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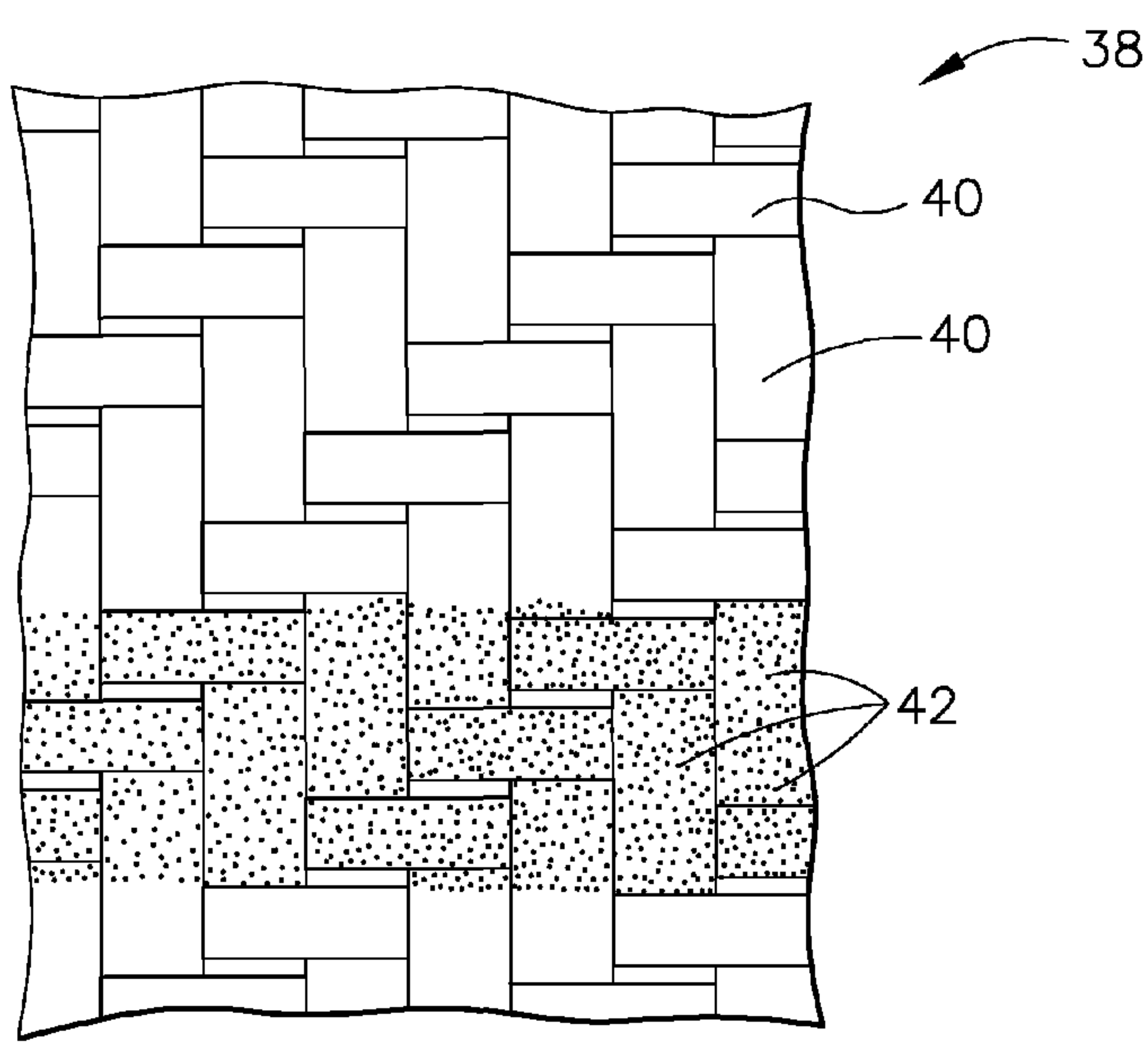
(54) **Titre : ARTICLES EN MATIERES COMPOSITES PRESENTANT DES ZONES DURCIES ET NON DURCIES**
(54) **Title: ARTICLES MADE FROM COMPOSITE MATERIALS HAVING TOUGHENED AND UNTOUGHENED REGIONS**



(57) **Abrégé/Abstract:**
Articles hawng a body including a composite mateiial haung at least one toughened region and at ieasi one untoughened region, the toughened region containing a toughening agent selected from the group consisting of poh mers. nano fibers, nano particles, and combinations thereof where the toughened region includes a toughened resin haung a fracture toughness of at least about 1.OMPa-m$^{1/2}$.

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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
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(54) Title: ARTICLES MADE FROM COMPOSITE MATERIALS HAVING TOUGHENED AND UNTOUGHENED REGIONS

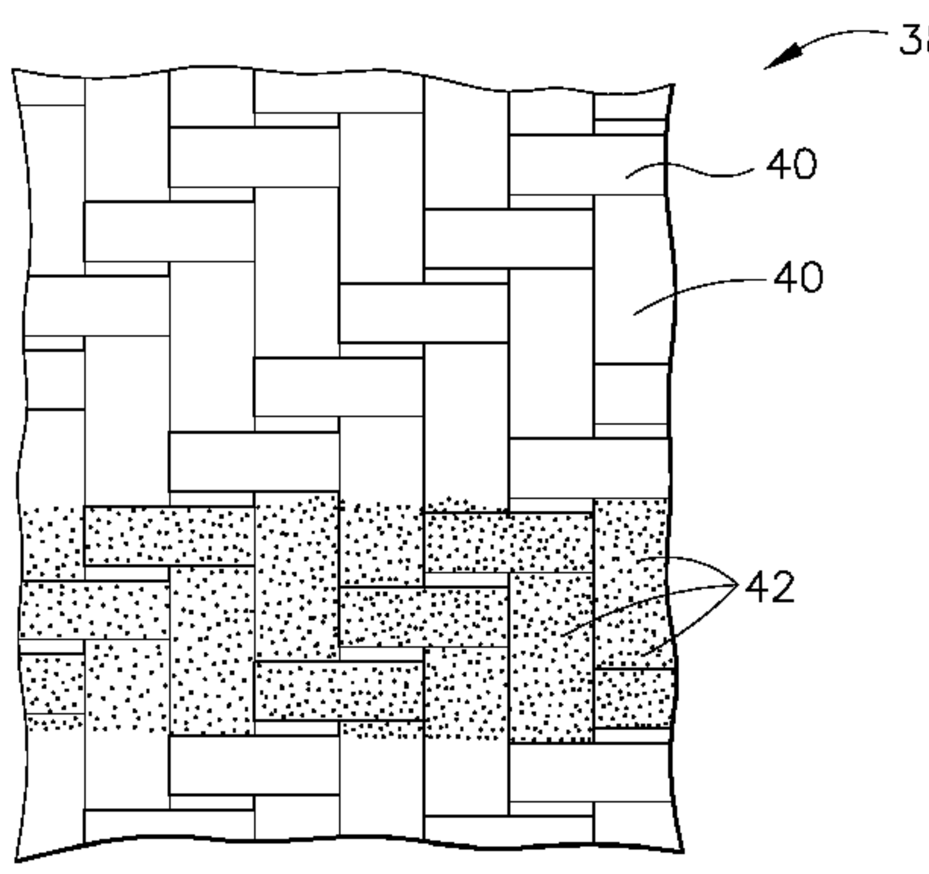

FIG. 4

(57) Abstract: Articles hawng a body including a composite mateiial haung at least one toughened region and at ieasi one untoughened region, the toughened region containing a toughening agent selected from the group consisting of poh mers. nano fibers, nano particles, and combinations thereof where the toughened region includes a toughened resin haung a fracture toughness of at least about 1.OMPa-m$^{1/2}$.

