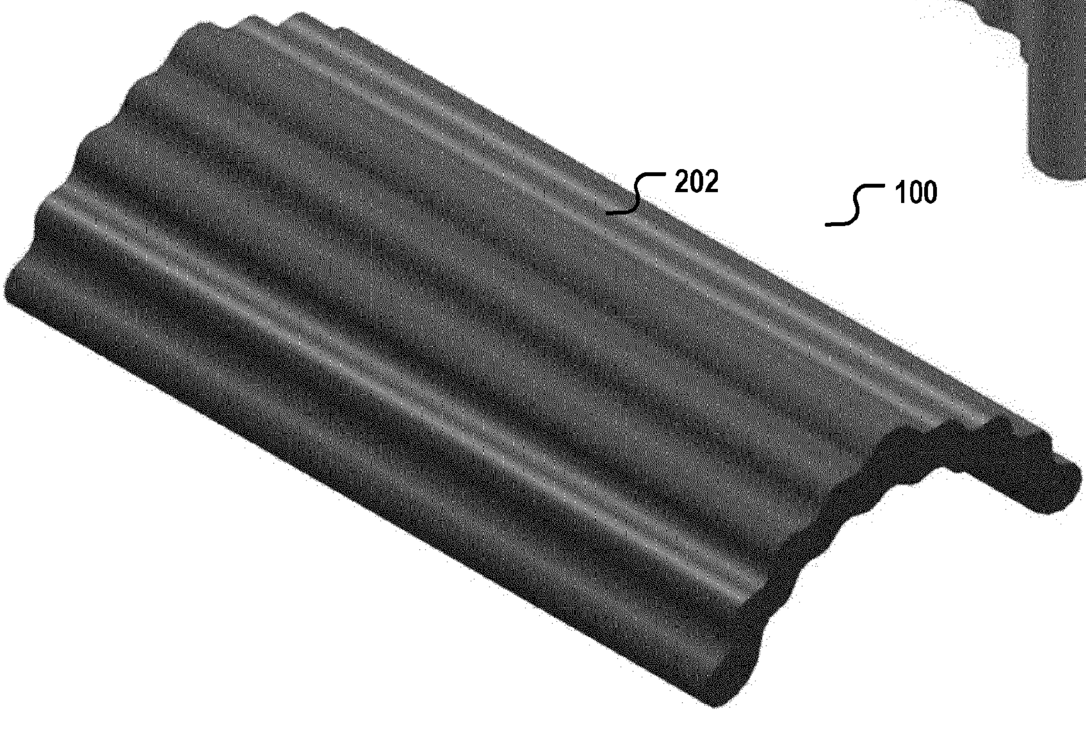

Fig. 2

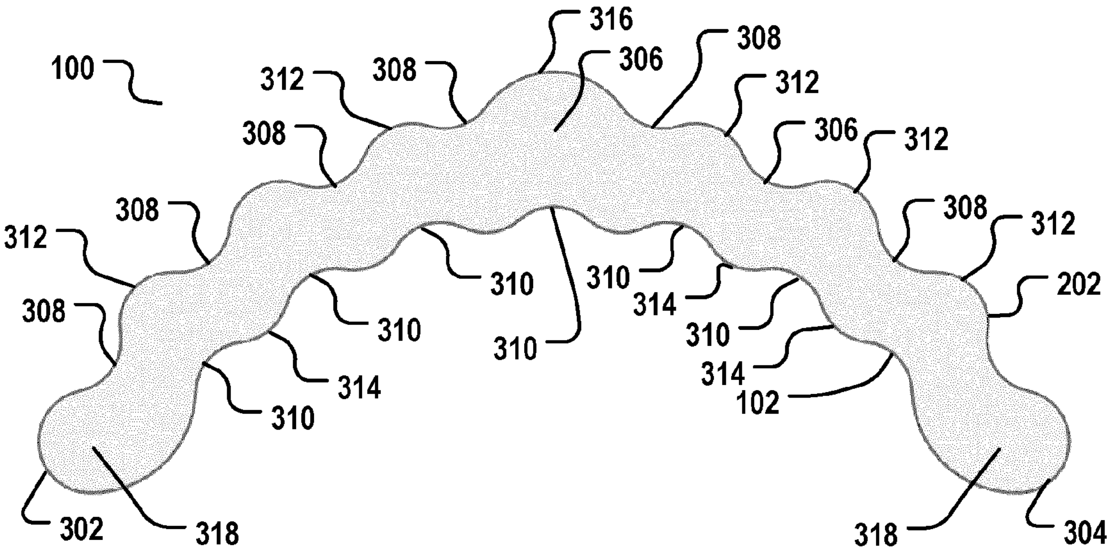
100
316
308
306
312
308
308
312
306
312
308
308
312
312
202
308
310
310
310
314
310
310
314
314
310
102
302
318
318
304

