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(54) METAL MATRIX COMPOSITES, AND METHODS FOR MAKING THE SAME

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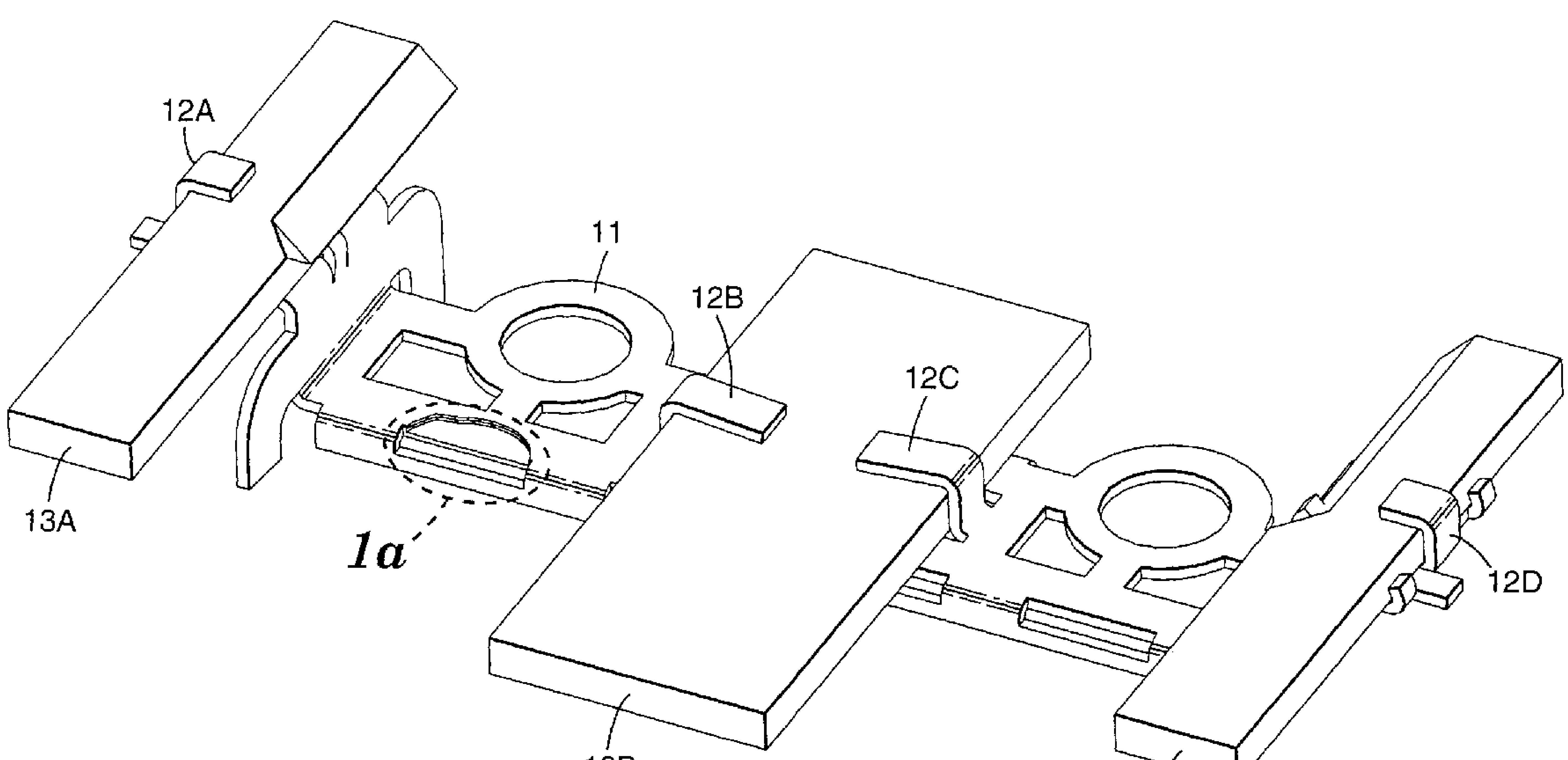
(57) ABSTRACT

A holder comprising an insert for reinforcing a metal matrix composite article and methods of making the same. In another aspect, the present invention provides metal matrix composite articles reinforced with an insert(s) and methods of making the same. Useful metal matrix composite articles comprising the inserts include brake calipers.