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ARTICLES MADE FROM COMPOSITE MATERIALS HAVING TOUGHENED AND UNTOUGHENED REGIONS

TECHNICAL FIELD

[0001] Embodiments described herein generally relate to articles made from composite materials. More particularly, embodiments herein generally describe fan casings made from composite materials having toughened and untoughened regions.

BACKGROUND OF THE INVENTION

[0002] In gas turbine engines, such as aircraft engines, air is drawn into the front of the engine, compressed by a shaft-mounted compressor, and mixed with fuel in a combustor. The mixture is then burned and the hot exhaust gases are passed through a turbine mounted on the same shaft. The flow of combustion gas expands through the turbine, which in turn spins the shaft and provides power to the compressor. The hot exhaust gases are further expanded through nozzles at the back of the engine, generating powerful thrust, which drives the aircraft forward.

[0003] Because engines operate in a variety of conditions, foreign objects may sometimes undesirably enter the engine. More specifically, foreign objects, such as large birds, hailstones, sand and rain may be entrained in the inlet of the engine. As a result, these foreign objects may impact a fan blade and cause a portion of the impacted blade to be torn loose from the rotor, which is commonly known as fan blade out. The loose fan blade may then impact the interior of the fan casing at an impact zone, thereby causing a portion of the casing to bulge or deflect. This deformation of the casing may result in increased stresses along the entire circumference of the fan casing.

[0004] In recent years composite materials have become increasingly popular for use in a variety of aerospace applications because of their durability and relative light weight. Although composite materials can provide superior strength and weight properties, and can lessen the extent of damage to the fan casing during impacts such as blade outs, improvements can still be made.

[0005] Current containment technology, such as that used to manufacture fan casings, generally requires the use of a thicker casing design at high stress regions. More specifically, current fan casings are often made using a thick, monolithic hardwall design, which can help fragmentize a released fan blade and minimize the extent of damage. The energy generated by a released fan blade impacting a hardwall fan casing can be dissipated by any of several controlled failure mechanisms including resin microcracking, composite material ply delamination, and composite material ply failure.

[0006] All of the previously described energy dissipation mechanisms require the use of an untoughened resin to ensure controlled failure of the fan casing upon impact of the released fan blade. More particularly, an untoughened epoxy resin can be applied uniformly to the entire fan casing during resin application. After curing, the resulting composite material will have the previously described controlled failure mechanisms. However, areas away from impact zones, or non-impact zones, need to be stronger in order to maintain the integrity of the casing should an impact occur. Therefore, additional layers of untoughened composite material are often applied in non-impact zones in order to provide strength and toughness, as well as compensate for the lower strength of the untoughened material. These additional layers add undesired weight to the fan casing.

[0007] Accordingly, there remains a need for articles having increased strength in desired regions without increasing the overall weight of the article.

BRIEF DESCRIPTION OF THE INVENTION

[0008] Embodiments herein generally relate to articles comprising a body comprising a composite material having at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof wherein the toughened region comprises a toughened resin having a fracture toughness of at least about 1.0MPa-$m^{1/2}$.

[0009] Embodiments herein also generally relate to fan casings including a body comprising a composite material having at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof wherein the untoughened region comprises an impact zone and wherein the toughened region comprises a toughened resin having a fracture toughness of at least about 1.0MPa-$m^{1/2}$.

[0010] Embodiments herein also generally relate to gas turbine engines including a fan casing having body made from a composite material comprising at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof; and a transition region between each toughened region and untoughened region wherein the composite material comprises a material selected from the group consisting of carbon fiber, glass fiber, ceramic fiber, graphite fiber, aramid fiber, and combinations thereof and wherein the toughened region comprises a toughened resin having a fracture toughness of at least about 1.0MPa-m$^{1/2}$ and the untoughened region comprises an untoughened resin having a fracture toughness of less than about 1.0MPa-m$^{1/2}$.

[0011] These and other features, aspects and advantages will become evident to those skilled in the art from the following disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] While the specification concludes with claims particularly pointing out and distinctly claiming the invention, it is believed that the embodiments set forth herein will be better understood from the following description in conjunction with the accompanying figures, in which like reference numerals identify like elements.

FIG. 1 is a schematic cut away view of one embodiment of a gas turbine engine in accordance with the description herein;

FIG. 2 is a schematic view of one embodiment of a material in accordance with the description herein;

FIG. 3 is a schematic view of one embodiment of a material having a toughening agent applied thereto in accordance with the description herein;

FIG. 4 is a schematic view of an alternate embodiment of a material having a toughening agent applied thereto in accordance with the description herein;

FIG. 5 is a schematic view of another alternate embodiment of a material having a toughening agent applied thereto in accordance with the description herein;

FIG. 6 is a schematic perspective view of one embodiment of a fan casing preform in accordance with the description herein; and

FIG. 7 is a schematic perspective view of one embodiment of a fan casing in accordance with the description herein.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Embodiments described herein generally relate to articles having toughened and untoughened regions. Generally, such articles can comprise a body comprising a composite material having at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof. While embodiments herein may generally focus on composite fan casings for gas turbine engines, it will be understood by those skilled in the art that the description should not be limited to such.

[0014] Turning to the figures, FIG. 1 is a schematic representation of one embodiment of a gas turbine engine 10 that generally includes a fan assembly 12 and a core engine 14. Fan assembly 12 may include a fan casing 16 and an array of fan blades 18 extending radially outwardly from a rotor disc 20. Core engine 14 may include a high-pressure compressor 22, a combustor 24, a high-pressure turbine 26 and a low-pressure turbine 28. Engine 10 has an intake end 30 and an exhaust end 32.

[0015] Initially, to make the composite materials and articles described herein, a material 38 may be provided as shown in FIG. 2. Any traditional fabric or multiaxial non-crimp fabric capable of being combined with a resin to produce a composite material is acceptable for use herein as material 38. In one embodiment, material 38 may be a fiber fabric selected from the group consisting of carbon fiber, glass fiber, ceramic fiber, graphite fiber, aramid fiber, and combinations thereof. As shown in FIG. 2, material 38 may generally comprise multiple interwoven fiber tows 40.

