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(54) MAGNETIC COMPOSITES

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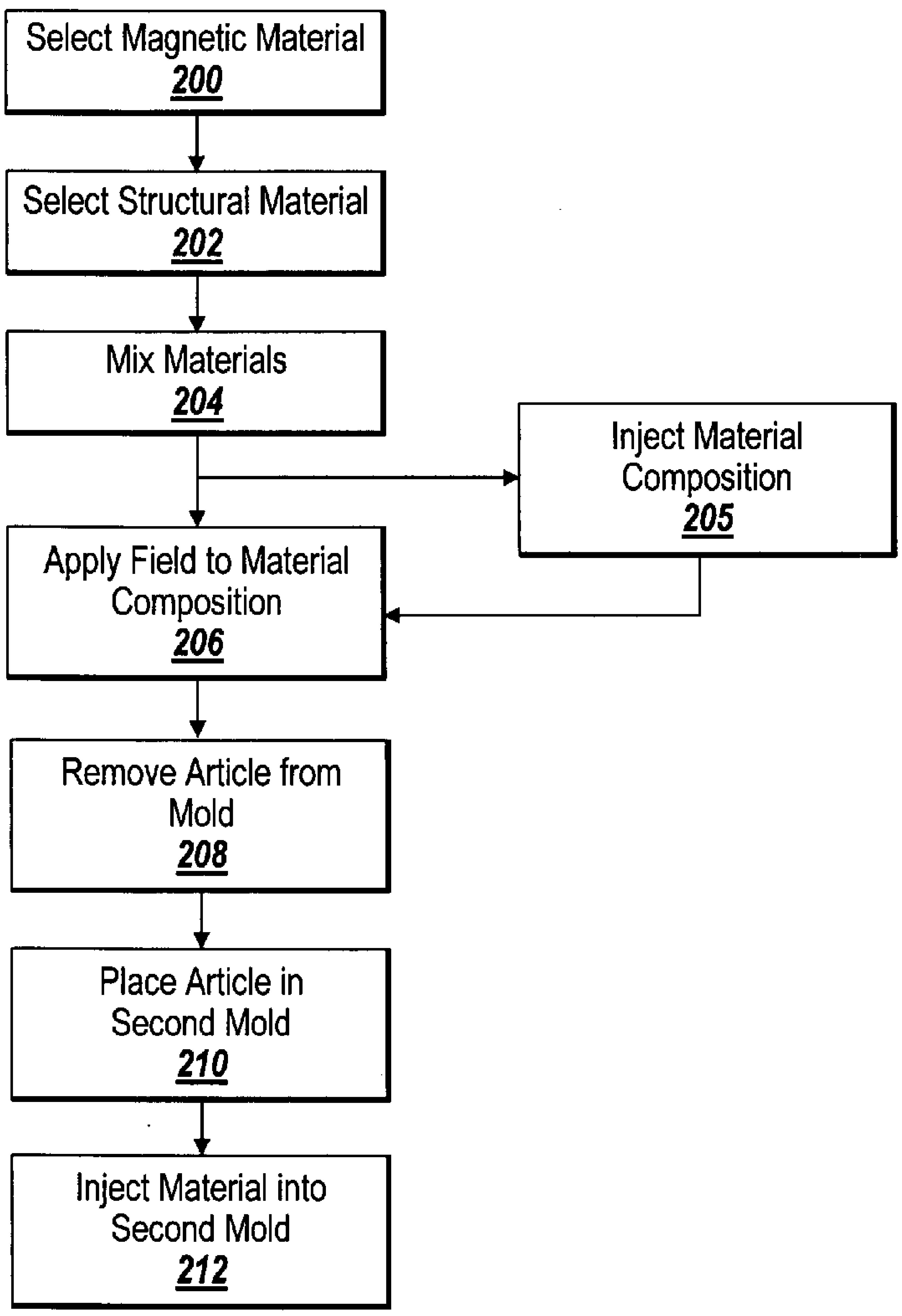
(57) **ABSTRACT**

The present invention discloses methods and magnetic material composites capable of withstanding one or more loads without the need for a substructure to provide structural support thereto. The magnetic composites are formable from composites such as epoxies, resins, plastics and the like together with rare earth or other magnetic or magnetizable compounds, or magnetic nano-particles to form structural magnetic composites. The magnetic composites have one or more portions with an aggregation of the magnetic material and one or more portions free of or substantially free of the magnetic material. The magnetic composites are suitable for use to form components of electrical motors, generators, pumps, fans, paints, coatings and parts or derivatives thereof.



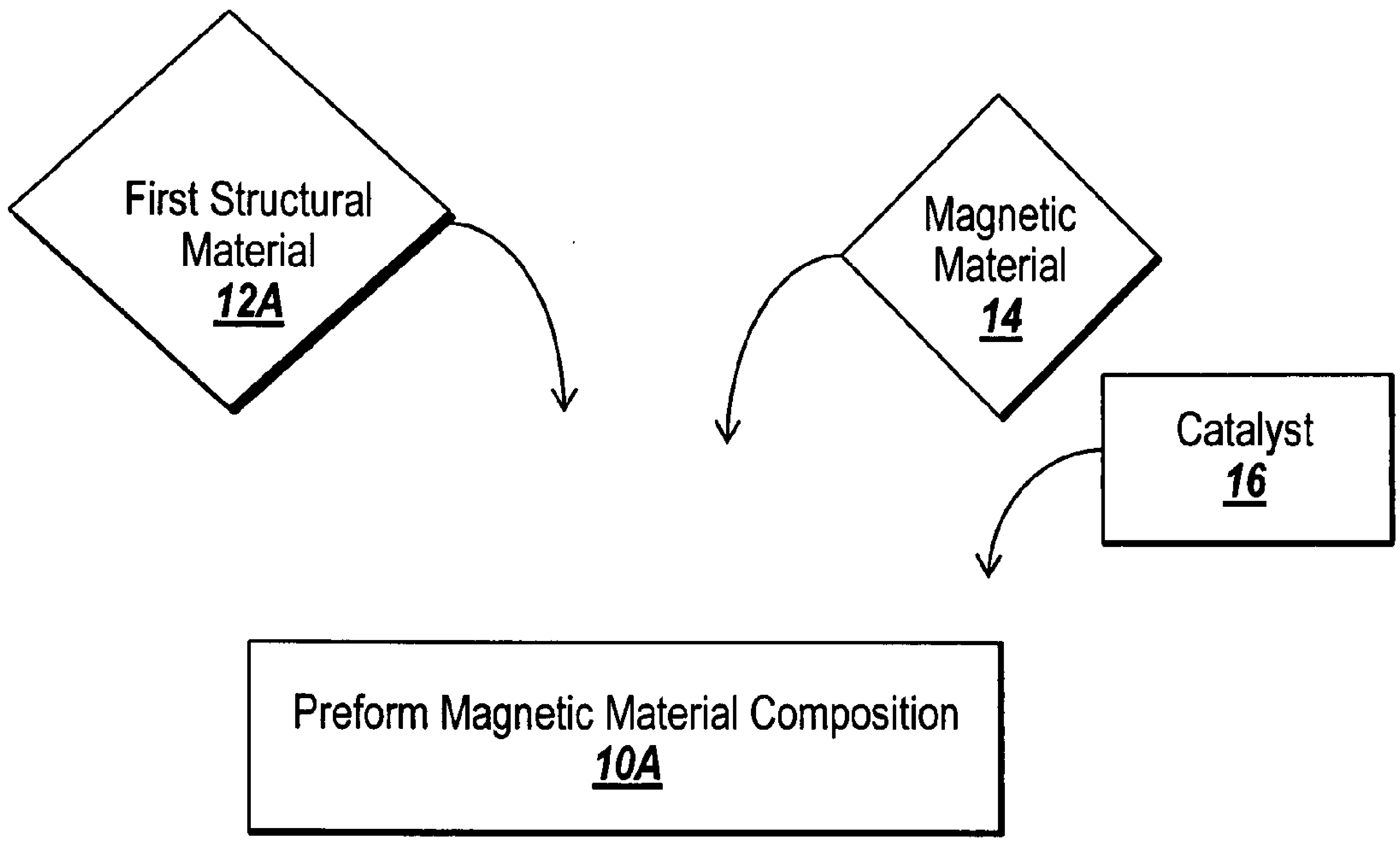

First Structural Material
12A
Magnetic Material
14
Catalyst
16
Preform Magnetic Material Composition
10A

Fig. 1A

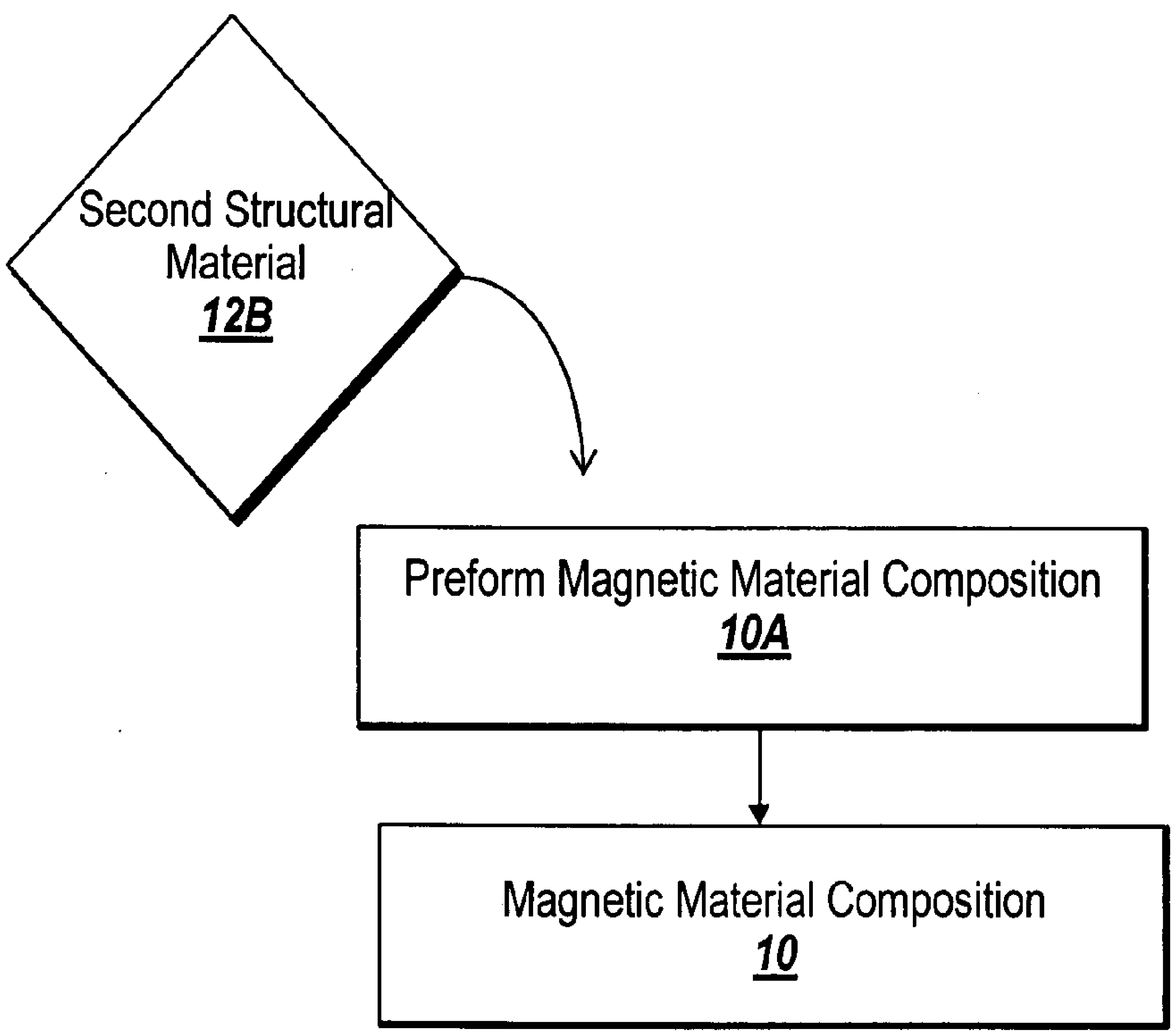

Second Structural Material
12B
Preform Magnetic Material Composition
10A
Magnetic Material Composition
10