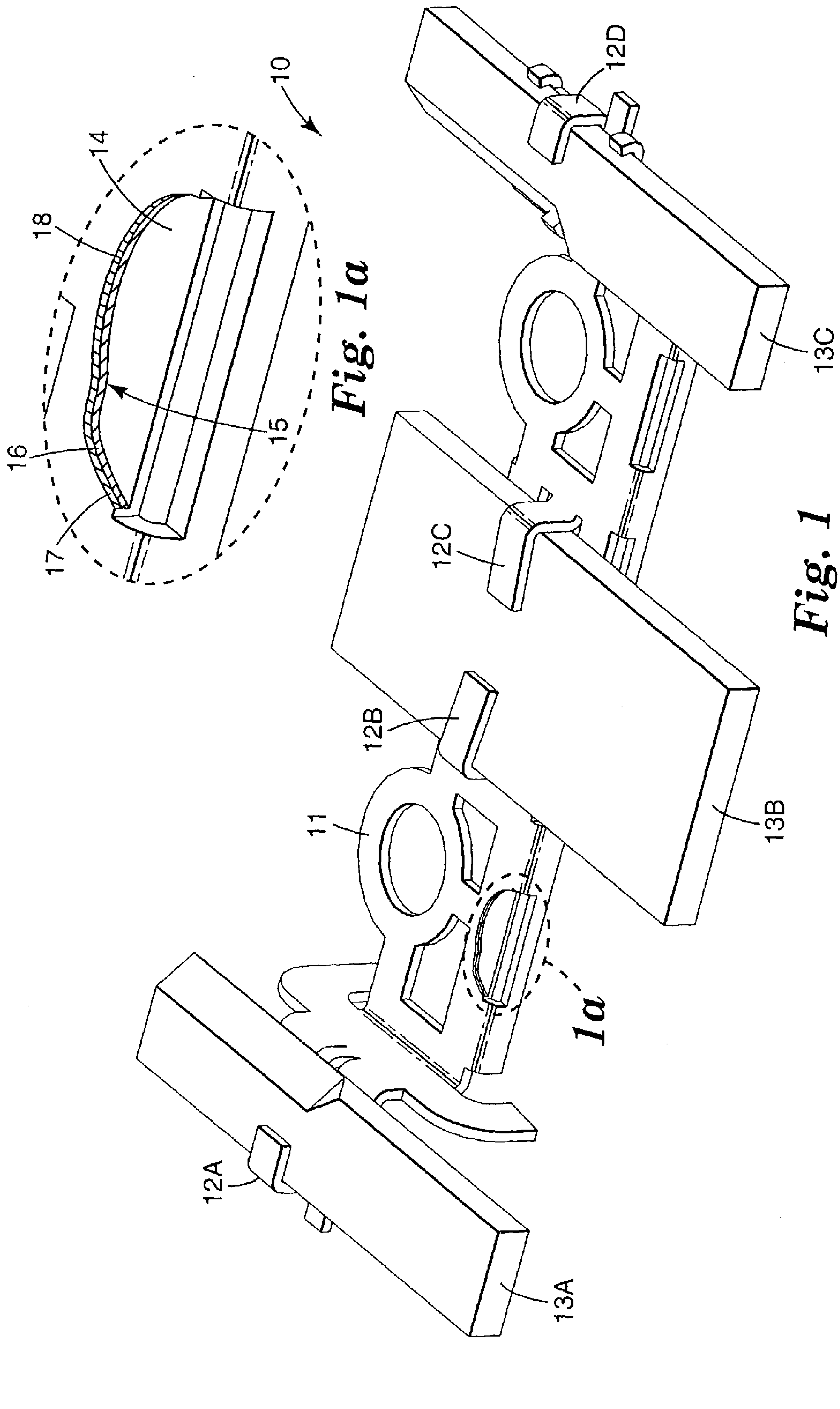


Fig. 1a

Fig. 1