[0016] Once material 38 is selected, a toughening agent 42 may be applied to a portion thereof. Toughening agent 42 may comprise anything capable of providing increased toughness to the finished composite material as compared to the toughness present in the composite material without the application of a toughening agent as described herein below. In one embodiment, toughening agent 42 may be selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof, though it should not be limited to such.

[0017] Toughening agent 42 may be applied to material 38 in a variety of ways. For instance, toughening agent 42 may comprise a polymer. More specifically, in one embodiment, toughening agent 42 may comprise a polymer fiber that can be joined to the desired portion or portions of material 38 such that when an untoughened resin is later applied, as set forth herein below, a toughened resin is produced. Joining may include placing the fiber onto the material or weaving the fiber into the material (as shown in FIG. 3) in the desired location or locations, for example. In another embodiment, toughening agent 42 may comprise a polymer powder (as shown in FIG. 4) or polymer liquid that may be sprayed onto material 38 in the desired area or areas.

[0018] In the previously described embodiments, a toughened resin can be produced when an untoughened resin is later applied. The toughened resin can generally correspond to the portion or portions of the material comprising the polymer toughening agent. As used herein, "toughened resin" refers to resin that, when cured, displays a fracture toughness, or K_{1C} (i.e. the material's resistance to fracture when a crack is already present), of at least about 1.0MPa-$m^{1/2}$.

[0019] Alternately, as shown in FIG. 5, toughening agent 42 may comprise nano fibers such as nano carbon fibers, nano particles such as nano clay particles, and combinations thereof. Such toughening agents can be combined with an untoughened resin 43 gel, powder, or liquid, to make a toughened resin 44. Toughened resin 44 may then be applied to the desired portion or portions of material 38. As used herein "untoughened resin" refers to resin that, when cured, displays a fracture toughness, or K_{IC}, of less than about 1.0MPa-m$^{1/2}$. It is the addition of the toughening agent to the untoughened resin that, when cured, provides the toughened resin as defined herein. While the ratio of nano fibers/particles to resin may vary, in one embodiment the nano fibers/particles may account for from about 5% to about 20% by weight of the toughened resin, with the untoughened resin accounting for from about 80% to about 95% by weight.

[0020] In general, untoughened resin, when cured, can produce an untoughened region while toughened resin, when cured, can produce a toughened region, as defined herein below. While not intending to be limited by theory, it is believed that in the context of polymer toughening agents (whether fibers, powders, liquids or some combination thereof), when the untoughened resin is applied to the preform having the applied toughening agent, the untoughened resin can react with the previously applied polymer toughening agent to provide added fracture resistance to the cured composite material in the area generally corresponding to the portion of the material comprising the toughening agent. When using nano fibers/particles, it is believed that such toughening agents can enrich the resin and provide for a toughened region in the composite material after curing.

[0021] Material 38 may be shaped to produce a preform of a desired article, which in one embodiment may comprise a fan casing preform 45. As shown in FIG. 6, fan casing preform 45 may comprise a body 47 having any form desired and may be fabricated using any tool known to those skilled in the art. See, for example, U.S. Patent Application No. 2006/0134251 to Blanton et al. While embodiments set forth herein generally describe application of the toughening agent followed by shaping of the material into a preform, those skilled in the art will understand that it is also acceptable for the material to first be shaped into the desired preform followed by application of the toughening agent.

[0022] An untoughened resin may then be applied to the entire preform. In one embodiment, the untoughened resin may comprise a resin selected from the group consisting of vinyl ester resins, polyester resins, acrylic resins, epoxy resins, polyurethane resins, bismaelimide resins, polyimide resins, and combinations thereof. The untoughened resin may be the same as, or different from, any untoughened resin previously used in combination with a toughening agent to produce the toughened resin. Any conventional resin application methods may be used herein to apply the untoughened resin to the preform.

[0023] The preform having the applied untoughened resin may then be cured to produce an article, such as fan casing 16, shown in FIG. 7. Curing can generally involve applying a resin to the material or preform, as previously described, followed by exposure of the resinated preform or material to high temperature and pressure. Any conventional curing process known to those skilled in the art is acceptable for use herein. Some examples of curing may include, but are not limited to, resin film infusion, resin transfer molding, and vacuum assist resin transfer molding.

[0024] As shown in FIG. 7, the resulting cured composite material 46 of fan casing 16 can have at least one toughened region 48, at least one untoughened region 50, and a transition region 51 between each toughened region 48 and untoughened region 50. As used herein, "untoughened region" 50 means an area of composite material 46 generally corresponding to the portion of the material comprising the untoughened resin. "Toughened region" 48 means an area of the composite material generally corresponding to the portion of the material comprising the toughened resin. Toughened region 48 can display an increased resistance to fracture when compared to untoughened region. Those skilled in the art will understand that toughened region 48 can generally correspond to portions of the material where the toughening agent was applied due to previously described interaction between the toughening agent and the untoughened resin. Toughened region 48 may be oriented in any in relation to fan casing 16.

[0025] Transition region 51 can generally be located between toughened region 48 and untoughened region 50 and can display varying degrees of toughness in order to facilitate the conversion between toughened region 48 and untoughened region 50. Moreover, those skilled in the art will understand that transition region 51 may be planar (as indicated by A in FIG. 7), normal to the plane (as indicated by B in FIG. 7), and combinations thereof, in relation to the fan casing, for example.

[0026] Additionally, in one embodiment shown in FIG. 7, fan casing 26 may comprise an impact zone 52 and a non-impact zone 54. "Impact zone" 52 refers to parts of fan casing 16 most susceptible to an impact from a released fan blade while "non-impact zone" 54 refers to parts of fan casing 16 that are less susceptible to impact damage from a released fan blade. It may be desirable to position untoughened region 50 in impact zone 52 to provide controlled resin microcracking and composite material ply delamination, both of which can facilitate the previously discussed dissipation of impact energy from a released fan blade. In contrast, it may be desirable to position toughened region 48 in a non-impact zone 54 as such areas can be more fracture resistant. Additionally, because toughened region 48 of fan casing 16 can have a reduced structural thickness compared to current fan casings, yet still provide the desired fracture resistance, fan casing 16 can have a reduced weight compared to current designs. Thus, exemplary embodiments may employ toughened and untoughened regions to provide controlled failure and weight reduction.

[0027] Additionally, the selective toughening concept described herein can also provide monetary savings. In general, toughened resins (i.e. those resins including toughening agents) are more costly than untoughened resins. However, to obtain the desired fracture resistance, multiple layers of composite material having untoughened resin must be used, which can increase the cost of fabricating the article. By using toughened resins only in select regions where increased fracture resistance is needed, and untoughened resin elsewhere, fewer layers of composite material are needed. This can lead to an overall cost savings in fabricating the article.