Fig. 1B

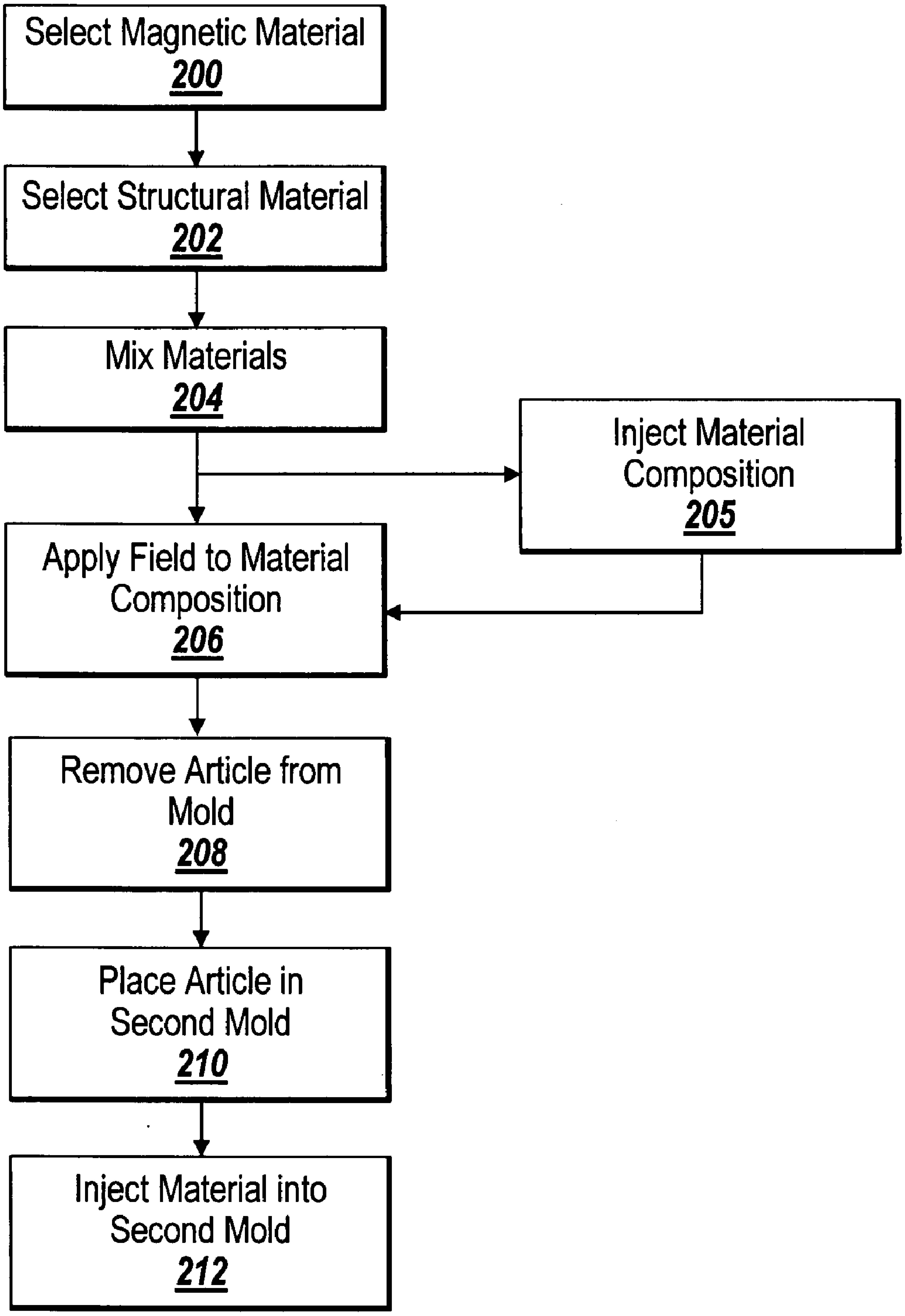

Select Magnetic Material
200
Select Structural Material
202
Mix Materials
204
Inject Material Composition
205
Apply Field to Material Composition
206
Remove Article from Mold
208
Place Article in Second Mold
210
Inject Material into Second Mold
212

Fig. 2

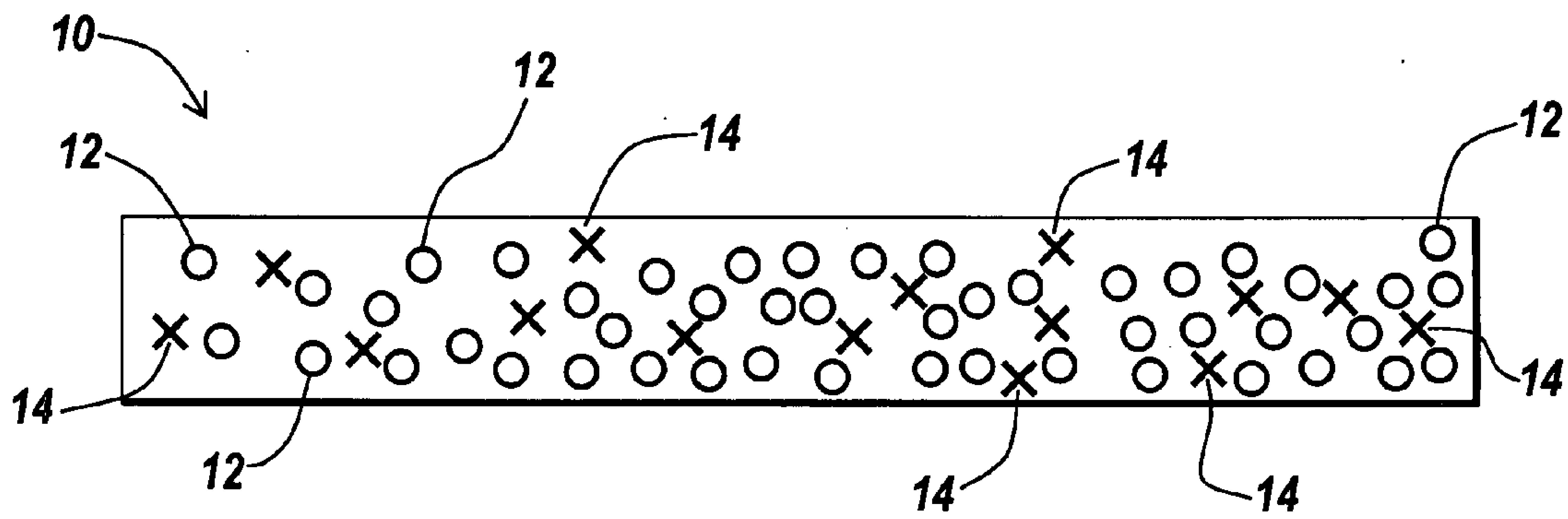

10
12
12
14
14
12
14
14
12
14
14
14

Fig. 3A

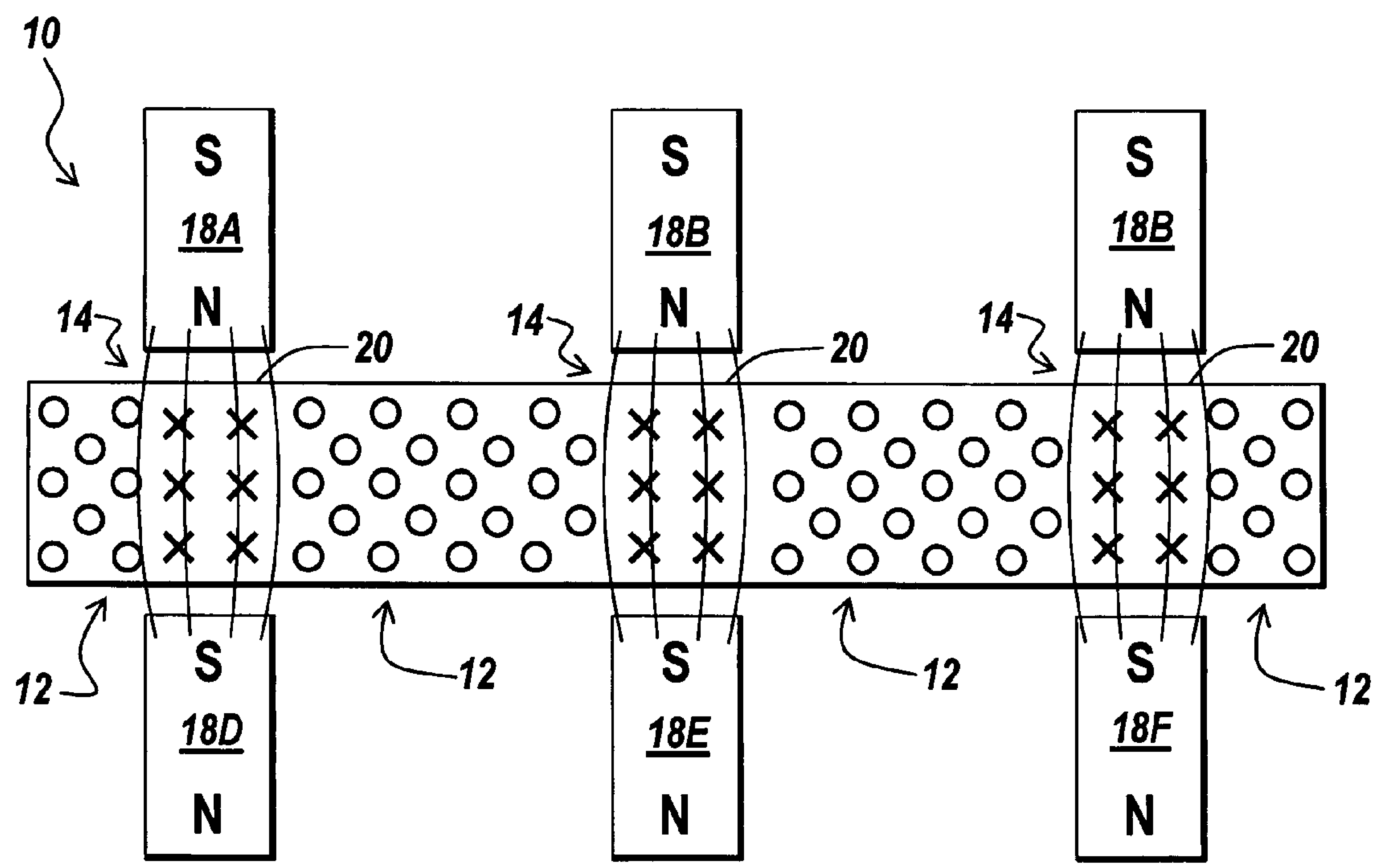
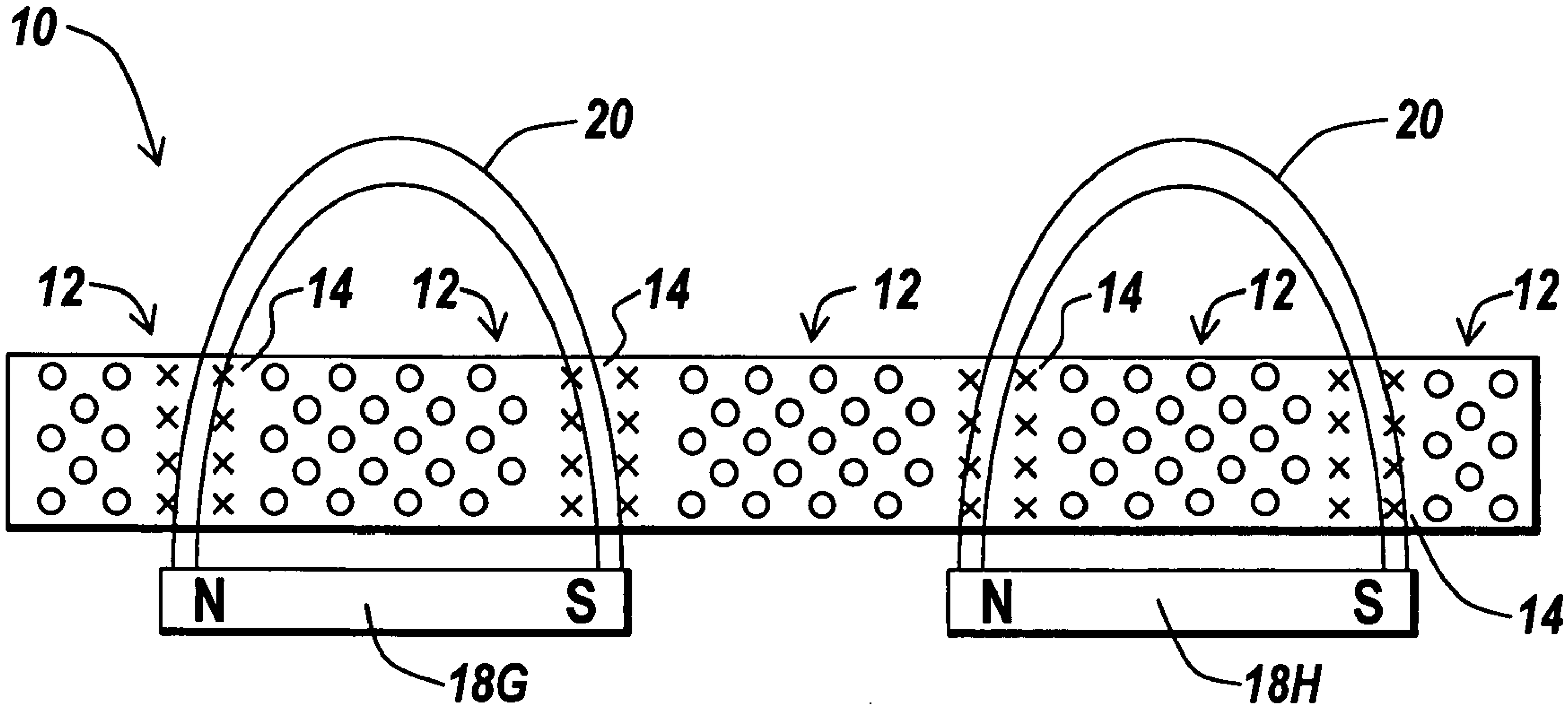