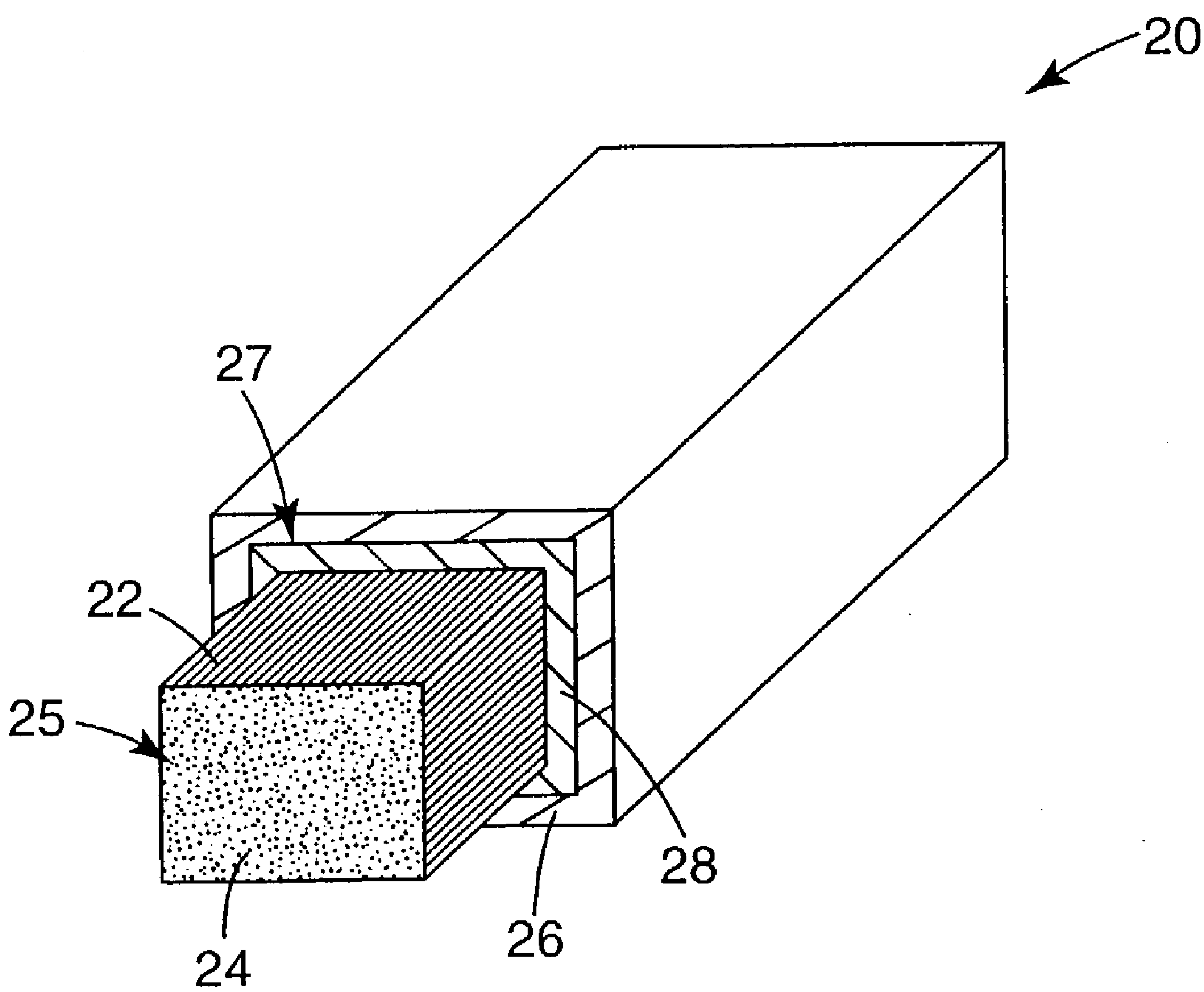


Fig. 2

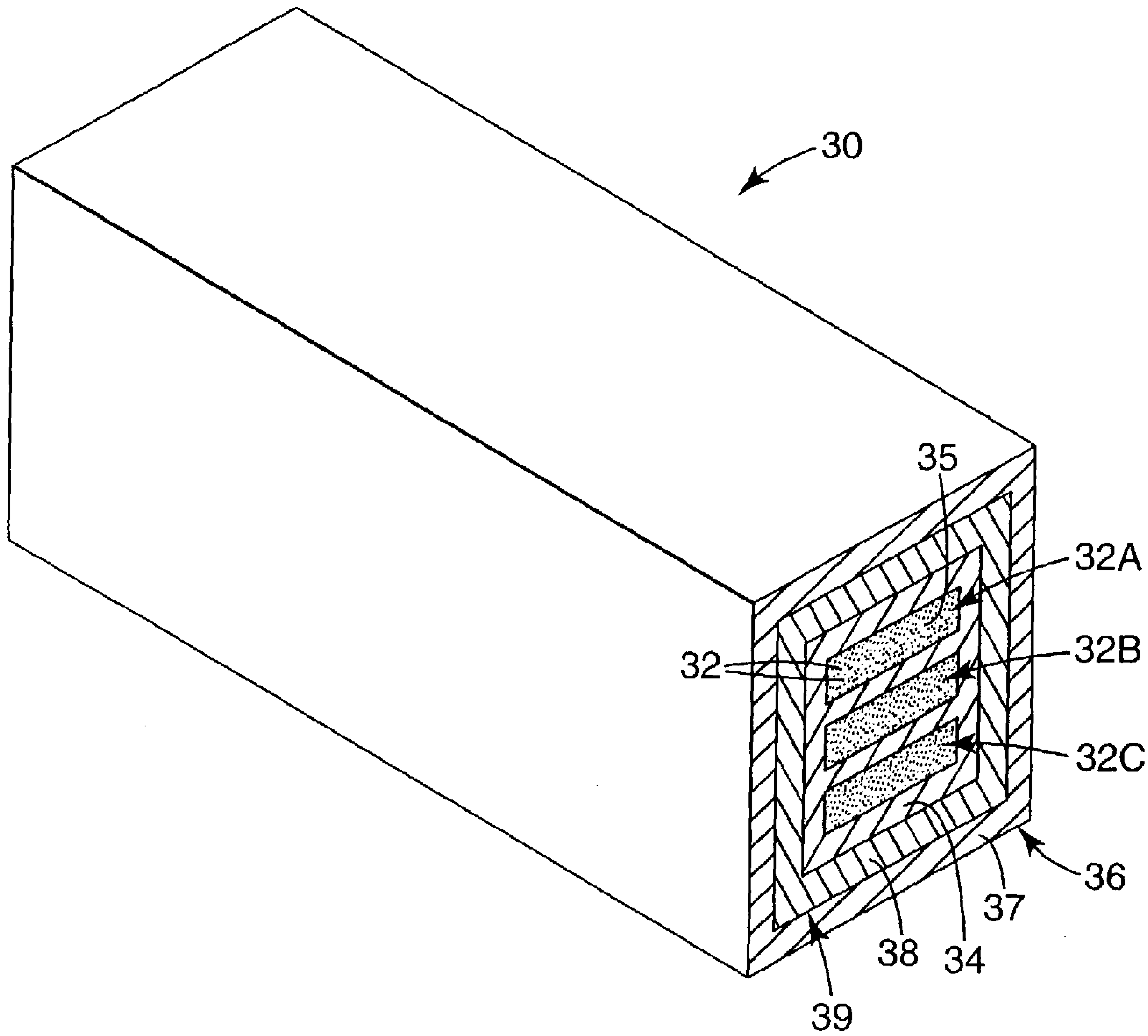