Fig. 3

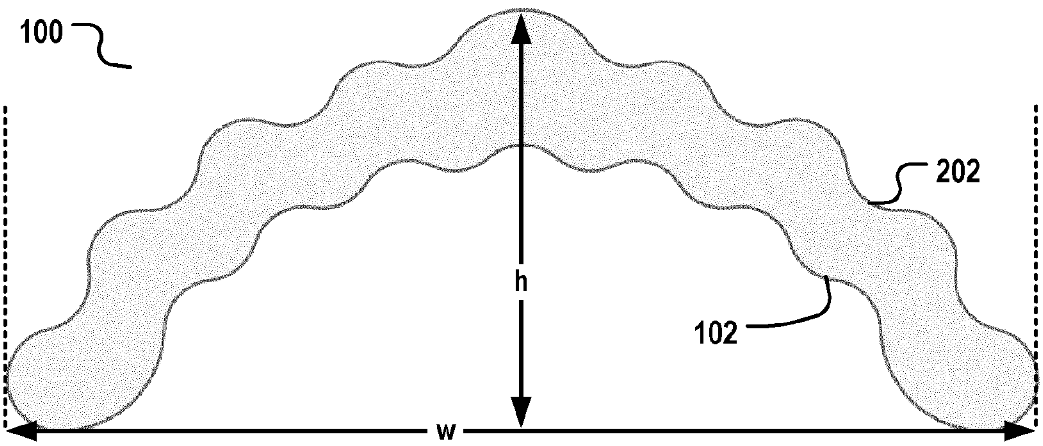
100
202
h
102
w

Fig. 4

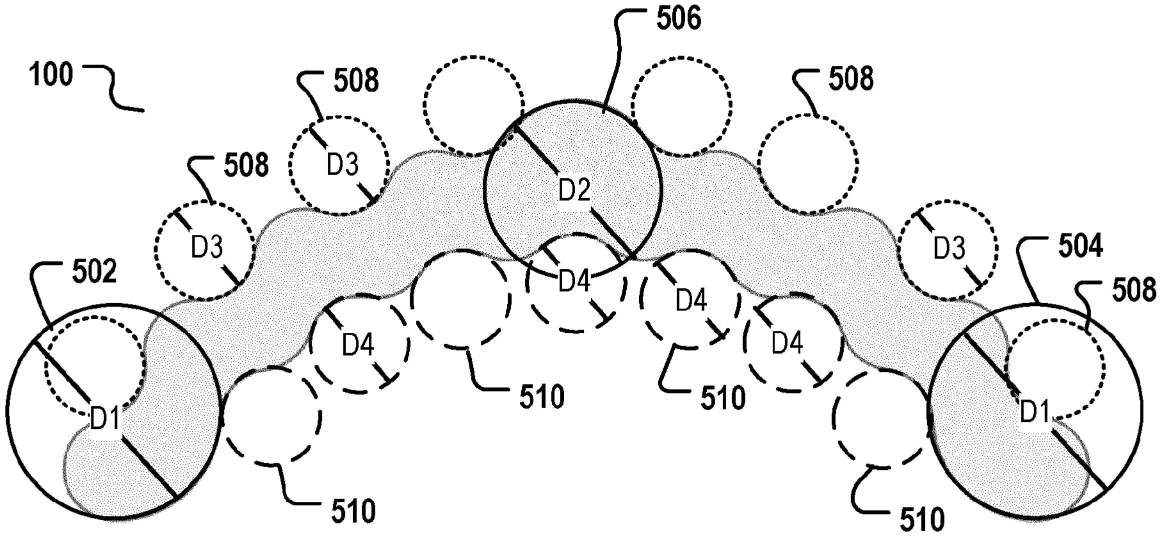
100
506
508
508
508
D3
D3
D2
D3
504
508
502
D4
D4
D4
D4
D1
D1
510
510
510
510