10
S
18A
N
S
18B
N
S
18B
N
14
20
14
20
14
20
12
12
12
12
S
18D
N
S
18E
N
S
18F
N

Fig. 3B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20
20
12
14
12
14
12
14
12
12
N
S
N
S
14
18G
18H

Fig. 3C

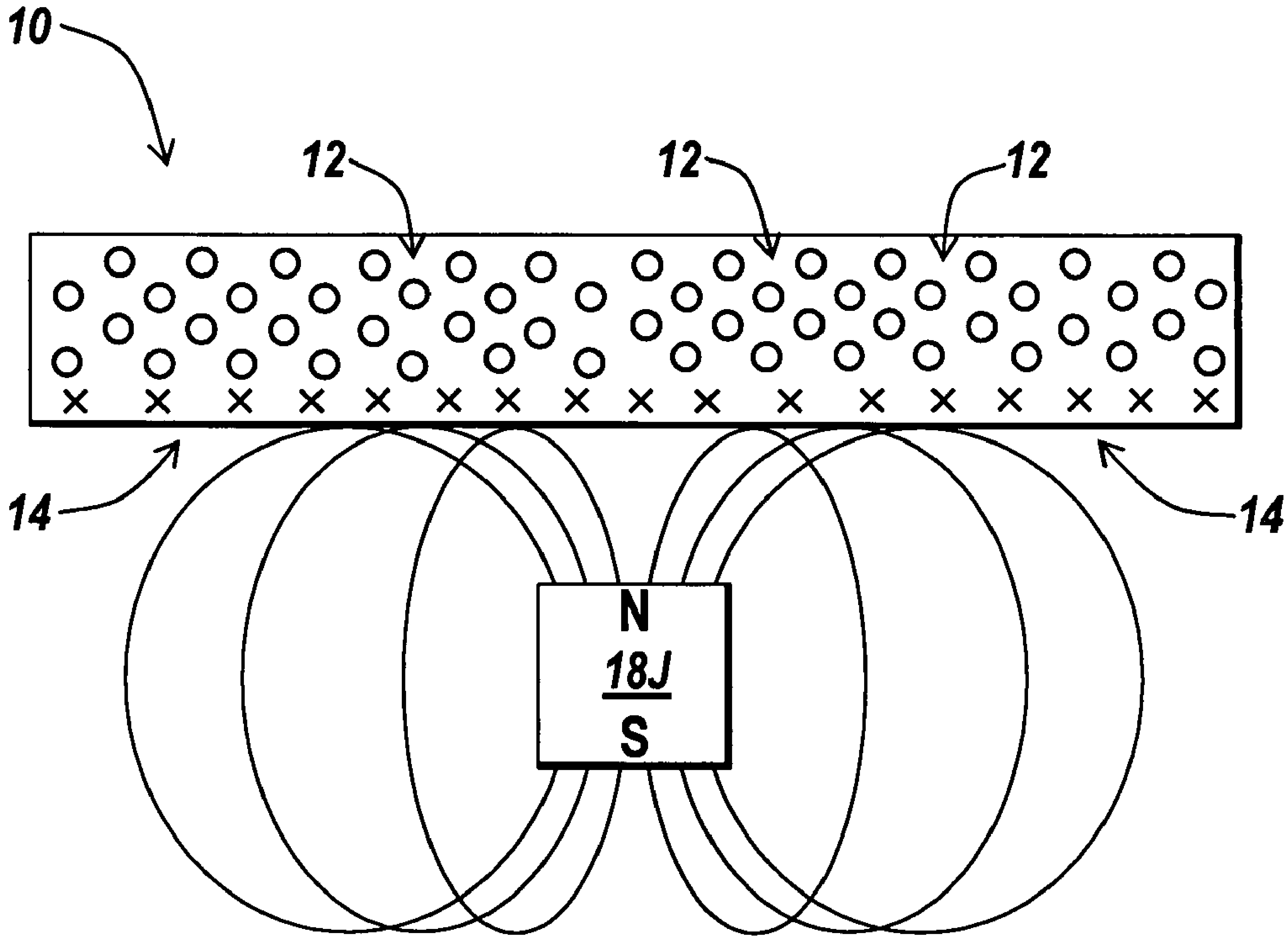
10
12
12
12
14
14
N
18J
S

Fig. 3D

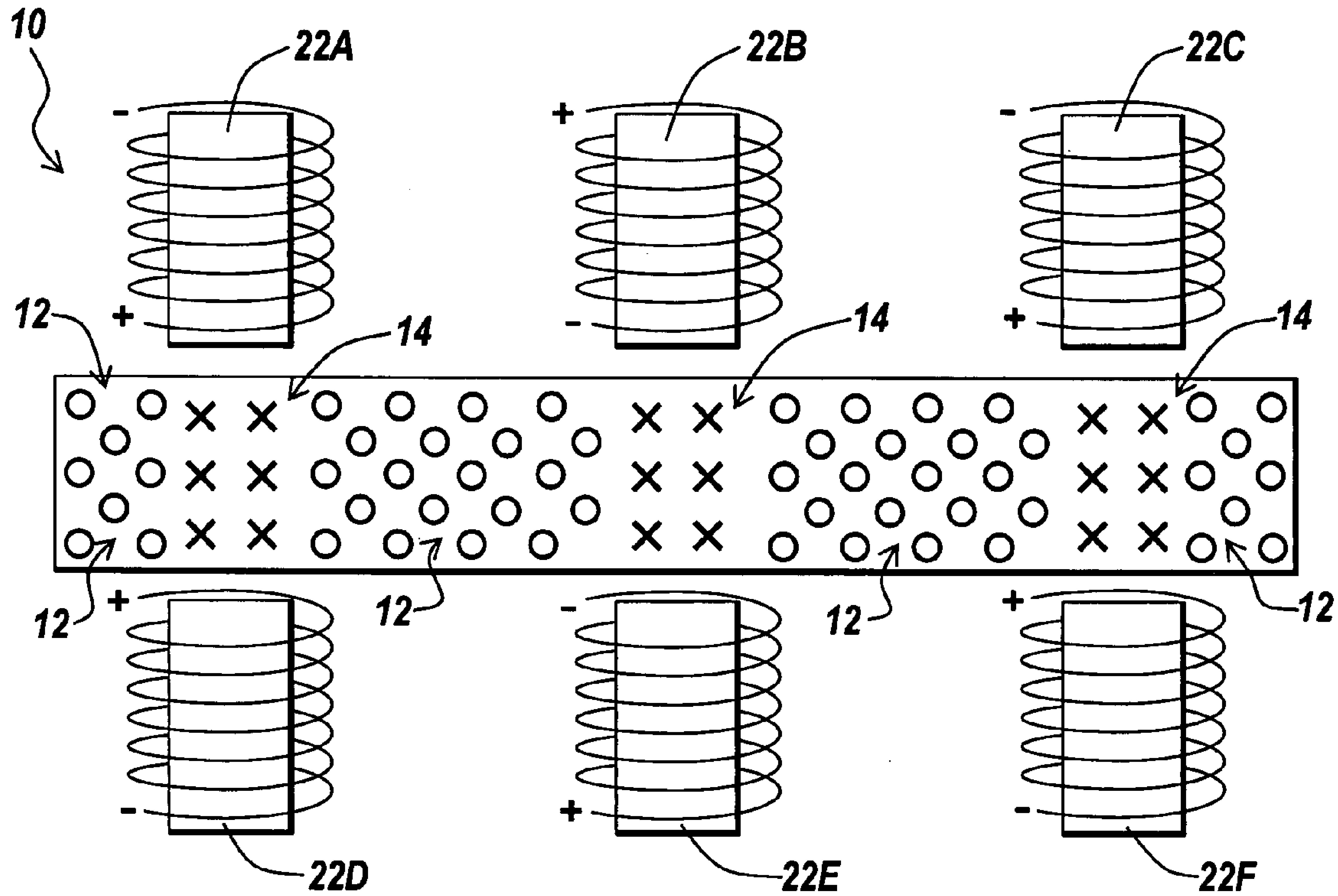
10
22A
22B
22C
-
+
-
+
-
+
12
14
14
14
12
12
12
12
+
-
+
-
+
-
22D
22E
22F