Fig. 3

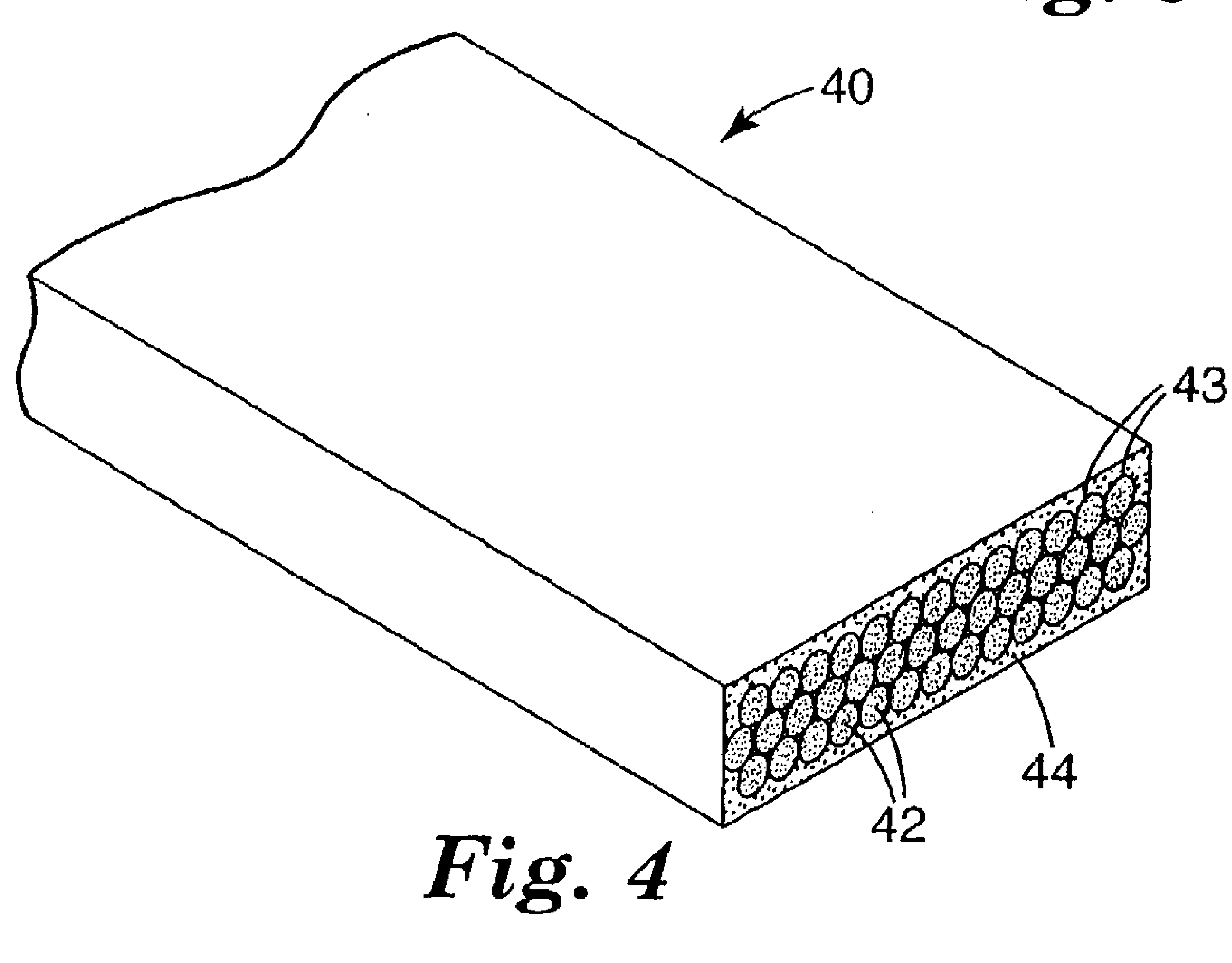


Fig. 4

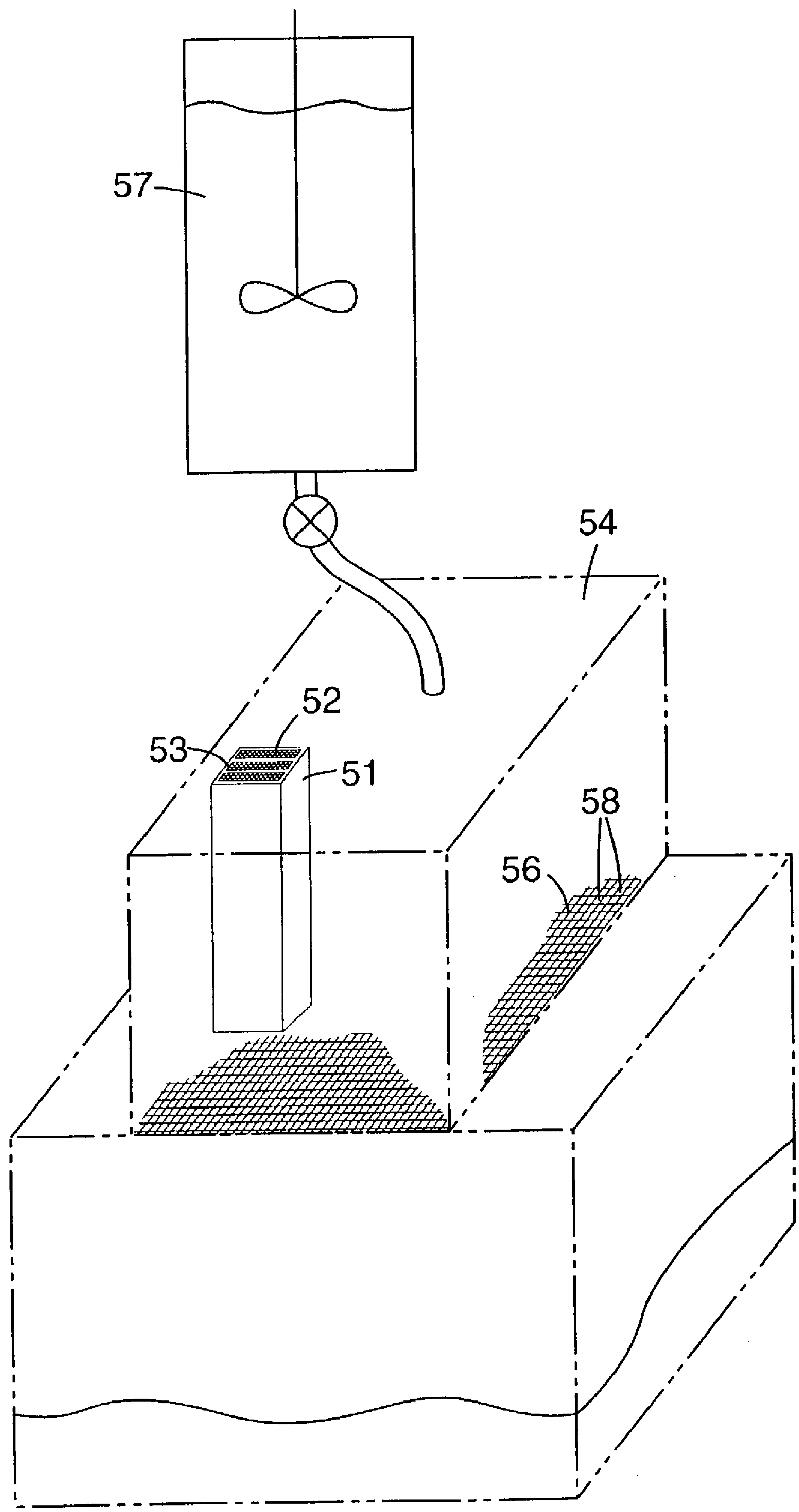