Fig. 5

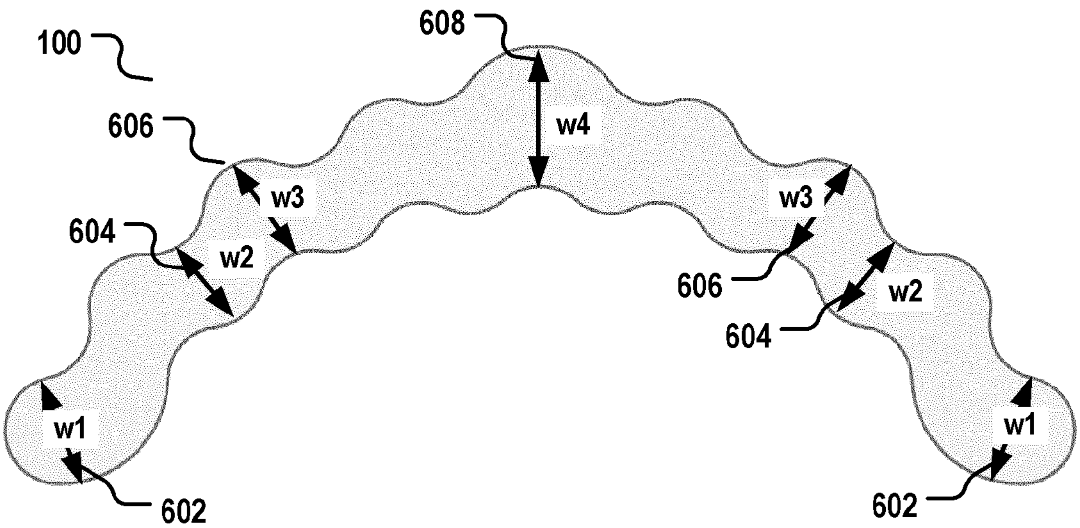
608
100
606
w4
w3
w3
604
w2
606
w2
604
w1
w1
602
602