Fig. 3E

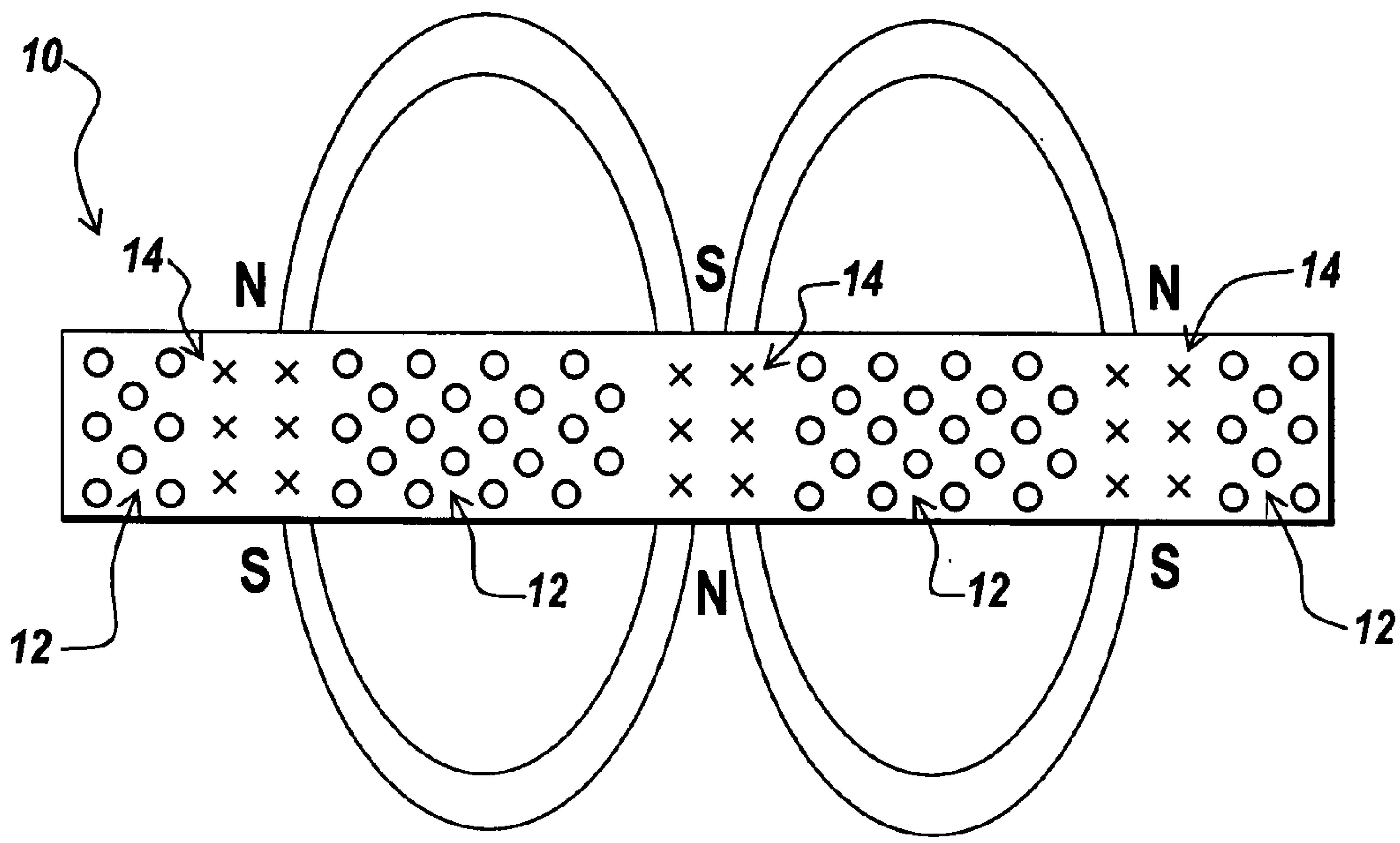
10
14
N
S
14
N
14
S
N
S
12
12
12
12

Fig. 3F

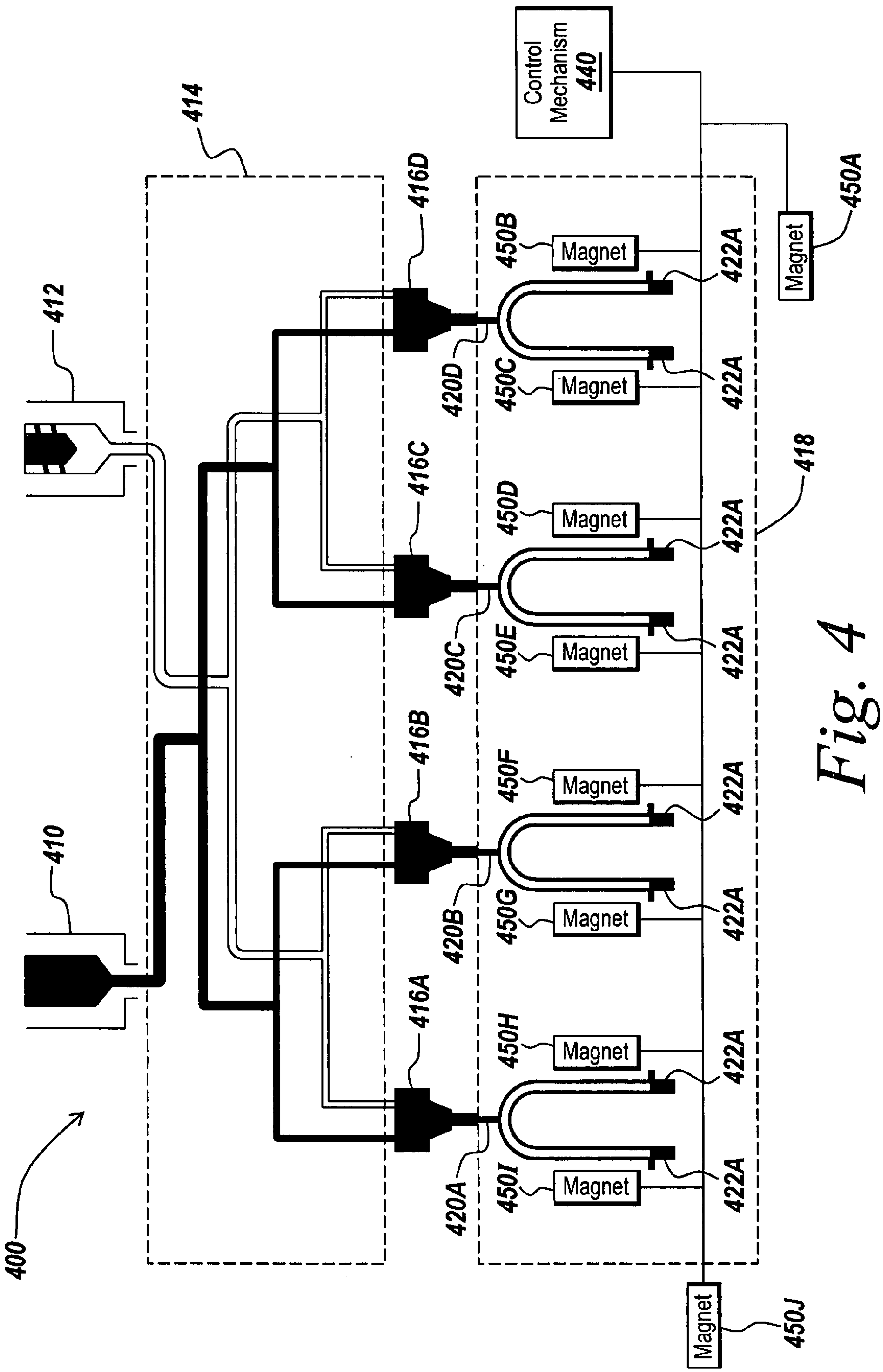
400
410
412
414
416A
416B
416C
416D
418
420A
420B
420C
420D
422A
Control Mechanism 440
Magnet
450A
450B
450C
450D
450E
450F
450G
450H
450I
450J

Fig. 4

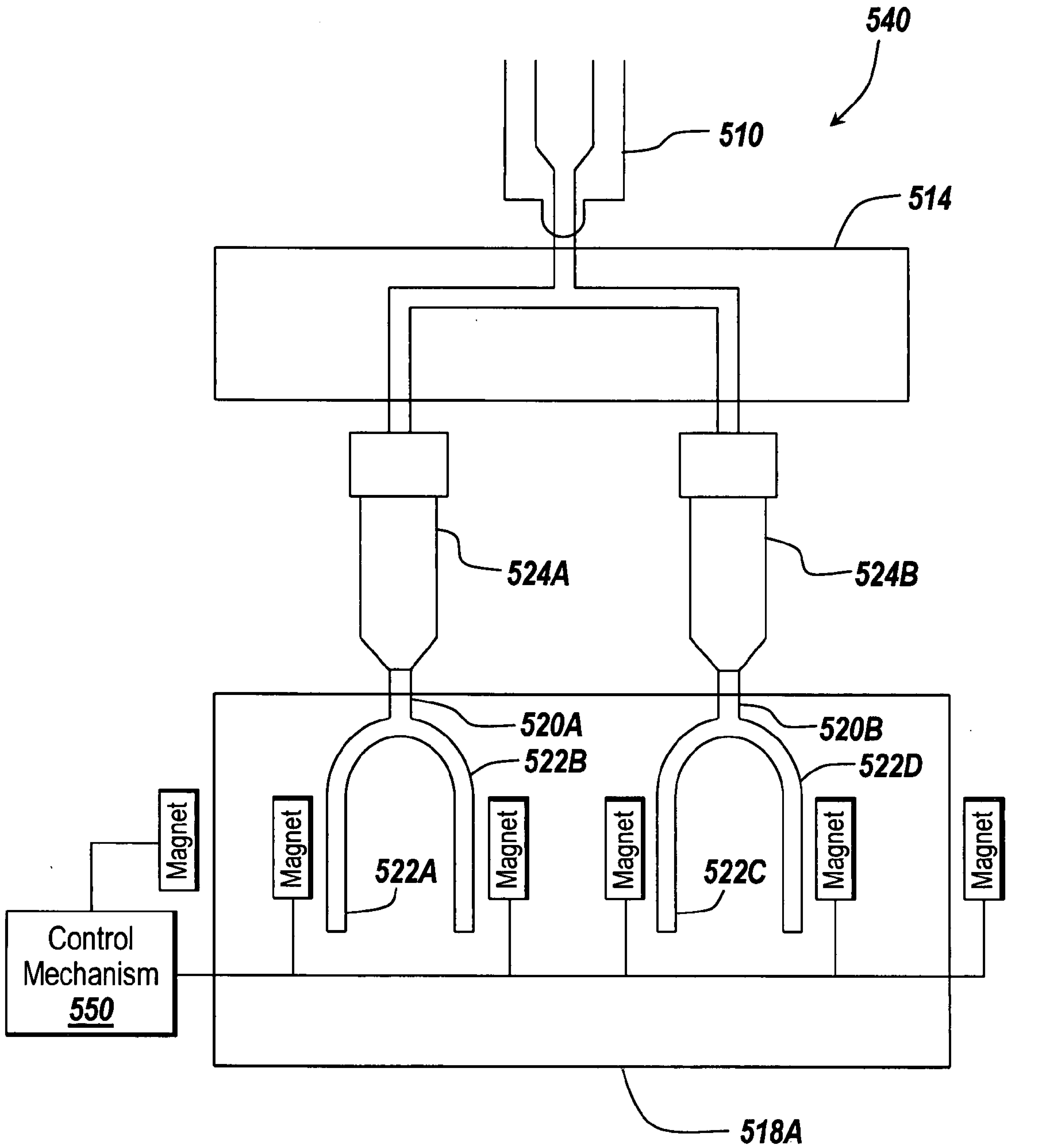
540
510
514
524A
524B
520A
522B
520B
522D
Magnet
Magnet
522A
Magnet
Magnet
522C
Magnet
Magnet
Control Mechanism 550
518A