Fig. 5

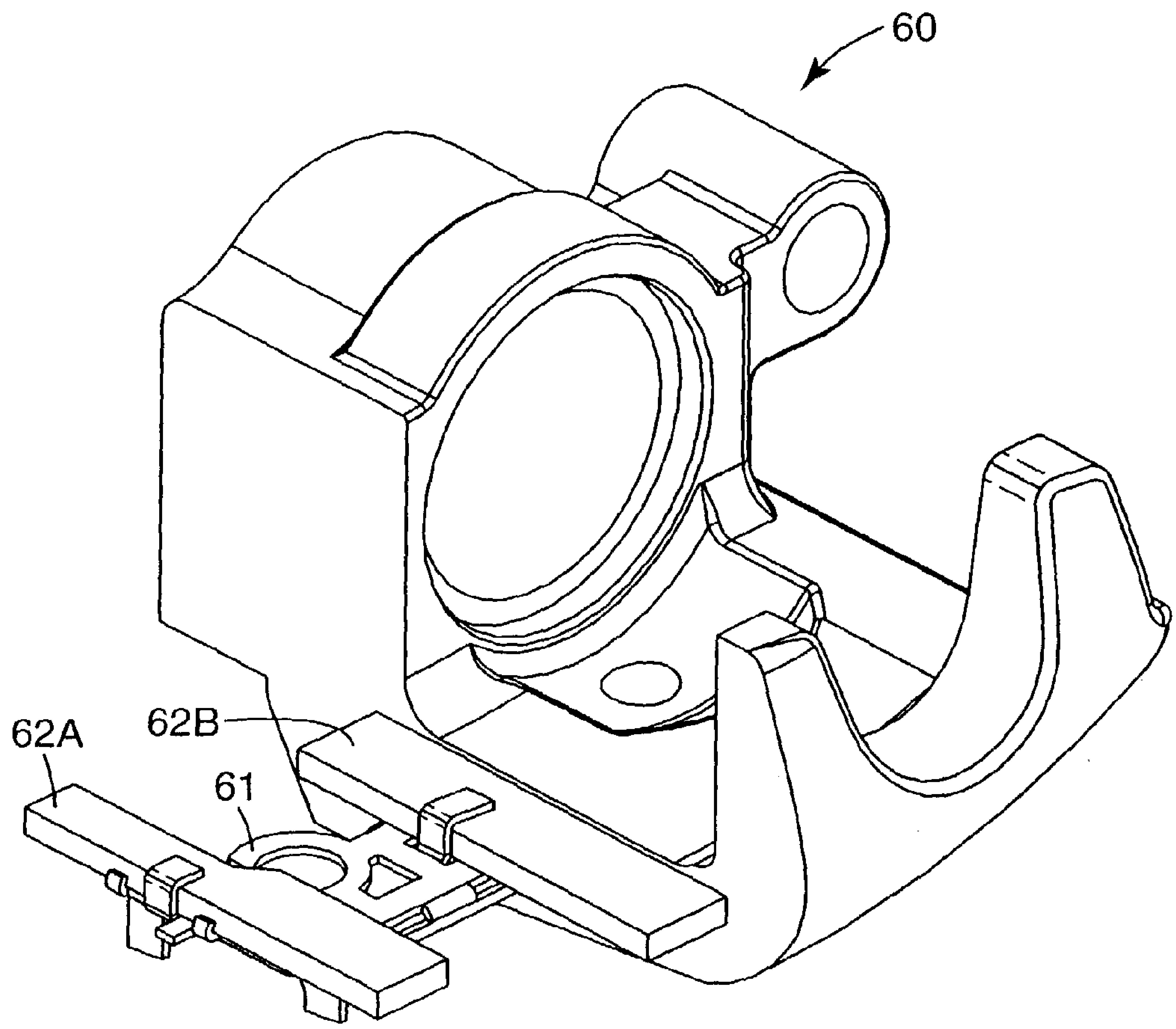


Fig. 6