[0028] Optionally, at least one toughened flange 56 may be coupled to toughened region 48. Toughened flange 56 may be selected from the group consisting of mounting flanges, attachment end flanges (as shown in FIG. 7), and combinations thereof. "Toughened flange" 56 refers to a flange that can be fabricated from the same, or similar, materials as toughened region 48 of fan casing 16. More specifically, toughened flange 56 can be made from a composite material having a toughening agent applied to at least a portion thereof, as described previously herein. In addition, toughened flange 56 may be coupled to a toughened region 48 of fan casing 16. By "coupled" it is meant that the toughened flange may be operably connected to the fan casing either after the lay-up of the fan casing preform is complete, or concurrent with the lay-up of the fan casing such that the toughened flange is an integral part of the finished cured fan casing. Using toughened materials to construct toughened flange 56 can provide added strength to both flange 56, as well as to the attachment between flange 56 and toughened region 48.

[0029] Those skilled in the art will understand that the previous description may apply equally to making any composite materials, and articles made from composite materials, and should not be limited to fan casings. Indeed, any gas turbine engine component constructed from composite materials may be fabricated using the methods and materials described herein. For example, the previous description may be used to fabricate a composite material airfoil having at least one toughened region and at least one untoughened region.

[0030] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention may include other examples that occur to those skilled in the art in view of the teachings herein.

WHAT IS CLAIMED IS:

1. An article including:

a body comprising a composite material having at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof wherein the toughened region comprises a toughened resin having a fracture toughness of at least 1.0 $MPa\text{-}m^{1/2}$.

2. The article of claim 1 wherein the composite material comprises a material selected from the group consisting of carbon fiber, glass fiber, ceramic fiber, graphite fiber, aramid fiber, and combinations thereof.

3. The article of claim 1 further comprising a transition region between each toughened region and untoughened region.

4. The article of claim 3 wherein the transition region is positioned in an orientation selected from the group consisting of planar, normal to the plane, and combinations thereof.

5. The article of claim 1 wherein the article comprises a fan casing.

6. The article of claim 1 further comprising at least one toughened flange coupled to the at least one toughened region wherein the toughened flange is selected from the group consisting of mounting flanges, attachment end flanges, and combinations thereof.

7. The article of claim 1 wherein the untoughened region comprises an impact zone.

8. A fan casing including:

a body comprising a composite material having at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof wherein the untoughened region comprises an impact zone and wherein the toughened region comprises a toughened resin having a fracture toughness of at least 1.0 MPa-$m^{1/2}$.

9. The fan casing of claim 8 wherein the composite material comprises a material selected from the group consisting of carbon fiber, glass fiber, ceramic fiber, graphite fiber, aramid fiber, and combinations thereof.

10. The fan casing of claim 8 further comprising a transition region between each toughened region and untoughened region.

11. The fan casing of claim 10 wherein the transition region is positioned in an orientation selected from the group consisting of planar, normal to the plane, and combinations thereof.

12. The fan casing of claim 8 further comprising at least one toughened flange coupled to the at least one toughened region wherein the toughened flange is selected from the group consisting of mounting flanges, attachment end flanges, and combinations thereof.

13. A gas turbine engine including:

a fan casing having body made from a composite material comprising at least one toughened region and at least one untoughened region, the toughened region comprising a toughening agent selected from the group consisting of polymers, nano fibers, nano particles, and combinations thereof; and

a transition region between each toughened region and untoughened region wherein the composite material comprises a material selected from the group consisting of carbon fiber, glass fiber, ceramic fiber, graphite fiber, aramid fiber, and combinations thereof and wherein the toughened region comprises a toughened resin having a fracture toughness of at least 1.0 MPa-$m^{1/2}$ and the untoughened region comprises an untoughened resin having a fracture toughness of less than 1.0 MPa-$m^{1/2}$.

14. The turbine engine of claim 13 further comprising at least one toughened flange coupled to the at least one toughened region wherein the toughened

flange is selected from the group consisting of mounting flanges, attachment end flanges, and combinations thereof.

15. The turbine engine of claim 13 wherein the untoughened region comprises an impact zone.

16. The turbine engine of claim 13 wherein the transition region is positioned in an orientation selected from the group consisting of planar, normal to the plane, and combinations thereof.

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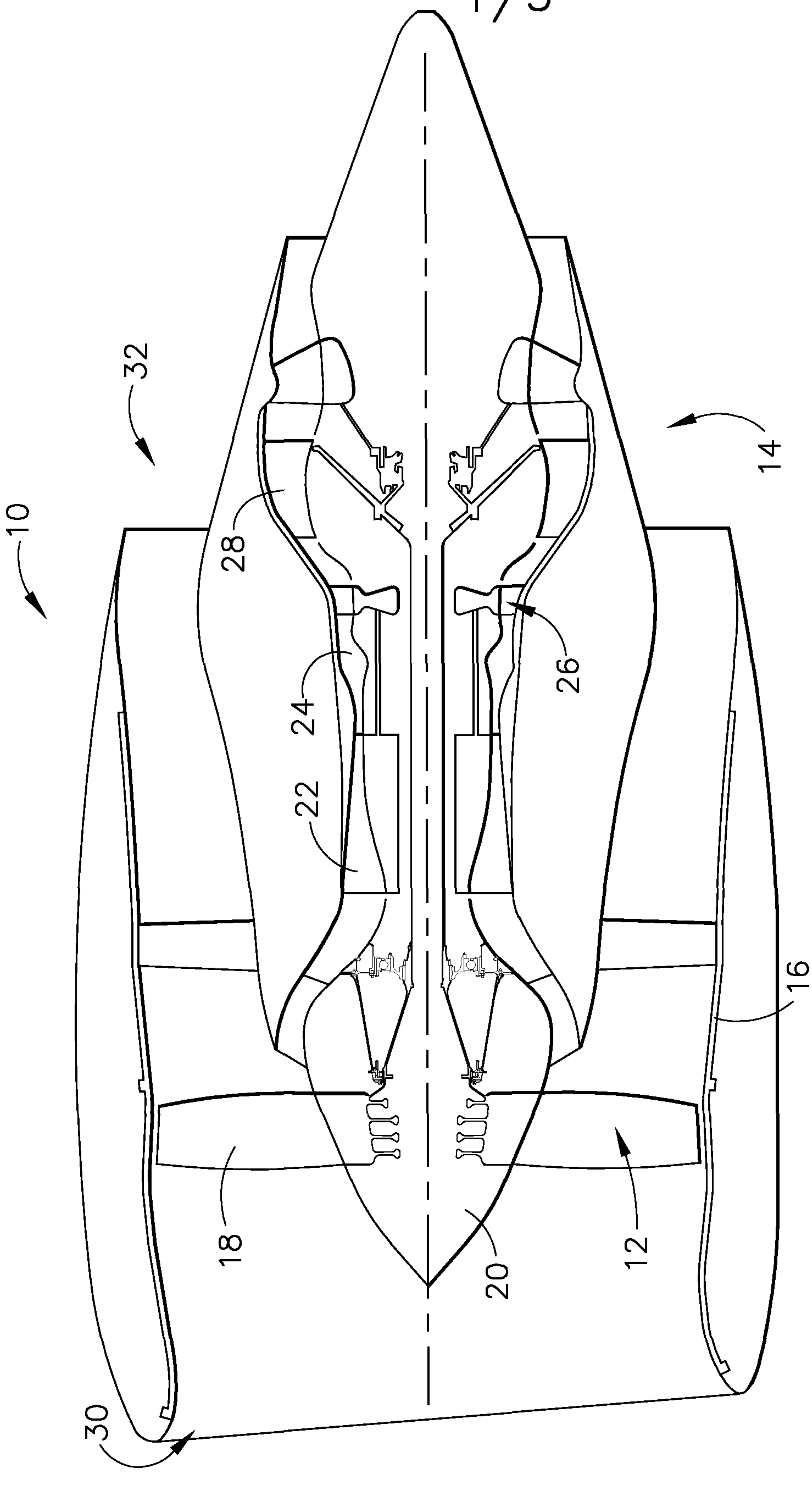