Fig. 5

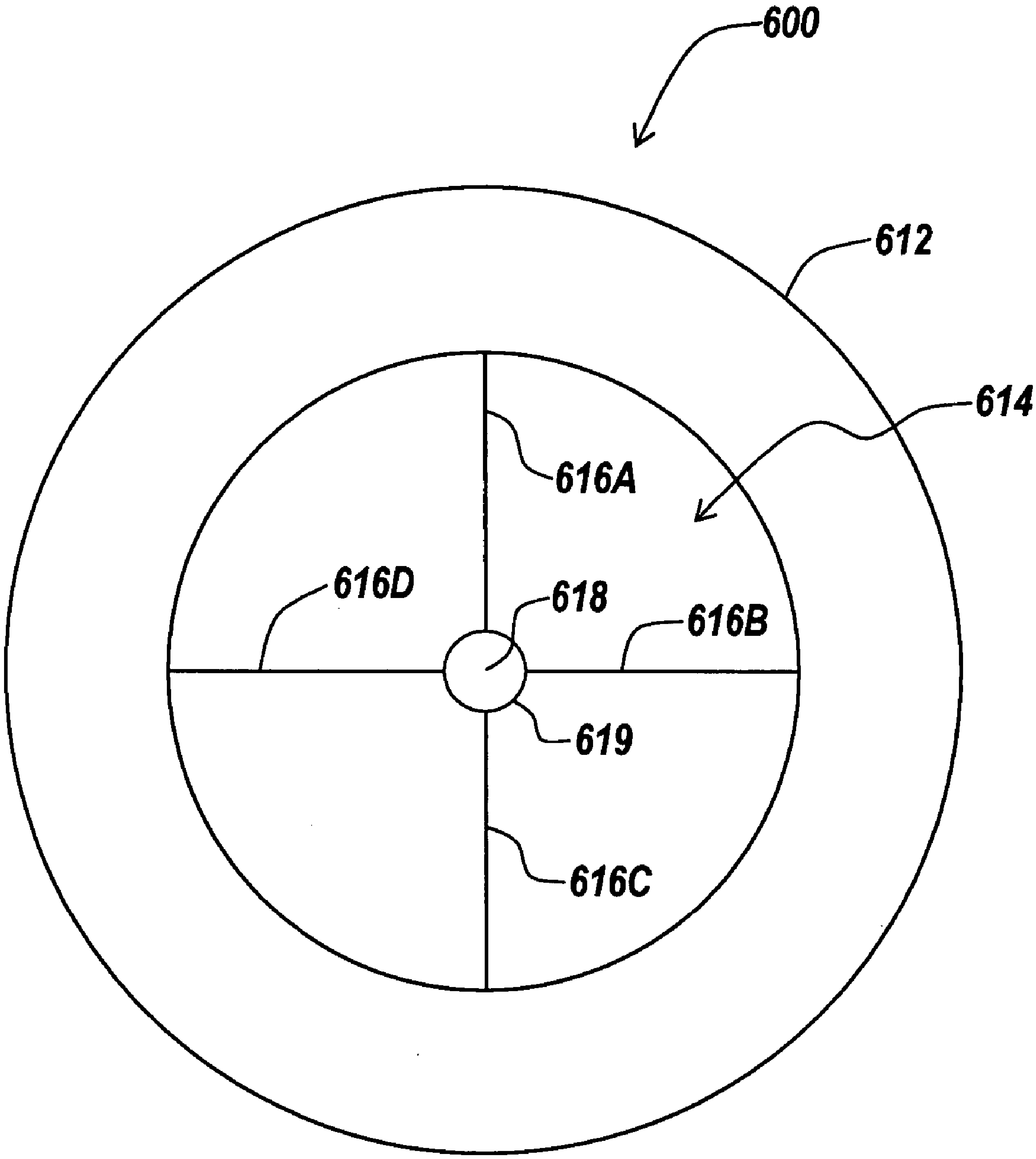

Fig. 6

MAGNETIC COMPOSITES

RELATED APPLICATIONS

[0001] This application claims priority to Provisional Application Ser. No. 60/838,737, filed Aug. 18, 2006, the contents of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to magnetic material composites. More particularly, the present invention relates to structural magnetic composites and illustrative methods and processes to form the same.

BACKGROUND OF THE INVENTION

[0003] Conventionally, magnets are formed by sintering or bonding compounds to form a magnet. Once formed, these magnets are attached to a mechanical element or member by a variety of methods, including mechanical fasteners, adhesives, lamination, or other means of affixation known in the art. The affixing of the magnets to the mechanical element is often to provide structural support to the magnet in order to overcome structural deficiencies in the magnetic material. The mechanical component, affixed through such conventional methods, may thus provide structural support for the magnet. The added structural support enables the magnet to support or resist one or more loads in order to perform a desired task or tasks, or to protect the magnet from breakage, degradation, oxidation and/or perform other functions.

[0004] In a process of forming a magnet through sintering, a compound to be magnetized is heated to align the molecules of the compound, optimizing polarity. A drawback to such conventional magnet manufacturing processes is that sintered magnets tend to be brittle, and often break if machined or attached to a structural element by mechanical means.

[0005] In a conventional bonding process for manufacturing a magnet, a compound to be magnetized is mixed with a bonding agent, such as an epoxy, a polymeric material, or the like, at an approximate weight ratio of magnetizable matter to bonding agent of between about 80:20 and about 98:2. In such a process, the magnetizable matter tends to be uniformly dispersed through out the bonding agent once cured. As a result, conventionally bonded magnets often have a relatively weak magnetic field due to the dispersion of the magnetizable matter substantially through out the cured bonding agent.

[0006] Other processes designed to overcome structural inadequacies of magnets include plating, laminating and coating, which often have the same deficiencies of sintered magnets and conventionally bonded magnets. Conventional bonded magnets also have limitations on how the evenly distributed magnetic material can be magnetized into complex pole patterns.

[0007] Despite known conventional techniques, magnetic components created using existing processes are limited due to required methods of attachment to substructures for structural support, and are often limited by the need for additional manufacturing steps and processes. Additionally, known conventional techniques often use or distribute magnetic materials inefficiently.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention provides new magnetic material composites and illustrative methods and processes to form the same that overcome deficiencies in the prior art. These magnetic material composites of the illustrative embodiment of the invention provide the desired properties of magnets having sufficient magnetic strength without the conventional structural limitations. Additionally, the magnetic material composites have the beneficial properties of other composites such as epoxies, plastics, and other like composites. The resulting magnetic material composites have a concentration of magnetic material in one or more portions. As a result, the interstitial spacing of the magnetic material in the magnetic material composite is significantly reduced, as compared to conventionally bonded magnets, to improve the magnetic field strength thereof. Additionally, the magnetic material composites of the present invention may be moldable, formable, machinable, shapeable or otherwise workable into any desired shape or form. The present invention advantageously allows formation of monolithic magnetic material composites having a desired shape, weight, thickness, and magnetic properties.

[0009] The use of magnetic material composites in accordance with the teachings of the present invention may reduce the number of parts required to manufacture a motor, a generator or other article of manufacture containing a magnet or magnets. Additionally, magnetic material composites formed in accordance with the teachings herein may reduce the steps involved in assembly processes, and result in monolithic chemically bonded structures capable of providing desired properties of magnets and structural properties of other composites including epoxies, paints, and coatings. The magnetic material composites as taught herein use materials more efficiently, providing superior material control and reduced waste within manufacturing processes. That is, the magnetic material composites and methods of formation of magnetic material composites as taught herein avoid the need for additional processing to attach a substructure for mechanical support and may reduce the amount of magnetic material needed to form bonded magnets utilized therein.

[0010] Uses for magnetized material composites as taught herein include electric motors and generators, bearings, filters, fans, pumps, paints, coatings, nano-impregnation processes and many other like structures, functions and operations having or involving magnets known in the art.

[0011] In one aspect of the present invention, a magnetic material composite is provided. The magnetic material composite is formed from a first structural material a magnetic material and a second structural material. The first structural material essentially encapsulates the magnetic material to form the magnetic material composite, and the magnetic material composite has one or more portions containing the magnetic material and one or more portions substantially free of the magnetic material. The second structural material essentially encapsulates the first structural material and the magnetic material. The magnetic material composite may be able to withstand structural loads without being fastened or joined to a substructure for structural support.

[0012] In another aspect of the present invention, a mold having one or more cavities for formation of a molded article is disclosed. A magnetic field generator associated with the mold is configured to generate one or more discrete magnetic fields in the mold. One or more control mechanisms associated with the mold is programmed to control duration and strength of any magnetic fields applied to the mold via the magnetic field generator. The magnetic fields applied to the mold facilitate formation of an article from a magnetic material composite having a magnetic material and a structural material.

[0013] In one aspect of the present invention, an article of manufacture is disclosed. The article of manufacture includes one or more mechanical elements formed from a magnetic material composite having a magnetic material and structural material. The magnetic material composite has one or more portions with an aggregation of the magnetic material and one or more portions substantially free of the magnetic material.

[0014] In another aspect of the present inventions, a method of manufacturing an article is disclosed. The method includes the steps of selecting a magnetic material and selecting a structural material. The method includes the step of mixing the magnetic material and the structural material to form a material composite having one or more portions containing an aggregation of the magnetic material and one or more portions substantially free of the magnetic material.

[0015] According to another aspect of the invention, a method of manufacturing an article of manufacture comprises the steps of providing a magnetic material composite having a magnetic material and another material, and causing the magnetic material to migrate within the magnetic material composite and aggregate in at least one portion of the magnetic material composite, such that at least one portion of the magnetic material composite is substantially free of the magnetic material.

[0016] In still another aspect, a method of manufacturing an article of manufacture comprises the steps of providing a magnetic material composite having a structural material and a magnetic material, wherein the magnetic material composite includes at least one portion containing the magnetic material and at least one portion substantially free of the magnetic material, and magnetizing the magnetic material.

[0017] According to still another aspect, a molding system is provided. The molding system comprises a working material source, a mold having a cavity, a distribution means for distributing a working material from said working material source to the cavity of the mold and at least one magnet for applying a magnetic field to the cavity of the mold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The foregoing and other objects, features and advantages of the invention will be apparent from the following description and apparent from the accompanying drawings in which like reference characters refer to the same parts through-out the different views. The drawings illustrate principles of the invention, and although not to scale, show relative dimensions.

[0019] FIGS. **1**A and **1**B is an exemplary drawing depicting formation of a magnetic material composite in accordance with an illustrative embodiment of the present invention.

[0020] FIG. **2** is an exemplary block flow diagram depicting the steps involved in the formation of a magnetic material composite in accordance an illustrative embodiment of the present invention.

[0021] FIG. **3**A is an exemplary diagram depicting a magnetic material composite of the present invention with the magnetic material substantially dispersed through out the structural material.

[0022] FIG. **3**B is an exemplary block diagram of a magnetic material composite, depicting migration and aggregation of magnetic material in a structural material according to an embodiment of the invention.

[0023] FIG. **3**C is another exemplary block diagram of a magnetic material composite of an illustrative embodiment of the invention, depicting migration and aggregation of a magnetic material in a structural material in accordance with the teachings of the present invention.

[0024] FIG. **3**D is another exemplary block diagram of a magnetic material composite, depicting migration and aggregation of a magnetic material in a structural material in accordance with the teachings of an illustrative embodiment of the present invention.

[0025] FIG. **3**E is an exemplary block diagram depicting magnetization of a magnetic material in a structural material forming a magnetic material composite according to an illustrative embodiment of the invention.

[0026] FIG. **3**F is an exemplary block diagram depicting magnetic fields of a magnetic material in the structural material of a magnetic material composite in accordance with an illustrative embodiment of the invention.

[0027] FIG. **4** is an exemplary block diagram of a co-injection system suitable for use in accordance with the teachings of the present invention.

[0028] FIG. **5** is an exemplary block diagram depicting an injection system suitable for use in accordance with the teachings of the present invention.

[0029] FIG. **6** is an exemplary diagram of a rotational apparatus formed in whole or part from a magnetic material composite as taught by an illustrative embodiment of the present invention.

DETAILED DESCRIPTION

[0030] The present invention discloses a structural magnetic composite, as well as methods and devices for forming the same. The present invention will be described below relative to certain illustrative embodiments. Those skilled in the art will appreciate that the present invention may be implemented and executed in a number of different applications and embodiments and is not specifically limited to the particular embodiments depicted herein.

[0031] The structural magnetic composite of the illustrative embodiments of the invention may advantageously have one or more portions with a concentration of magnetic material and one or more portions with little or no magnetic particles. The ability to concentrate the magnetic material in the structural magnetic composite allows shaping of a magnetic field and shaping of a magnetic field strength while minimizing an amount of magnetic material, and allowing a structure formed from the structural magnetic composite to withstand forces applied to the structure or a component of the structure without the need to fasten the structure to a substructure for structural support.

[0032] A structural magnetic composite according to the present invention includes a first structural material, such as an epoxy, plastic, or similar polymeric substance, a magnetic material, such as a magnetic particle(s), magnetizable particle(s), a magnetic compound, a magnetizable compound and/or a magnetic nano-particle(s) and a second structural material, such as an epoxy, plastic, or similar polymeric substance molecularly compatible with the first structural material. The magnetic material is introduced to and mixed with the first structural material, preferably while the first structural material is at least partially in a fluid medium phase, such that the magnetic material is held in suspension within the fluid medium phase of the first structural material in a largely encapsulated form. In turn, once the composite of the first structural material and the magnetic material reach a gel phase, the second structural material is added to adhere or bond to the first structural material and the magnetic material. The second structural material essentially encapsulates the first structural material and the magnetic material or may adhere or bond to one or more selected surfaces thereof. In some embodiments of the present invention, the weight ratio of magnetic material to structural material in the resulting magnetic material composite is between about 80:20 and about 98:2.

[0033] In some embodiments of the present invention, a first structural material and a magnetic material are admixed and one or more magnetic fields are applied to the admixed materials to cause the magnetic particles or compound(s) of the magnetic material migrate and aggregate in a desired manner in one or more portions of the magnetic material composite before the structural material cures. Then, prior to the curing of the first structural material, for example, at or near the beginning of a gel phase or at anytime prior to the gel phase entering a solid phase or state, a second structural material of the same or like type is adhered to or bonded to the magnetic material composite in whole or in part to form an article. The a second structural material has a molecular structure compatible with the first structural material

[0034] To facilitate explanation of the present invention, the term "magnetic material" as used herein includes a magnetic particle or particles, a magnetizable particle or particles, a magnetic compound, a magnetizable compound, a magnetic or magnetizable nano-particle or nano-particles, and combinations thereof. The term "magnetic material" is not meant to be limited to a material that exhibits a magnetic moment in the absence of an external magnetic field and includes materials that exhibit a magnetic moment in the presence of an external magnetic field.