Fig. 6

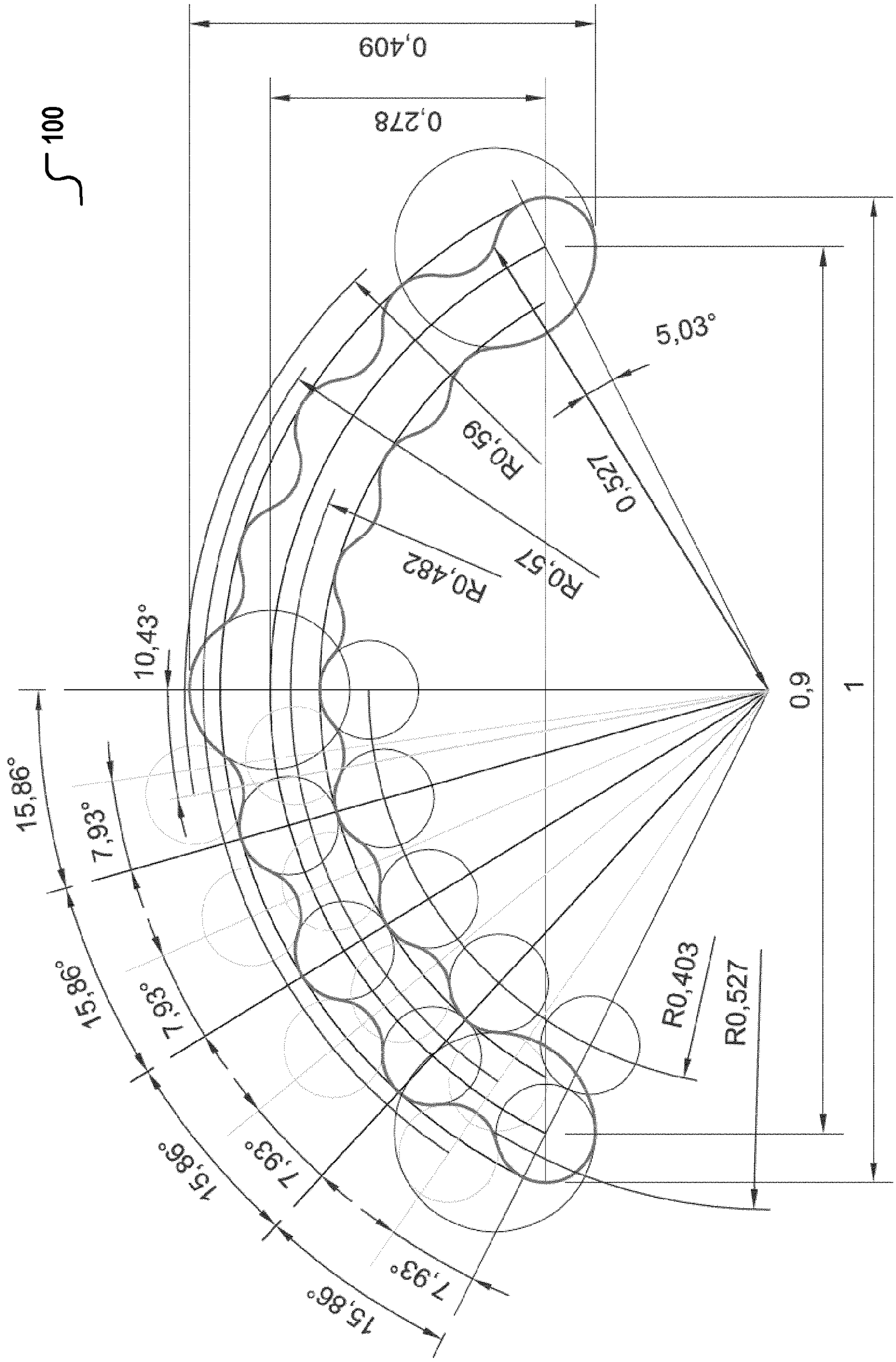
100
0,409
0,278
5,03°
R0,59
0,527
R0,57
R0,482
10,43°
0,9
1
15,86°
7,93°
15,86°
7,93°
R0,403
R0,527
15,86°
7,93°
7,93°
15,86°