FIG. 1

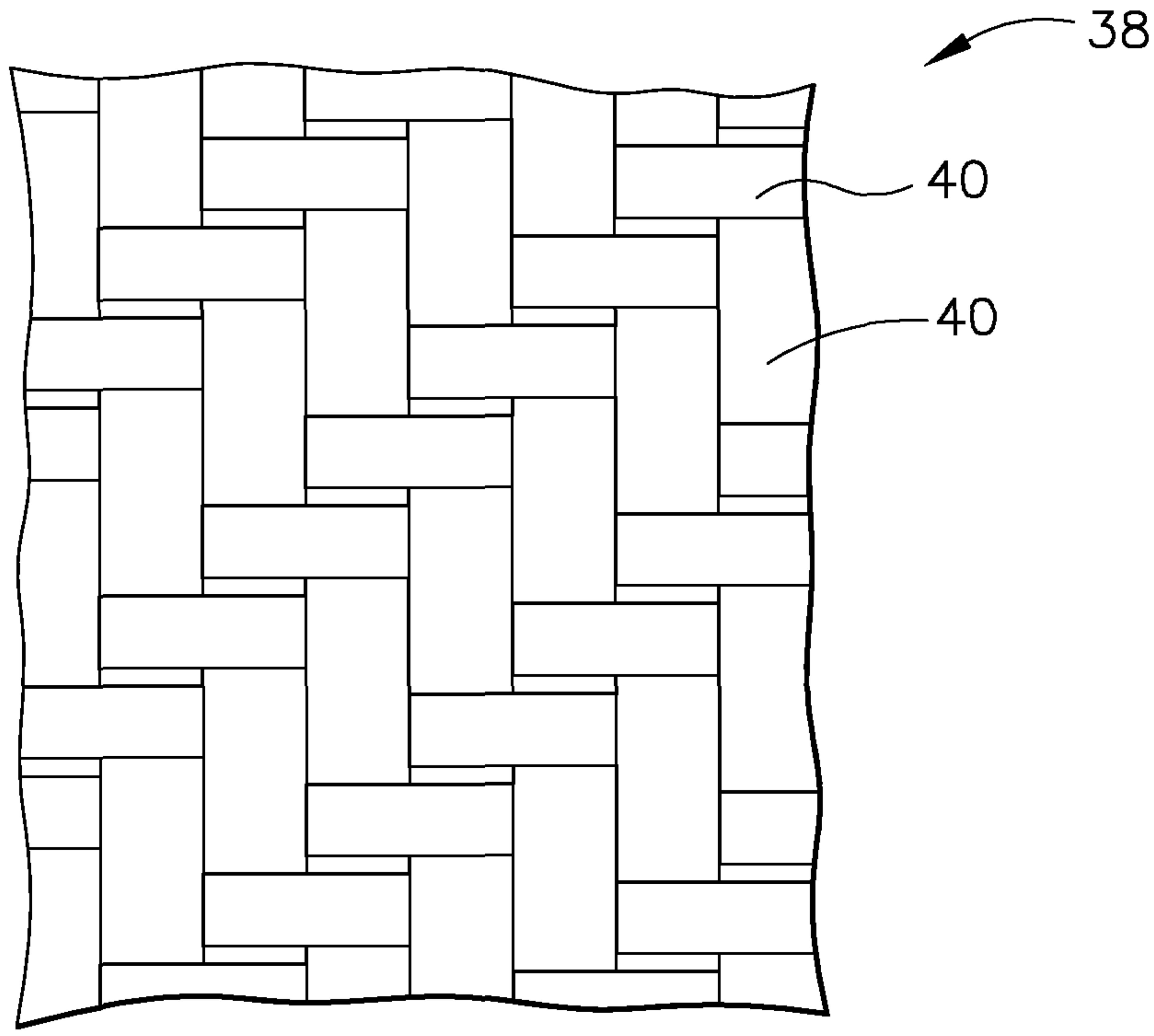


FIG. 2

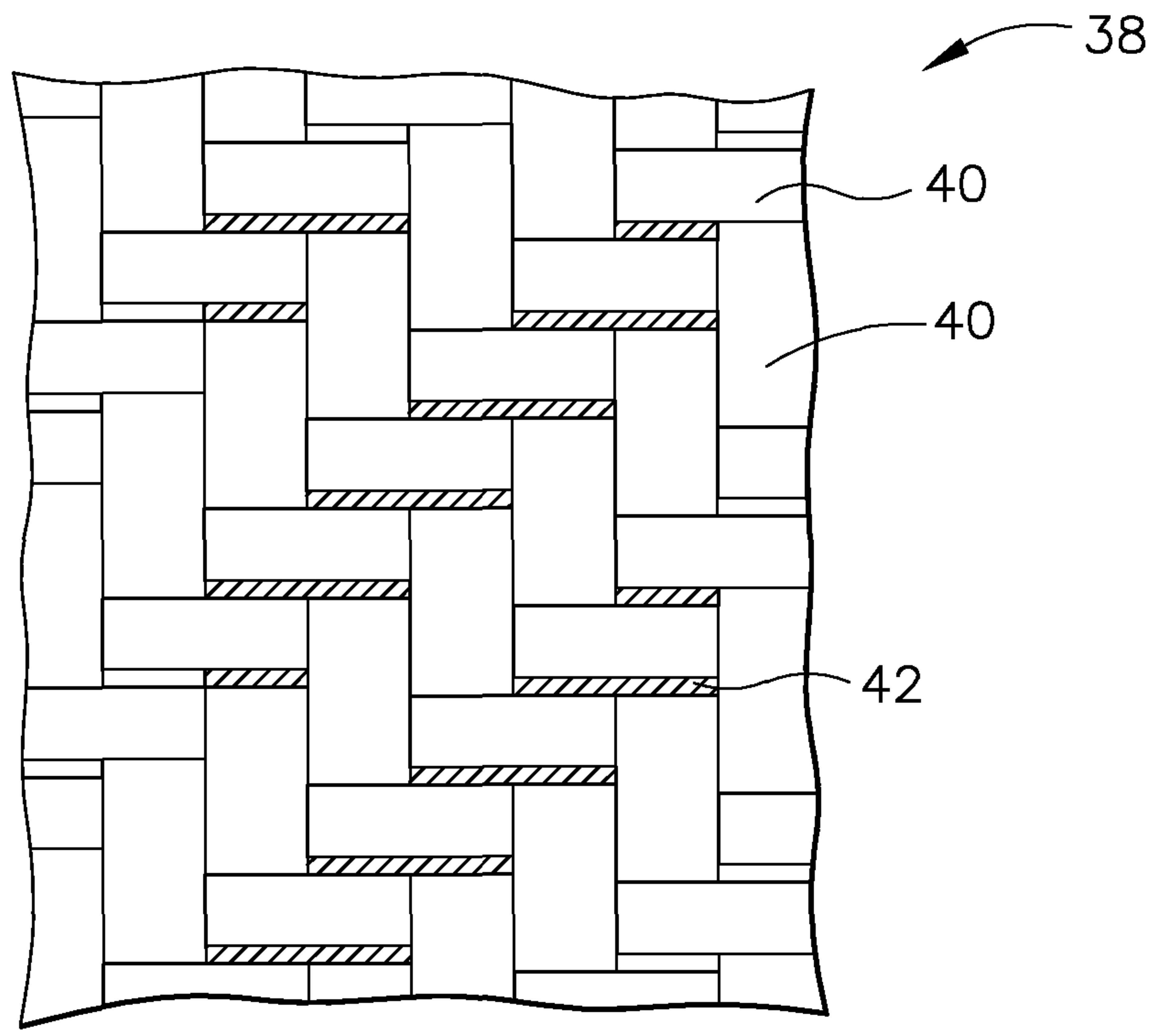