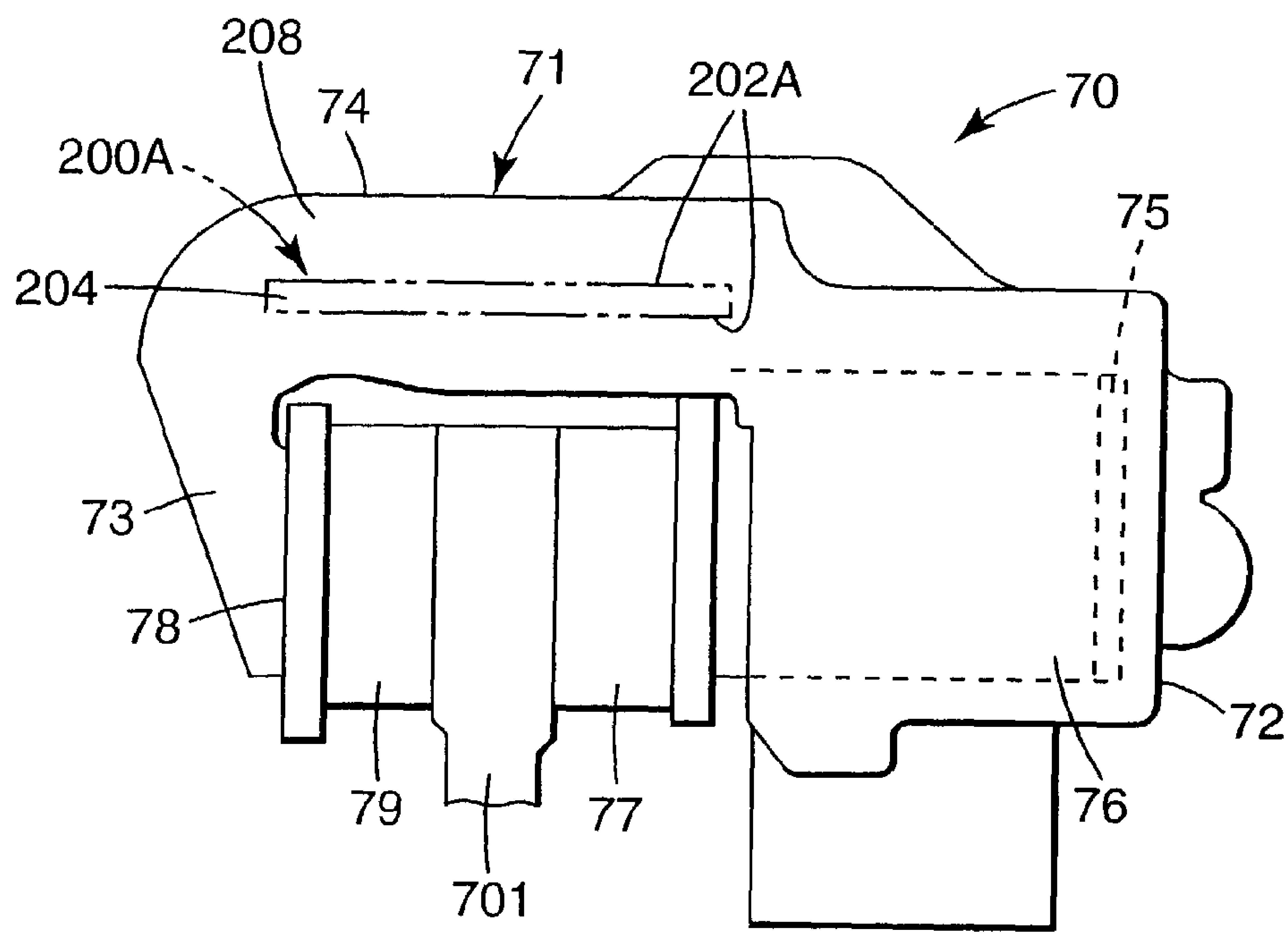

208
74
71
202A
70
200A
75
204
73
78