[0035] As used herein, a "magnetic material composite" and "magnetic material composition" refers to a composite material comprising at least a magnetic component and another component.

[0036] As used herein, a "structural magnetic composite" refers to a composite material comprising at least a magnetic component and a structural component.

[0037] As used herein, the terms "structural magnet", "structural magnets" and the like refer to a monolithic article of manufacture having a composition and structure to support and resist one or more loads (i.e., forces applied to the article of manufacture), having a magnetic moment in one or more portions thereof, and having one or more portions free of or substantially free of magnetic material admixed with a structural component or material during formation of the monolithic article of manufacture.

[0038] As used herein, the term "magnetic particle" or "magnetic compound" refers to a ferromagnetic material or compound that exhibits a magnetic moment in the absence of an external magnetic field. Examples of a magnetic material include, but are not limited to iron, cobalt, nickel and the like iron oxide, ferrites of cobalt, zinc and similar known metals frequently used in powder.

[0039] As used herein, the term "magnetizable particle" or "magnetizable compound" refers to a metallic particle or a compound that becomes magnetized in the presence of an external magnetic field.

[0040] As used herein, the term "magnetic nano-particle" refers to a particle having a size in any dimension from about 1 nm to about 100 nm.

[0041] As used herein, the term "structural material" refers to a material having a composition and structure to support and resist one or more loads (i.e., forces applied thereto).

[0042] As used herein, the term "stratify" refers to the formation or arrangement of a material, such as a magnetic material, into one or more layers or spatial distributions.

[0043] To form a magnetic material composite in accordance with an illustrative embodiment of the present invention, the magnetic material may be uniformly distributed and admixed throughout a material, such as a first structural material. Preferably, the first structural material is in a fluid, for example, liquid, medium phase when mixed with the magnetic material. The magnetic material is then stratified to form a layer or layers of magnetic material in or on the first structural material or to form different spatial distributions of the magnetic material in or on the first structural material. Then, once the first structural material and the magnetic material have sufficiently gelled, but not fully cured, a second structural material of the same or like type is adhered to or bonded to the composite of first structural material and magnetic material.

[0044] In some embodiments, a catalyst may be introduced to the then-fluid first structural material to facilitate hardening. In some embodiments, a catalyst may be introduced to the then-fluid second structural material added to the gel phase of the composite first structural material and magnetic material to facilitate hardening. Additionally, during the fluid phase of the first structural material or the second structural material, the material may be used in a molding or other formation process to form an article of manufacture. Such molding or formation processes may include injection, rotary or other molding process, application as a resin in a fiberglassing process, roll formation, sheet formation, and other such methods known in the art. An electric current or magnetic field may then be introduced through the mold or form such as to cause the magnetic material mixed with the structural material to migrate and aggregate in a desired manner in one or more portions of the magnetic material composite before the structural material cures.

[0045] In turn, the composite of the first structural material and magnetic material may be removed from the mold during the gel phase of the cure process and placed in a second mold or form. The second structural material of the same or like type as of the first structural material is added to the second mold or form and allowed to bond or adhere to the article formed from the first mold to form the structural material of the present invention.

[0046] Once the structural material has cured, one or more portions of the magnetic material composite is thus free or substantially free of the magnetic material admixed to the first structural material component of the formed article. Further, once the magnetic material has migrated, aggregated and aligned, an electric current or magnetic field may then be introduced to the material to magnetize the magnetic material, if not yet magnetized, thereby creating a magnet or structural magnet that overcomes conventional structural limitations.

[0047] Alternatively, the fluid medium phase of the magnetic material composite, comprising the first structural material and the magnetic material, may be combined with a hardening catalyst (if needed) and applied to a surface, such as in a fiberglassing process, a coating process and other processes known in the art. Once applied to the surface, an electric current or magnetic field may then be introduced to the surface to cause the magnetic material to migrate and aggregate in a desired manner in one or more portions of the structural-magnetic material composite before the material cures. Once the structural-magnetic material composite has cured, one or more portions of the material is free or substantially free of the magnetic material admixed to the structural material component on the coated surface. Further, once the magnetic material has migrated, aggregated and aligned, an electric current or magnetic field may then be introduced to the material to magnetize the magnetic material, if not yet magnetized or to align the molecular orientation of the structural material.

[0048] By controlling the application of the electric current, the magnetic field, or both to the composite, it is possible to align the magnetic moments of the magnetic material to stratify disposition of the magnetic material during the fluid medium phase of the structural material to form different layers or spatial distribution in the magnetic material composite with different magnetic properties and to align the molecular orientation of the structural material. Thus, the magnetic material may be aligned in a desired direction, in a desired portion or portions of the article, on the surface of an article or combinations thereof.

[0049] The above processes can be used for a structural material that comprises an epoxy, polymer, or similar material known in the art, and with a hardening process that may include the use of an introduced hardener catalyst. The above processes can be used with a variety of curing processes, such as, but not limited to, electrical induction curing, temperature curing, and other processes known in the art.

[0050] The resulting articles of manufacture, when removed from the form or mold, have a structural shape and size as (by way of example) rotor arrays, stator arrays, rotor/impeller arrays, and other like structural components. Likewise, the resulting coated surfaces once cured require little or no finishing and may act as a structural element or a protective layer. In addition, the forming processes may be combined with other fabrication processes, such as the embedding of other components in or around the structural composite material to create parts with additional components such as winding coils, and the like.

[0051] FIGS. **1**A and **1**B illustrate an illustrative magnetic material composite **10** taught by the present invention. The magnetic material composite **10** comprises a first structural material **12**A, a magnetic material **14** and a second structural material **12**B. The first structural material **12**A and the magnetic material **14** may be admixed to first form a preform magnetic material composite **10**A. In turn the second structural material **12**B is adhered to or bonded to the preform magnetic material composite **10**A to form the magnetic material composite **10**. The structural materials may comprise any suitable polymeric material having a composition to support and resist one or more loads (i.e., forces applied thereto). Short chain polymers are preferred for use in the structural material **12**A of the illustrative embodiment of the invention, although long chain polymers may also be used in the structural material **12**A. Short chain polymers are preferred for use in the structural material **12**B of the illustrative embodiment of the invention, although long chain polymers may also be used in the structural material **12**B. The magnetic material **14** may include particles, materials and/or compounds that exhibit a magnetic moment in the absence of an external magnet field and/or particles, materials, and/or compounds that exhibit a magnetic moment in the presence of an external magnetic field.

[0052] The illustrative preform magnetic material composite **10**A and magnetic material composite **10** may be formable into a number of shapes, dimensions and sizes. The illustrative magnetic material composite **10** is well suited for use as one or more elements in a pump, a motor, a turbine or any other article or manufacture that may include one or more magnets. The illustrative magnetic material composite **10** facilitates formation of monolithic mechanical members having structural support monolithically integrated therein to allow the magnetic material composite **10** to resist one or more loads without an additional substructure and having one or more magnetic properties. Beneficially, the illustrative magnetic material composite **10** may have a number of desired structural properties and magnetic properties tailored to a particular application. The illustrative magnetic material composite **10** avoids the drawbacks of mechanically fastening magnets to a substructure for structural support. Additionally, the illustrative magnetic material composite **10** avoids the drawbacks of conventionally bonded magnets, as the magnetic material composite **10** has one or more portions free or substantially free of the magnetic material **14** and one or more portions in which the magnetic material **14** is aggregated and aligned in a desired fashion.

[0053] To obtain a desired magnetic property of the magnetic material composite **10**, a magnetic field, an electric field, or a combination of both a magnetic field and an electric field are applied to the magnetic material composite **10** in a state that allows the magnetic material **14** to migrate and aggregate in the first structural material **12**A, thereby achieving a desired magnetic property and, to, when desired, align the molecular orientation of the structural material. For example, a magnetic field, an electric field or a combination of both may be applied to the magnetic material composite

10 to stratify the magnetic material 14 into one or more layers or one or more spatial distributions. In another example, a magnetic field, an electric field or a combination of both may be applied to the preform magnetic material composite 10A before it cures to cause the magnetic material to migrate and aggregate near a surface of, for example, a cavity in a mole or the surface of an object coated with the magnetic material 14 and the first structural material 12A. The magnetic material composite 10 is well suited for use in a lamination process, such as with fiberglass, carbon fiber and the like. Additionally, the magnetic material composite 10 may be used to form an object or article of manufacture with a vacuum bagging process. A vacuum bagging process provides both pressure and vacuum to facilitate cure of the magnetic material composite 10 by compacting the material composite, providing good consolidation and interlaminar bond and drawing out trapped air and other gases to result in a low void content.

[0054] The magnetic material composite 10 may maintain a liquid form or a partially liquid form or gel until cured, at which time a phase transition is complete and the magnetic material composite 10 becomes a solid.

[0055] A catalyst 16 may be added with the first structural material 12A and/or the magnetic material 14 of the magnetic material composite to accelerate a chemical reaction of the compounds or materials forming the first structural material 12A.

[0056] The first structural material 12A may take the form of a powder, a liquid or a combination of a powder and a liquid. Likewise, the magnetic material 14 may take the form of a powder, a liquid, a powder suspended in a liquid and combinations thereof.

[0057] In some embodiments of the present invention, the first structural material 12A and the magnetic material 14 initially forms a colloidal dispersion. That is, the particles or droplets of the magnetic material 14 are distributed evenly throughout the first structural material 12A before an electric or magnetic field is applied to cause the magnetic material 14 to migrate and aggregate in one or more portions of the perform magnetic material composite 10A. In some embodiments the size of dispersed particle are between 1 nm and 1000 nm in at least one dimension. Once the particles or compounds of the magnetic material 14 are sufficiently dispersed in the first structural material 12A a magnetic field, an electric field or a combination of both is applied to the perform magnetic material composite 10A to cause the magnetic material 14 to migrate and aggregate in a desired area, position, layer and the like of the preform magnetic material composite 10A prior to cure thereof.

[0058] The preform magnetic material composite 10A may have a viscosity that allows the preform magnetic material composite 10A to be applied to a surface of an object similar in manner to paint or a coating such that the preform magnetic material composite 10A bonds to a surface of the object. Once the preform magnetic material composite 10A is applied to a surface of an object as a coating or a paint, a magnetic field, an electric field or a combination thereof may be applied to cause the magnetic material 14 to migrate and aggregate into a desired shape or pattern before the preform magnetic material composite 10A sufficiently bonds to a surface of the object. That is, the magnetic material 14 may be caused to migrate and aggregate to from a protective surface for the object. In turn, the preform magnetic material 10A may be coated or bonded to a layer of the second structural material 12B.

[0059] FIG. 1B illustrates the second structural material 12B is adhered or bonded to a portion of the first structural material 12A. The second structural material 12B may essentially encapsulate the first structural material 12A and in turn the magnetic material 14 or may adhere or bond to a limited surface area of the first structural material 12A. The second structural material 12B is molecularly compatible with the first structural material 12A. The second structural material 12B may comprise any suitable polymeric material having a composition to support and resist one or more loads (i.e., forces applied thereto). Short chain polymers are preferred for use in the structural material 12B of the illustrative embodiment of the invention, although long chain polymers may also be used in the structural material 12B.

[0060] FIG. 2 illustrate steps taken to form a magnetic material composite 10 according to illustrative embodiments of the invention. FIG. 2 is discussed in relation to FIGS. 1, 3A, 3B, 3C, 3D, 3E and 3F.

[0061] Referring to FIG. 2, in step 200, a magnetic material 14 is selected. As discussed above the magnetic material 14 may be in the form of a powder, a flake, a solid of any sort, a liquid, a solid suspended in a liquid and other forms known in the art.

[0062] In step 202, a first structural material 12A is selected. As discussed above in relation to FIG. 1, the first structural material 12A may be a composite material, a polymeric material and/or other materials known in the art. The first structural material 12A may take a number physical forms including, but not limited to, a powder, a flake, and other solids, along with a liquid and particles suspended in a liquid and other materials known in the art. The first structural material 12A is preferably in a fluid phase form in an initial stage.