FIG. 3

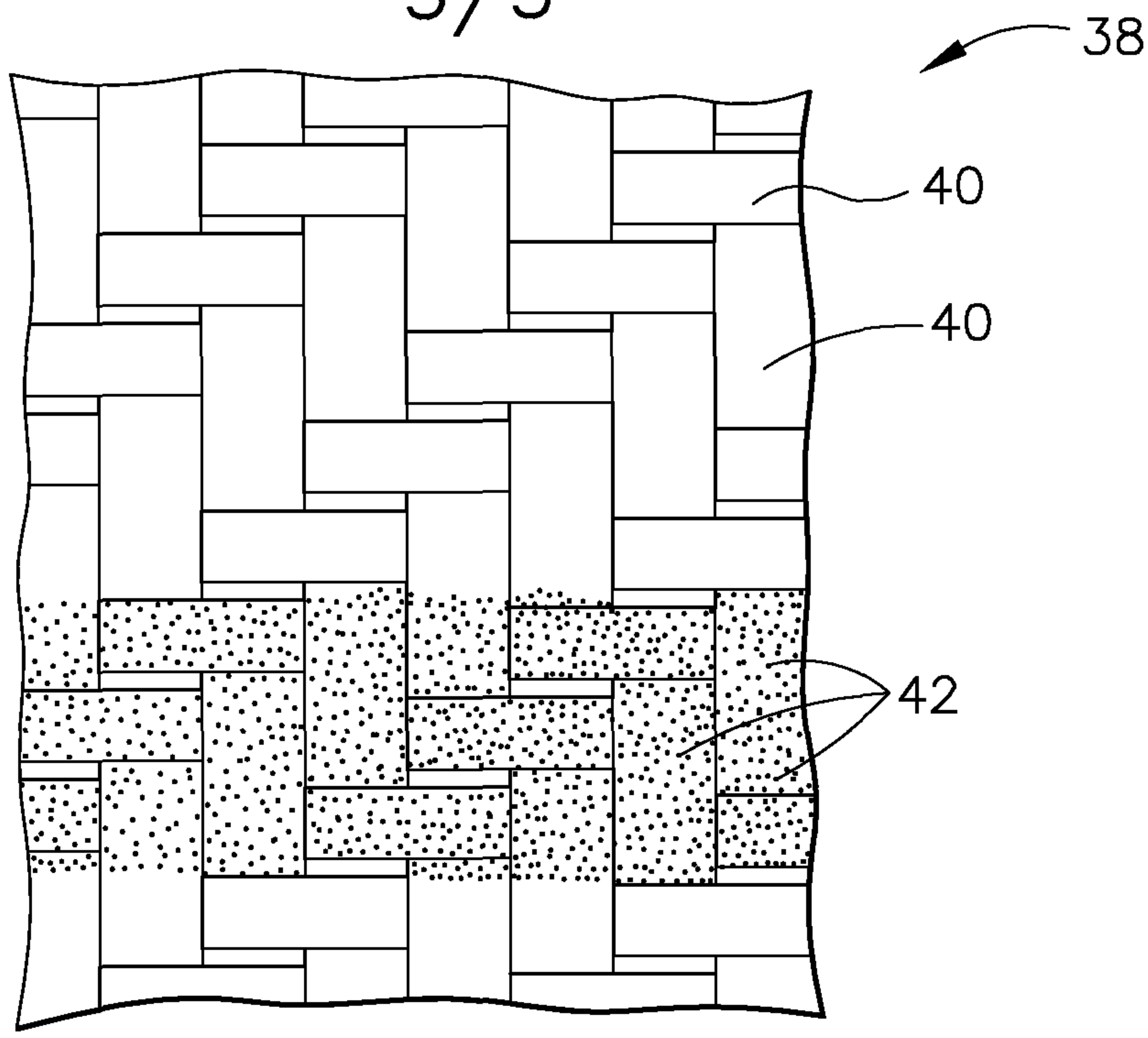


FIG. 4

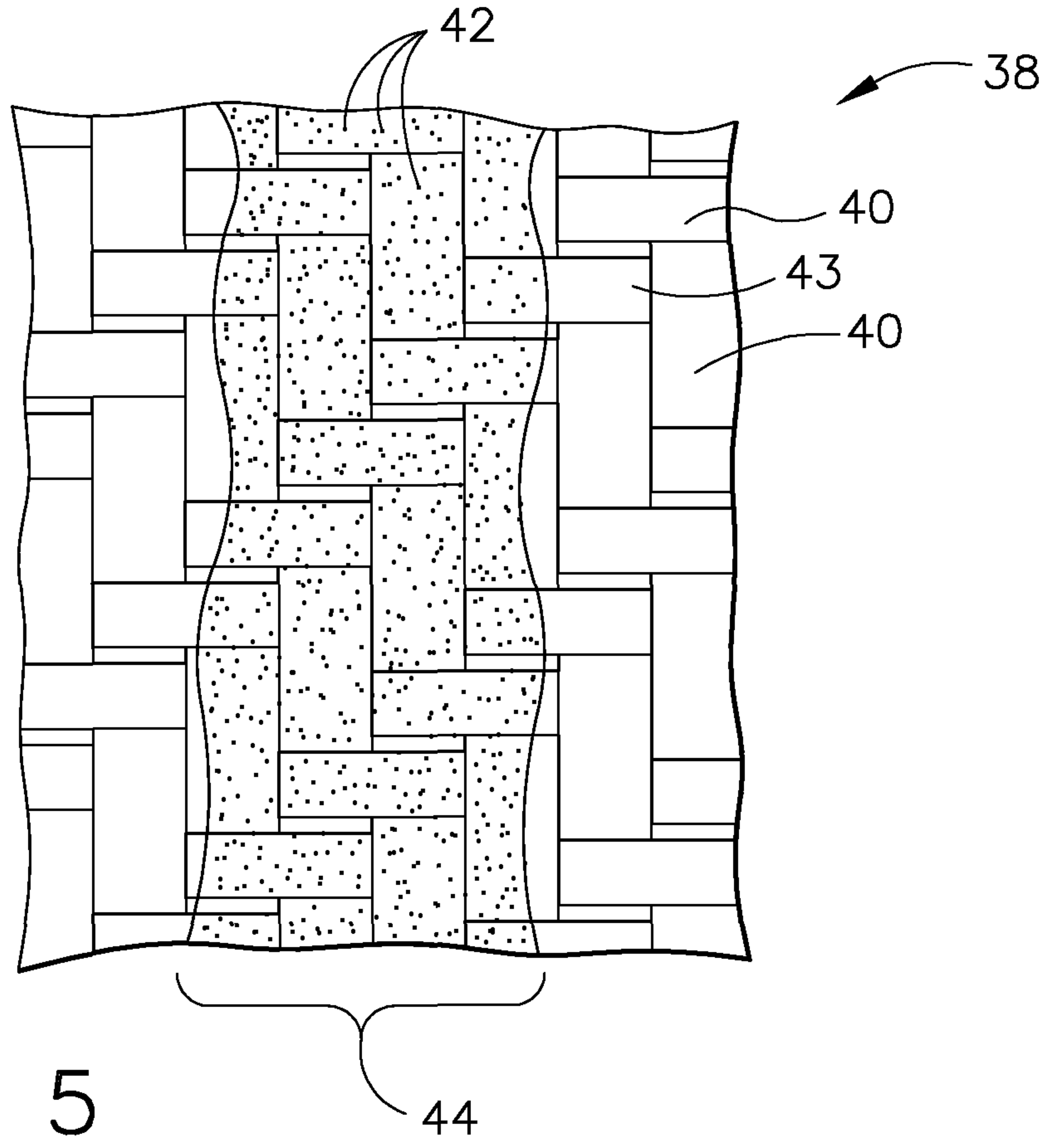