Fig. 7A

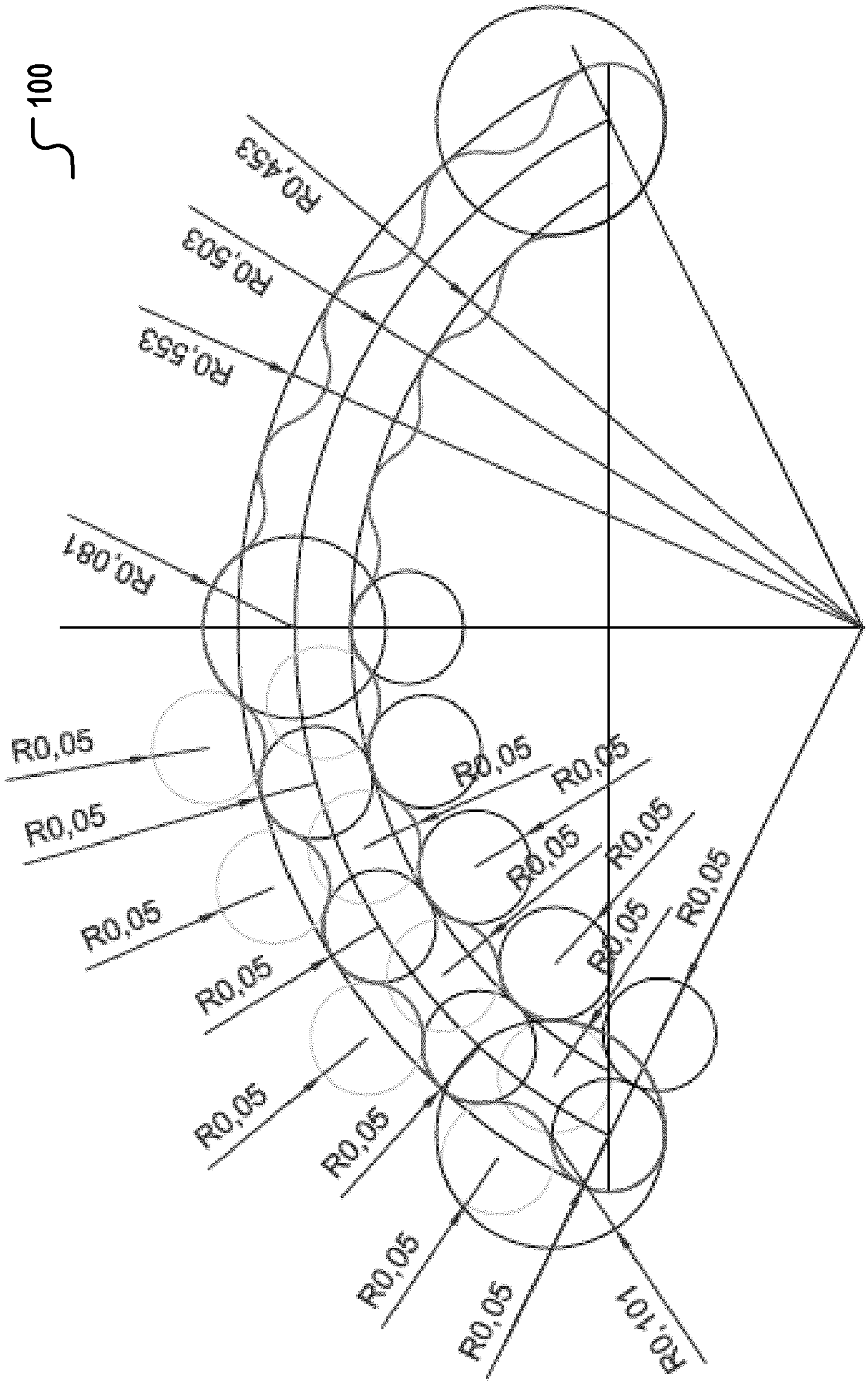
100
R0,453
R0,503
R0,553
R0,081
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,05
R0,101