[0063] In step 204, the selected magnetic material 14 and the selected first structural material 12A are admixed to form the preform magnetic material composite 10A. FIG. 3A illustrates an exemplary admixed preform magnetic material composite 10A with the magnetic material 14 admixed in and substantially dispersed throughout the first structural material 12A, though one skill in the art will recognize that the magnetic material may be dispersed in any suitable manner.

[0064] In step 205, the admixed preform magnetic material composite 10A may be injected into one more cavities of a mold. In some embodiments, in step 205, the first structural material 12A and the magnetic material 14 are injected separately in a simultaneous fashion or nearly simultaneous fashion or in a sequential fashion or any combination thereof. In turn, in step 206 a magnetic field is applied to the one or more cavities of the mold to cause the magnetic material 14 to migrate and aggregate in a desired fashion according to the supplied magnetic field. FIGS. 4 and 5 depict exemplary systems and molds suitable for use in accordance with the teachings of the present invention.

[0065] In some embodiments, the admixing of the first structural material 12A and the magnetic material 14 occurs in one or more cavities of the mold. In some embodiments, the first structural material **12**A and the magnetic material **14** are added or co-injected into one or more cavities of the mold. In some embodiments, the first structural material **12**A and the magnetic material **14** are added or injected into one or more cavities of the mold in a sequential manner.

[**0066**] In step **206**, a field is applied to the preform magnetic material composite **10**A to cause the magnetic material **14** to migrate and aggregate in a desired manner in one or more portions of the preform magnetic material composite **10**A. As a result, the first structural material **12**A may essentially encapsulate or otherwise form a carrier material for the magnetic material **14**.

[**0067**] FIG. **3**B illustrates an exemplary application of a magnetic field to the preform magnetic material composite **10**A to cause the magnetic material **14** to migrate and aggregate in a desired pattern in one or more portions of the preform magnetic material composite **10**A. FIG. **3**B illustrates six magnets **18**A-**18**F. Each magnet **18**A-**18**F has a north pole and a south pole. The magnets **18**A-**18**F are placed in close proximity to the preform magnetic material composite **10**A while still in a state that allows migration and aggregation of the magnetic material **14**.

[**0068**] The magnets **18**A-**18**F generate magnetic fields **20**. The magnetic fields **20** developed between opposing magnets, i.e., **18**A and **18**B, **18**B and **18**E, and **18**C and **18**F to cause the magnetic material to migrate and aggregate in a desired manner in one or more portions of the preform magnetic material composite **10**A. In this illustrative example, the magnetic material **14** is stratified to form three layers of magnetic material within the preform magnetic material composite **10**A, though one skilled in the art will recognize that the magnetic material composite may have more or fewer than three layers of magnetic material therein. As a result, the layers of structural material between the layers of the magnetic material **14** may be free of or substantially free of the magnetic material **14**. The number of magnets illustrated is merely exemplary and any number of magnets may be used to achieve a desired distribution and alignment of the magnetic material **14** in the preform magnetic material composite **10**A.

[**0069**] Additionally, the magnets **18**A-**18**F may be used to align the magnetic material **14** to form an anisotropic magnet in the magnetic material composite **10**.

[**0070**] FIG. **3**C illustrates another embodiment of the present invention. In some embodiments, two magnets **18**G and **18**H are placed in close proximity to the preform magnetic material composite **10**A while the preform magnetic material composite **10**A is in a state suitable to allow the magnetic material **14** to migrate and aggregate therein. The magnetic field or fields generated by the magnets **18**G and **18**H cause the migration and aggregation of the magnetic material **14** relative to the first structural material **12**A. Additionally, the magnets **18**G and **18**H may be used to align the magnetic material **14** to form an anisotropic magnet in the preform magnetic material composite **10**A.

[**0071**] FIG. **3**D illustrates another exemplary embodiment of the present invention. In some embodiments, one magnet **18**J may be used to cause the magnetic material **14** to migrate and aggregate in a desired manner in one or more portions of the magnetic material composite **10**. For example, the magnet **18**J may cause the magnetic material **14** to migrate and aggregate along a surface and/or end portion of the preform magnetic material composite **10**A while the preform magnetic material composite **10**A is in a state that allows the magnetic material **14** to migrate and aggregate.

[**0072**] The number of magnets depicted in FIG. **3**B, **3**C, **3**D and **3**E are merely illustrative. Additional, magnets may be used as necessary to cause the magnetic material **14** to migrate and aggregate in a desired fashion in one or portions of the preform magnetic material composite **10**A.

[**0073**] As will be discussed in more detail in relation to FIG. **4**, the magnets **18**A-**18**J may be associated with one or more cavities of a mold to cause migration aggregation alignment of the magnetic material **14** in the preform magnetic material composite **10**A prior to cure thereof.

[**0074**] In some embodiments, additional steps may be taken once the magnetic field or electric field is applied to the preform material composite **10**A in step **206** of FIG. **2**. For example, the preform magnetic material composite **10**A once cured or at any time after the magnetic material **14** has migrated, aggregated and aligned in a desired fashion, may be again subjected to a magnetic field to magnetize the magnetic material **14**.

[**0075**] In step **208**, an article formed by steps **200** through **206** is removed from the mold while in a gel state or phase. In step **210**, the article may be placed in a cavity of a second mold. In step **212**A, a second structural material **12**B is selected and injected into the cavity of the second mold. In turn, the injected second structural material **12**B bonds to the surface of the preform material composite **10**A, preferably without additional preparation of the article. In some embodiments, the second structural material **12**B is molecularly compatible with the first structural material **12**A. Once the injected second structural material **12**B cures sufficiently, the article may be removed from the second mold.

[**0076**] FIGS. **3**E and **3**F illustrate exemplary embodiments of a magnetic material composite formed in accordance with the teachings of the invention, where the magnetic material **14** becomes magnetized in the presence of an external magnetic field after mixture and/or encapsulation with the first structural material **12**A. Electromagnets **22**A-**22**F may be used to magnetize the magnetic material **14** after magnets **18**A-**18**F have caused the magnetic material **14** to migrate and aggregate in a desired fashion in one or more portions of the preform magnetic material composite **10**A. FIG. **3**F depicts the magnetic field **24** and the magnetic field **14** of the preform magnetic material composite **10**A once magnetized by the electromagnets **22**A-**22**F. Those skilled in the art will appreciate the number of electromagnets **22**A-**22**F depicted in FIG. **3**E and the magnetic fields **24** depicted in FIG. **3**F is merely illustrative. The number of electromagnetic used to magnetize the magnetic material **14** of the preform magnetic material composite **10**A may be less than six or more than six and the strength of the magnetic field **24** may vary depending on the magnetic properties of the magnetic material **14** admixed with the first structural material **12**A.

[**0077**] Additionally, in some embodiments, the magnetic material may be magnetized prior to admixing with the first structural material **12**A.

[**0078**] FIG. **4** illustrates an exemplary system **400** suitable for practicing the present invention. The illustrated system is a co-injection molding system **400** that is configured to inject at least two materials into a mold cavity. Working materials suitable for use with the present invention include the magnetic material **14** and the first structural material **12**A, such as polymer based materials. The illustrative co-injection molding system **400** includes a first working material source **410**, a second working material source **412**A, and a distribution means **414**. The illustrative co-injection molding system **400** further includes nozzle assemblies **416**A-**416**D and mold **418**. Mold **418** includes gates **420**A-**420**D and cavities **422**A-**422**H. The cavities **422**A-**422**H have any suitable shape suitable for forming a structural magnet having a desired shape.

[**0079**] The illustrative co-injection molding system **400** includes a control mechanism **440** and magnets **450**A-**450**J. The magnets **450**A-**450**J may be permanent magnets, electromagnets or a combination of permanent magnets and electromagnets. The magnets **450**A-**450**J have an operation and a function similar to the magnets depicted in FIGS. 3B-3D. That is, the magnets **450**A-**450**J are used to apply a magnetic field to the preform magnetic material composite **10**A while in the cavities **422**A-**422**H to cause the magnetic material **14** to migrate and aggregate in a desired fashion in one or more portions of the preform magnetic material composite **10**A. Additionally, the magnets **450**A-**450**J may be used to align the magnetic material **14** to form one or more anisotropic magnets or to magnetize the magnetic material **14** or both. The magnets may have any suitable size, shape, number, arrangement and/or orientation suitable for the uses described above and are not limited to the illustrative embodiment.

[**0080**] The control mechanism **440** is preferably programmable and may include electronic and optical components and may include a central processing unit (CPU), memory, storage such a hard drive or optical drive, an input control, a modem, a network interface, a display and the like. The CPU is able to execute instructions and control the duration and the strength of the magnetic fields supplied by the magnets **450**A-**450**J. The CPU is able to execute instructions to also control field strength of a magnetic field supplied by the magnets **450**A-**450**J. Additionally, the CPU may control each component of the control mechanism **440** and may read or write to a memory such as instructions or data so that the control mechanism **440** can control the magnets **450**A-**450**J.

[**0081**] FIG. **4** illustrates a combination of magnets located within the mold **418** (i.e., magnets **450**B-**4501**) and magnets affixed to or adjacent to an exterior portion of the mold **450** (i.e., magnets **450**A and **450**J). In some embodiments of the present invention the mold **418** has only interior magnets, for example any of magnets **450**B-**450**I, placed in close proximity to each cavity in a mold. In some embodiments, the mold **418** may only have magnets located on an exterior surface or in close proximity to an exterior surface, for example, magnets **450**A and **450**J. In other embodiments, the mold **418** may have a combination of magnets located internally to the mold and magnets affixed to an external surface of the mold.

[**0082**] The number of magnets depicted both internal to the mold **418** and external to the mold **418** are merely illustrative and are meant to illustrate the principal that a magnetic field may be applied to the material injected into any of the cavities **422**A-**422**J to cause the magnetic material **14** to migrate, and aggregate in a desired fashion in one or more portions of the preform magnetic material composite **10**A while in the mold **418**. Additionally, any of the magnets **450**A-**450**J may be used to align the magnetic material **14** to form an anisotropic magnet in the preform magnetic material composite **10**A and, if desired, to magnetize the magnetic material **14**. The principals of migration, aggregation, alignment and magnetization are discussed above in relation to FIG. **2** and FIGS. **3**A-**3**D.

[**0083**] For the purposes of the discussion herein, the use of the term "distribution means" refers to a plurality of interconnected fluid carrying passages for distributing at least one fluid flow received from an inlet to one or more egresses. A distribution means can include a number of sets of manifold blocks or a number of sets of fluid carrying passages. Known terms of art, such as hot runner and manifold, are examples of a suitable distribution means.

[**0084**] The first working material source **410**, second working material source **412**A, and distribution network **414** cooperatively operate to deliver at least two working material streams to nozzle assemblies **416**A-**416**D upstream of gates **420**A-**420**D. Nozzle assemblies **416**A-**416**D combine the working material streams and feed gates **420**A-**420**D with a combined material stream for delivery to cavities **422**A-**422**H. In one embodiment, the first working material source **410** is the source of the first structural material **12**A and the second working material source **412**A is the source of the magnetic material **14**.

[**0085**] In one embodiment of the present invention, first and second working material sources **410** and **412**A are reciprocating screw injection units and distribution means **414** is a hot runner having separate flow channels for each working material and being arranged such that the material flow through each flow channel is balanced and equal.

[**0086**] FIG. **5** illustrates an exemplary system suitable for practicing the present invention. Injection molding system **540** is configured to inject one working material into a mold cavity. In some embodiments the magnetic material composite **10** is admixed prior to use in an injection molding system. In such embodiments, the injection molding system may include a single material source. Injection molding system **540** includes a working material source **510** and a distribution network **514**. Injection molding system **540** further includes nozzle assemblies **524**A, **524**B, and mold **518**. Mold **518** includes gate **520**A, gate **520**D, cavity **522**A, cavity **522**B and magnets **550**A-**550**F. The working material source **510** is the source for the preform magnetic material composite **10**A.