FIG. 5

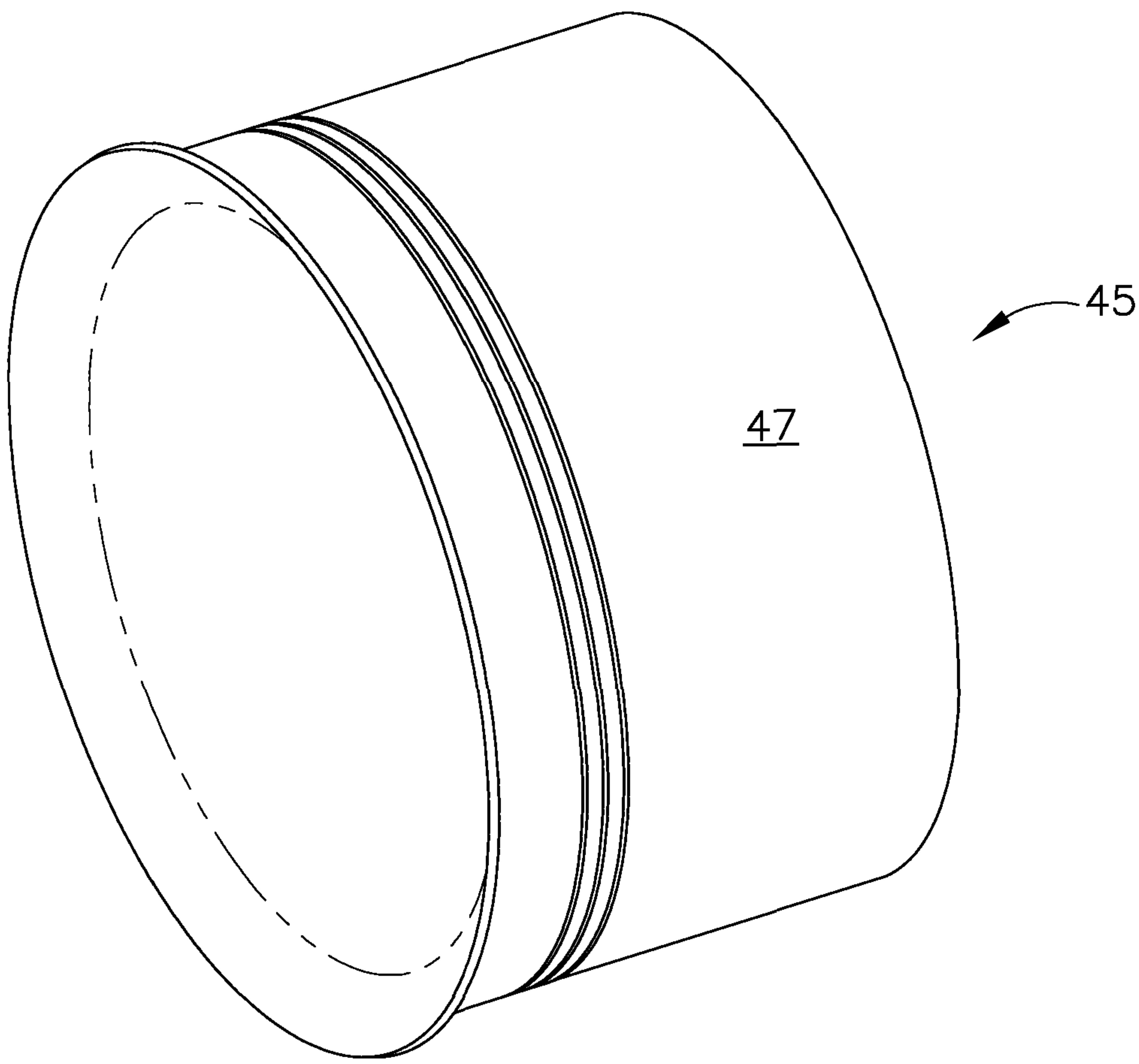


FIG. 6

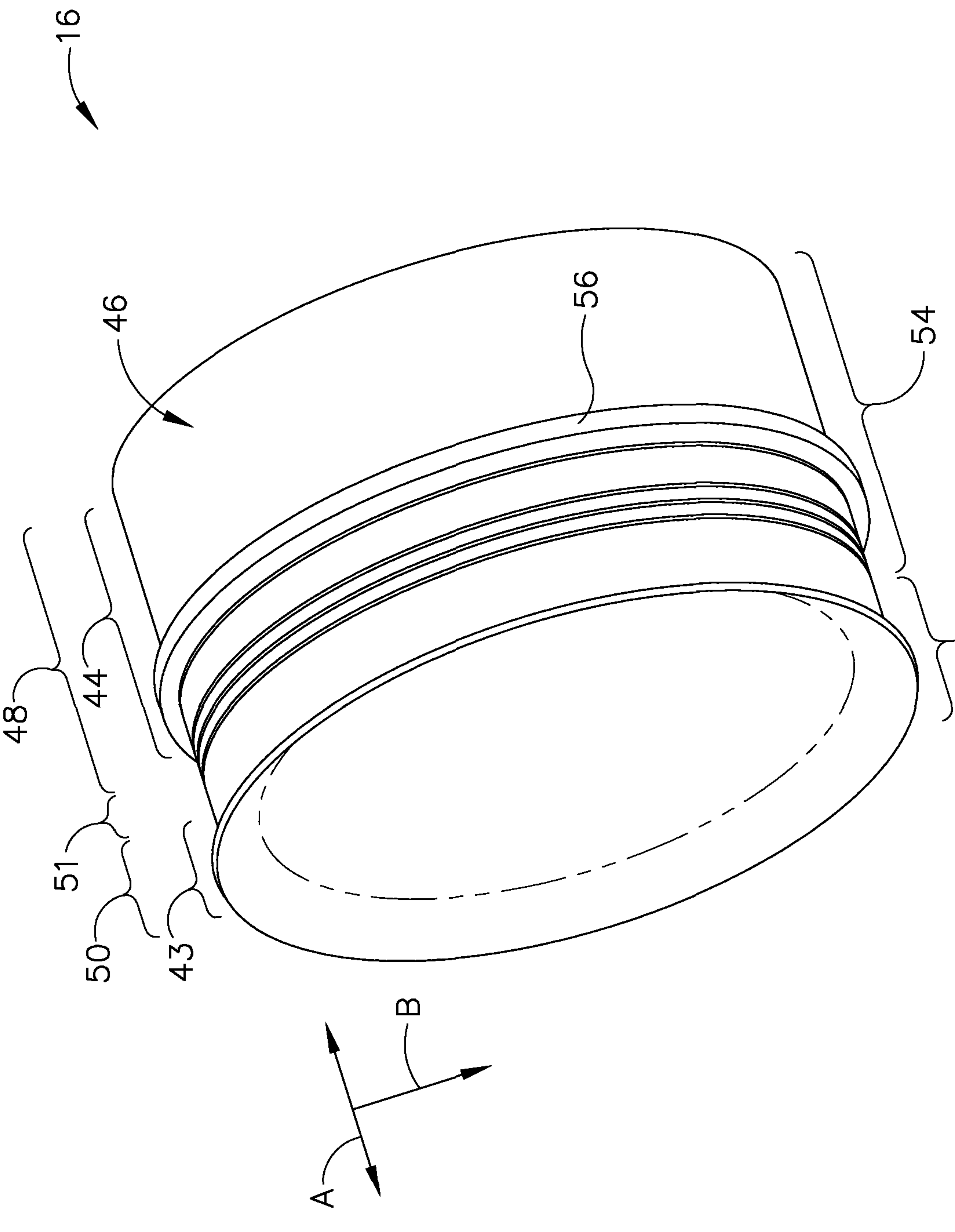