72
79
77
76
701

Fig. 7A

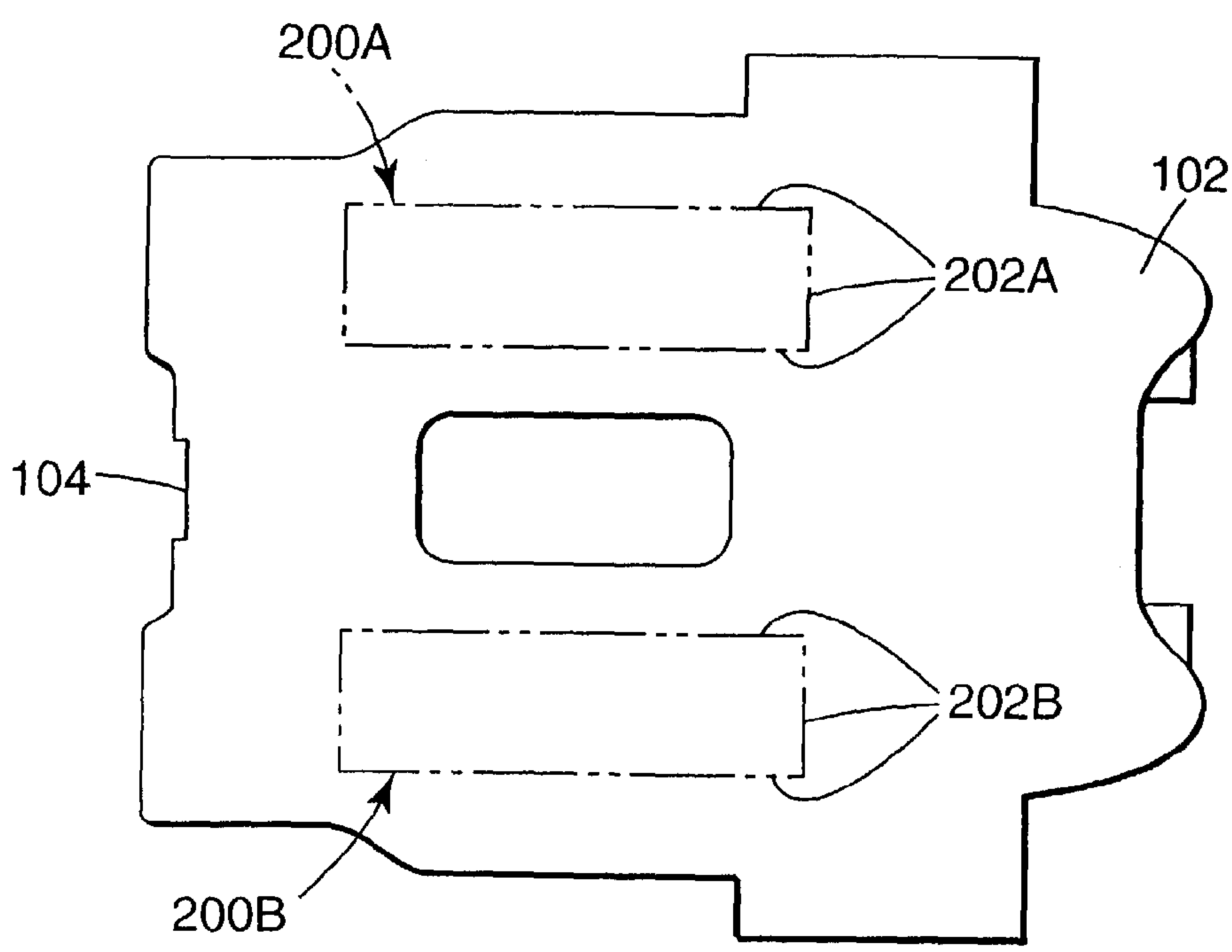

200A
102