Fig. 7B

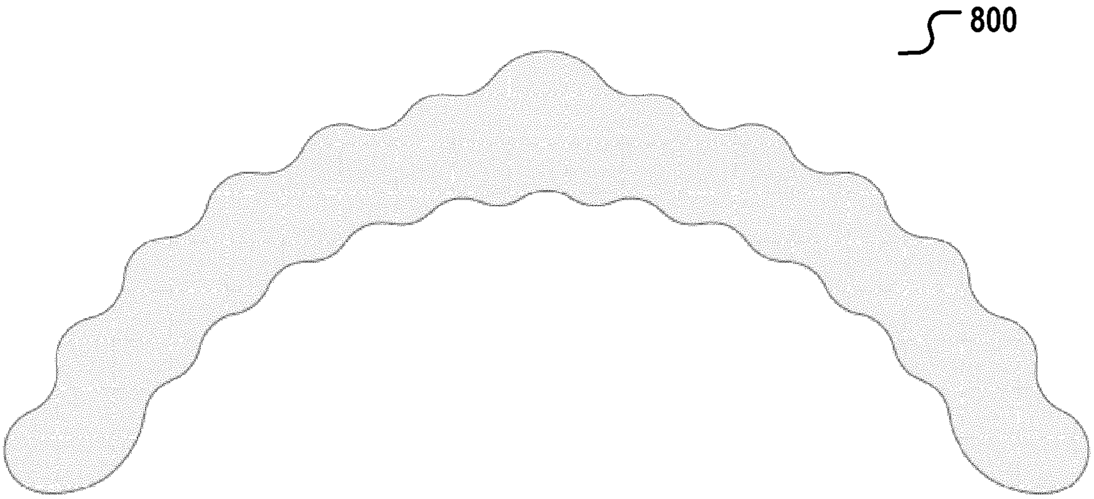

Fig. 8

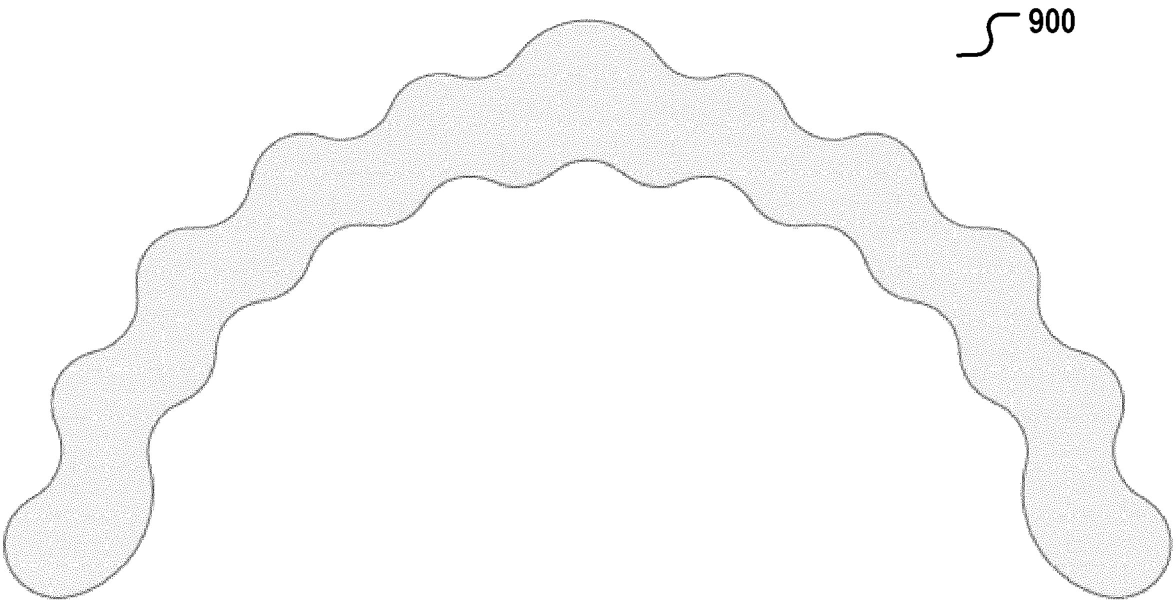

Fig. 9

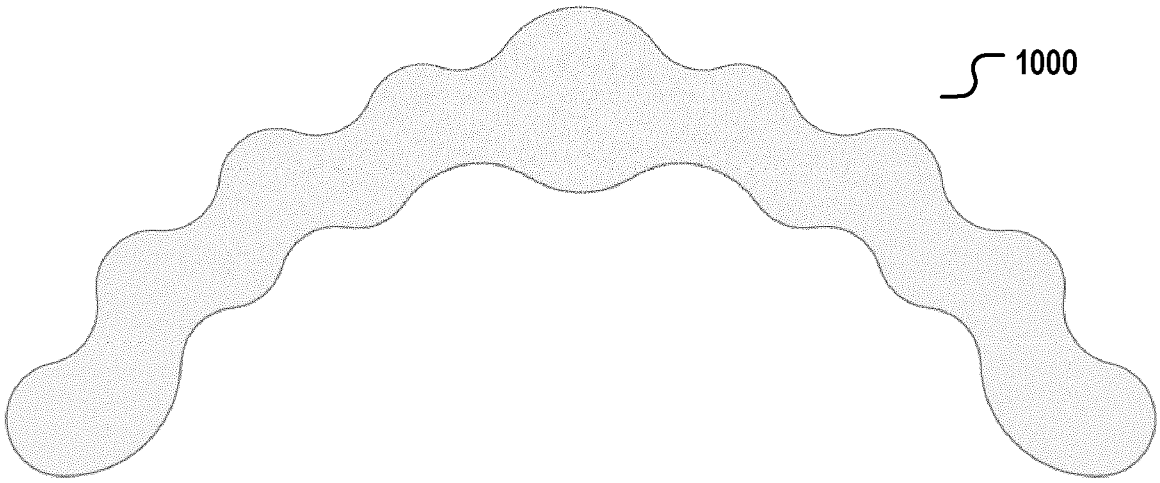

Fig. 10

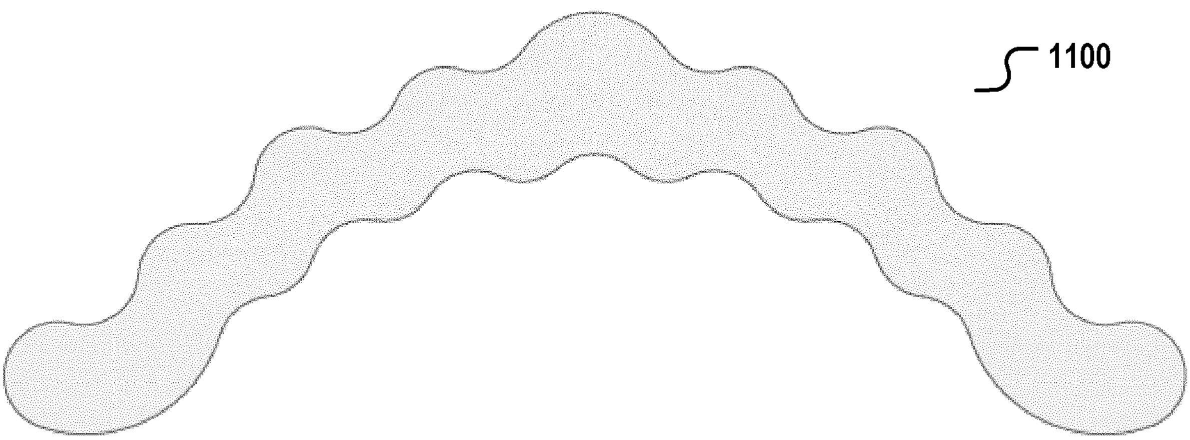

Fig. 11

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 21 0617

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 10 793 973 B2 (AUGUSTE JEAN CLAUDE [US]; MA HARRY R [US]; TEN CATE THIOLON BV [NL]) 6 October 2020 (2020-10-06)	1,6-21	INV. D01D5/253 D01D5/00 D01F6/04 D01F6/60 D06N7/00 E01C13/08
Y	* claims 1,11,23 * * figure 2 * -----	2-5	
Y	EP 1 950 350 A1 (TEN CATE THIOLON BV [NL]) 30 July 2008 (2008-07-30) * claim 12; figure 6 * -----	2-5	

TECHNICAL FIELDS SEARCHED (IPC)

D01D
D06N
E01C
D01F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 June 2024	Beyazit, Selim

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 21 0617

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-06-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 10793973 B2	06-10-2020	NONE	
EP 1950350 A1	30-07-2008	AU 2003250972 A1	28-01-2005
		AU 2004256218 A1	20-01-2005
		AU 2010200523 A1	04-03-2010
		CN 1823200 A	23-08-2006
		CN 101429747 A	13-05-2009
		CN 103628385 A	12-03-2014
		DK 1664436 T3	22-08-2016
		EP 1664436 A2	07-06-2006
		EP 1950350 A1	30-07-2008
		ES 2586534 T3	17-10-2016
		PL 1664436 T3	31-05-2017
		PT 1664436 T	24-08-2016
		US 2006159917 A1	20-07-2006
		WO 2005005730 A1	20-01-2005
		WO 2005005731 A2	20-01-2005

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 000003480344 A1 **[0003]**
- US 10793973 B2 **[0005]**
- EP 1950350 A1 **[0006]**
- US 006491991 B2 **[0007]**
- KR 1019890002109 **[0008]**