[**0087**] The injection molding system **540** includes a control mechanism **540** and magnets **550**A-**550**F. The magnets **550**A-**550**F may be permanent magnets, electromagnets or a combination of permanent magnets and electromagnets. The magnets **550**A-**550**F have an operation and a function similar to the magnets depicted in FIGS. **3**B-**3**D. That is, the magnets **550**A-**550**F are used to apply a magnetic field to the preform magnetic material composite **10**A while in the cavities **522**A-**522**D to cause the magnetic material **14** to migrate and aggregate in a desired fashion in one or more portions of the preform magnetic material composite **10**A. Additionally, the magnets **550**A-**550**F may be used to align the magnetic material **14** to form one or more anisotropic magnets or to magnetize the magnetic material **14** or both.

[0088] The control mechanism **540** is programmable and may include electronic and optical components and may include a central processing unit (CPU), memory, storage such a hard drive or optical drive, an input control, a modem, a network interface, a display and the like. The CPU is able to execute instructions and control the duration and the strength of the magnetic fields supplied by the magnets **550**A-**550**F. The CPU is able to execute instructions to also control field strength of a magnetic field supplied by the magnets **550**A-**550**F. Additionally, the CPU may control each component of the control mechanism **540** and may read or write to a memory such as instructions or data so that the control mechanism **540** can control the magnets **550**A-**550**F.

[0089] FIG. **5** illustrates a combination of magnets located within the mold **518**A (i.e., magnets **550**B-**550**E) and magnets affixed to or adjacent to an exterior portion of the mold **518**A (i.e., magnets **550**A and **550**F). In some embodiments of the present invention the mold **518**A has only interior magnets, for example, magnets **550**B-**550**E, which may be placed in close proximity to each cavity in a mold. In some embodiments the mold **518**A may only have magnets located on an exterior surface or in close proximity to an exterior surface, for example, magnets **550**A and **550**F. In other embodiments, the mold **518**A may have a combination of magnets located internally to the mold and magnets affixed to an external surface of the mold.

[0090] The number of magnets depicted both internal to the mold **518**A and external to the mold **518**A are merely illustrative and are meant to illustrate the principal that a magnetic field may be applied to the material injected into any of the cavities **522**A-**522**D to cause the magnetic material **14** to migrate and aggregate in a desired fashion in one or more portions of the preform magnetic material composite **10**A while in the mold **518**A. Additionally, any of the magnets **550**A-**550**F may be used to align the magnetic material **14** to form an anisotropic magnet in the preform magnetic material composite **10**A and, if desired, to magnetize the magnetic material **14**. The principals of migration, aggregation, alignment and magnetization are discussed above in relation to FIG. **2** and FIGS. **3**A-**3**D.

[0091] The working material source **510** and distribution means **514** cooperatively operate to deliver a working material stream to nozzle assemblies **524**A and **524**B upstream of gates **520**A and **520**B. Nozzle assemblies **524**A and **524**B feed gates **520**A and **520**B with a working material stream for delivery to cavities **522**A, **522**B and **522**C, **522**D, respectively.

[0092] The injection systems depicted in FIGS. **5** and **6** are well suited for use to inject the second structural material **12**B. That is, the injection systems depicted in FIGS. **5** and **6** are configurable to include additional material sources or the cavities of the mold may include removable inserts that allow the preform of magnetic material **10**A to be removed and then reinserted into the cavity for bonding to the second structural material **12**B to form the composite magnetic material **10**.

[0093] FIG. **6** illustrates an end view of an exemplary fluid movement apparatus **610** according to the teachings of the present invention. The fluid movement apparatus **610** may be a pump, a turbine, a fan, a motor having one or more elements, parts or components formed from the magnetic material composite **10**.

[0094] The fluid movement apparatus **610** includes a stator assembly **612**A and a rotatable element such as an impeller assembly **614**. The impeller assembly **614** includes a number of impeller blades **616**A-**616**D that extend radially from a center point **618**. The center point **618** represents the point about which the impeller assembly **614** rotates. The center point **618** may also be an axle or shaft having either mechanical bearings or magnetic bearings about which the impeller assembly **614** rotates. Those skilled in the art will appreciate the impeller assembly **614** is illustrated with four impeller blades merely for illustrative purposes and can include fewer than four impeller blades or more than four impeller blades depending on the application and use of the fluid movement apparatus **610**. Further, those skilled in the art will appreciate the impeller blades of the impeller assembly **614** can have a curved shape and be twisted depending upon the fluid material being handled and the application in which the fluid movement apparatus **610** operates.

[0095] In some embodiments, the impeller blades **616**A-**616**D are formed from the magnetic material composite **10**. In some embodiments, the stator assembly **612**A is formed from the magnetic material composite **10**. In some embodiments, the impeller blades **616**A-**616**D and the stator assembly **612**A are formed from the magnetic material composite **10**. Additionally, in some embodiments the impeller blades **616**A-**616**D form a rotor assembly having magnetic properties. An operational, functional and structural relationship of the fluid movement apparatus **610** is discussed in more detail in U.S. application Ser. No. 11/293,982, the content of which is incorporated herein by reference.

[0096] The various embodiments of the above described magnetic material composite are well suited for use in various industries such as boating, air handling, petroleum, chemical, pharmaceutical, medical, automotive, aeronautic, magnetic levitation, hydroelectricity and other commercial, residential and industrial applications.

[0097] While the present invention has been described with reference to illustrative embodiments thereof, one skilled in the art will appreciate that there are changes in form and detail that may be made without departing from the intended scope of the present invention as defined in the pending claims. For example, the magnetic material composite **10** may have a varying thickness, or may include additional materials such as adhesives to facilitate bonding of the material to a surface of an object.

What is claimed is:

1. A magnetic material composite, comprising:

a first structural material,

a magnetic material admixed with the structural material to form the magnetic material composite, and

a second structural material molecularly compatible with the first structural material,

wherein the first structural material essentially encapsulates the magnetic material and the second magnetic material essentially encapsulate the first structural material and the magnetic material composite has at least one portion of the first structural material containing the magnetic material and at least one portion of the first structural material substantially free of the magnetic material.

2. The magnetic material composite of claim 1, wherein the structural material comprises a polymeric material.

3. The magnetic material composite of claim 1, wherein the magnetic material comprises at least one of: a magnetic particle, a magnetizable particle, a magnetic compound, a magnetizable compound, a magnetic nano-particle, a magnetizable nano-particle, a magnetic nano-particle compound, a magnetizable nano-particle compound and combinations thereof.

4. The magnetic material composite of claim 1, wherein said magnetic material is magnetized prior to admixing with said structural material.

5. The magnetic material composite of claim 1, wherein the at least one portion containing the magnetic material comprises a surface of the magnetic material composite, an end of the magnetic material composite and a layer within the magnetic material composite.

6. The magnetic material composite of claim 1, wherein said structural material is configured to provide structural support to withstand a load placed on the magnetic material composite.

7. The magnetic material composite of claim 1, wherein the magnetic material is stratified or concentrated in the magnetic material composite.

8. A mold having at least one cavity for formation of a molded article comprising:

a magnetic field generator configured to generate one or more discrete magnetic fields in said mold, and

one or more control mechanisms programmed to control at least one of duration and strength of any of said magnetic fields applied in the mold to form an article from a structural magnetic composite comprising a magnetic material and a structural material.

9. The mold of claim 8, wherein the one or more control mechanisms are programmed to control at least one of the duration and the strength of any of said magnetic fields in the mold as applied to the structural magnetic composite sufficient to align a magnetic polarity of said magnetic material contained in one of the cavities of said mold.

10. The mold of claim 8, wherein the one or more control mechanisms are programmed to control at least one of the duration and the strength of any of said magnetic fields in the mold as applied to the structural magnetic composite capable to magnetize the magnetic material contained in one of the cavities of said mold.

11. The mold of claim 8, wherein the magnetic field generator comprises one or more electromagnets responsive to the one or more control mechanisms to generate any of the magnetic fields applied to said mold.

12. The mold of claim 8, wherein the magnetic field generator comprises at least one permanent magnet configured to generate any of said magnetic fields applied to said mold.

13. The mold of claim 8, wherein two or more materials with different magnetic or structural properties are separately introduced to the mold to control the concentration and distribution of magnetic and structural materials.

14. The mold of claim 13, wherein the two or more materials are introduced to the mold simultaneously.

15. The mold of claim 13, wherein the two or more materials are introduced to the mold in series.

16. The mold of claim 13, wherein the two or more materials are introduced to the mold such as to ensure a unified chemical bond between the magnetic compound and the non-magnetic compound.

17. The mold of claim 16, wherein the magnetic material is injected into the mold, magnetizables are aligned, polarized and magnetized, and the structural material is introduced into the mold before the structural material substantially cures.

18. An article of manufacture comprising:

one or more mechanical elements formed from a magnetic material composite comprising a magnetic material and structural material,

wherein the magnetic material composite has at least one portion with an aggregation of the magnetic material and at least one portion substantially free of the magnetic material.

19. The article of manufacture of claim 18, wherein the article comprises any of a motor, a generator, a pump, or a fan having a rotatable member formed in whole or in part from the magnetic material composite.

20. A method of manufacturing an article, the method comprising the steps of:

selecting a magnetic material,

selecting a structural material, and

mixing the magnetic material and the structural material to form a material composite having at least one portion containing an aggregation of the magnetic material and at least one portion substantially free of the magnetic material.

21. The method of claim 15, further comprising the step of injecting the material composite into a cavity of a mold.

22. The method of claim 15, further comprising the step of forming a sheet of material from the material composite.

23. The method of claim 15, wherein the material composite comprises a liquid having properties that allows the material composite to be applied to a surface of an object with any of a brush, a roller or a spray gun.

24. The method of claim 15, further comprising the step of forming the material composite into a coating suitable for application to a surface of an object.

25. The method of claim 16, further comprising the step of applying an electrical current to said cavity of said mold.

26. The method of claim 16, further comprising the step of, applying a magnetic field to said cavity of said mold.

27. The method of claim 21 further comprising the step of, controlling at least one of a duration and a strength of said magnetic field to stratify said magnetic material contained in said cavity.

28. The method of claim 21, further comprising the step of controlling at least one of a duration and a strength of said magnetic field applied to align a magnetic polarity of said magnetic material contained in the cavity of said mold.

29. The method of claim 15 further comprising the steps of,

removing the article from the cavity of the mold,

placing the article in a cavity of a second mold, and injecting the cavity of the second mold with a magnetic neutral compound molecularly compatible with the article.

30. The method of claim 25, wherein the magnetic neutral compound molecularly compatible with the article bonds with the article without additional preparation of the article.

31. The method of claim 15, further comprising the step of applying an electrical field to the material composite.

32. The method of claim 15, further comprising the step of applying a magnetic field to the material composite.

33. A method of manufacturing an article of manufacture, comprising the steps of:

providing a magnetic material composite having a magnetic material and another material; and

causing the magnetic material to migrate within the magnetic material composite and aggregate in at least one portion of the magnetic material composite, such that at least one portion of the magnetic material composite is substantially free of the magnetic material.

34. The method of claim 33, wherein the step of causing the magnetic material to migrate and aggregate comprises the step of applying one of a magnetic field, an electrical field and combinations thereof to the magnetic material composite.

35. The method of claim 33, further comprising the step of shaping the magnetic material composite into a selected form.

36. The method of claim 33, further comprising the step of curing the magnetic material composite into a solid phase.

37. The method of claim 33, wherein the magnetic material composite further includes a catalyst to facilitate said step of curing.

38. A method of manufacturing an article of manufacture, comprising the step of:

providing a magnetic material composite having a structural material and a magnetic material, wherein the magnetic material composite includes at least one portion containing the magnetic material and at least one portion substantially free of the magnetic material; and

magnetizing the magnetic material.

39. The method of claim 38, wherein the step of magnetizing the magnetic material comprises at least one of: applying a magnetic field, an electrical field and a combination thereof to the magnetic material composite.

40. A molding system, comprising:

a working material source;

a mold having a cavity;

a distribution means for distributing a working material from said working material source to the cavity of the mold; and

at least one magnet for applying a magnetic field to the cavity of the mold.

41. The molding system of claim 40, wherein the working material source comprises a first material source and a second material source, and the distribution means mixes the first material and second material together to form a working material prior to distributing the working material to the cavity of the mold.

42. The molding system of claim 40, further comprising a control system for controlling the application of the magnetic material to the cavity of the mold.

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