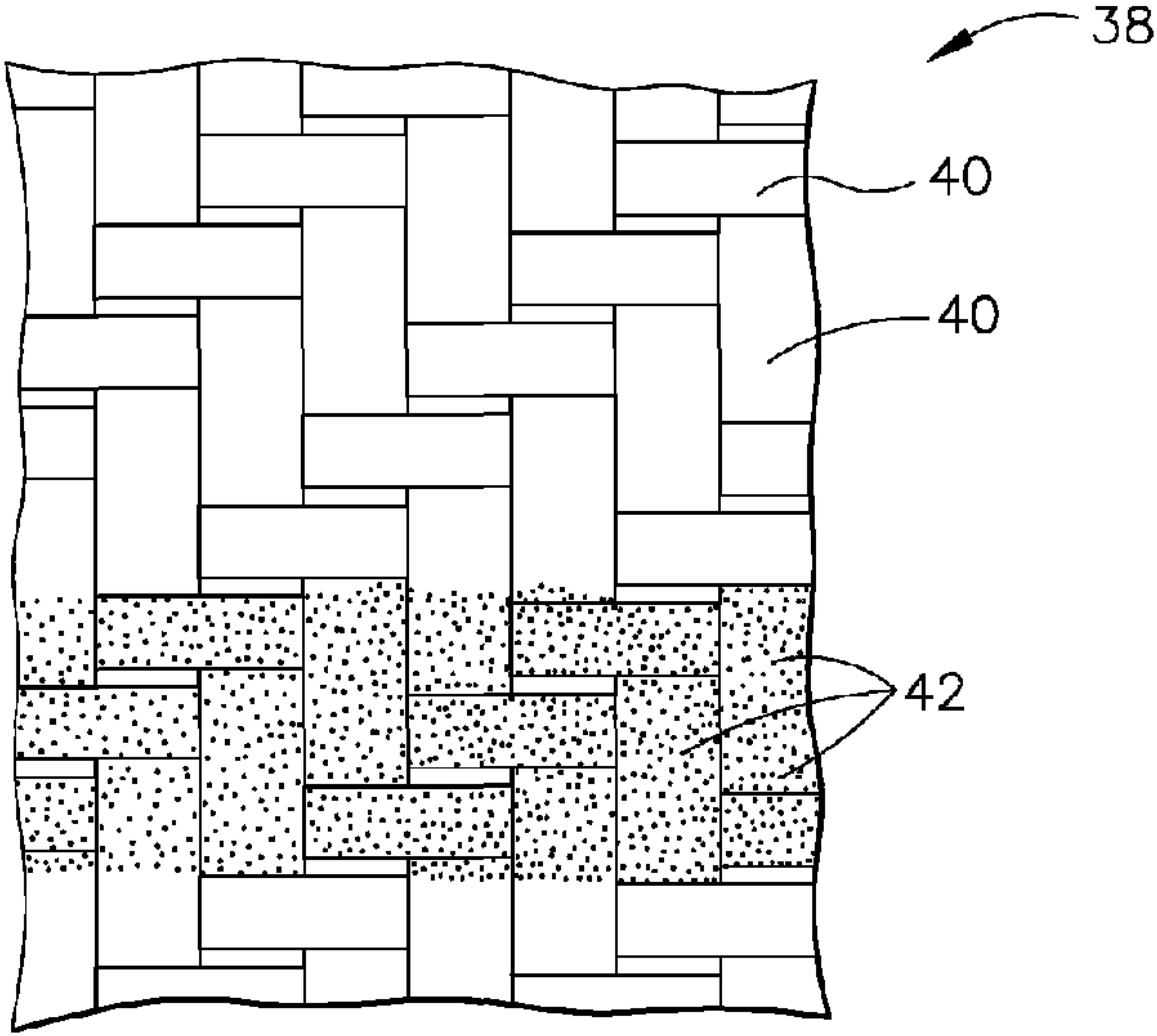


FIG. 7



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