202A
104
202B
200B

Fig. 7B

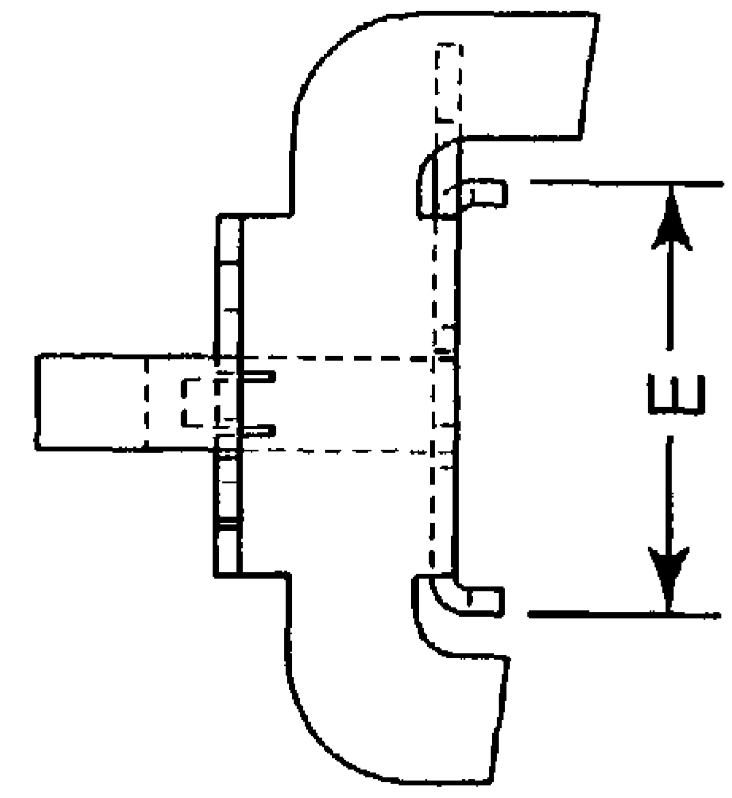


Fig. 8C

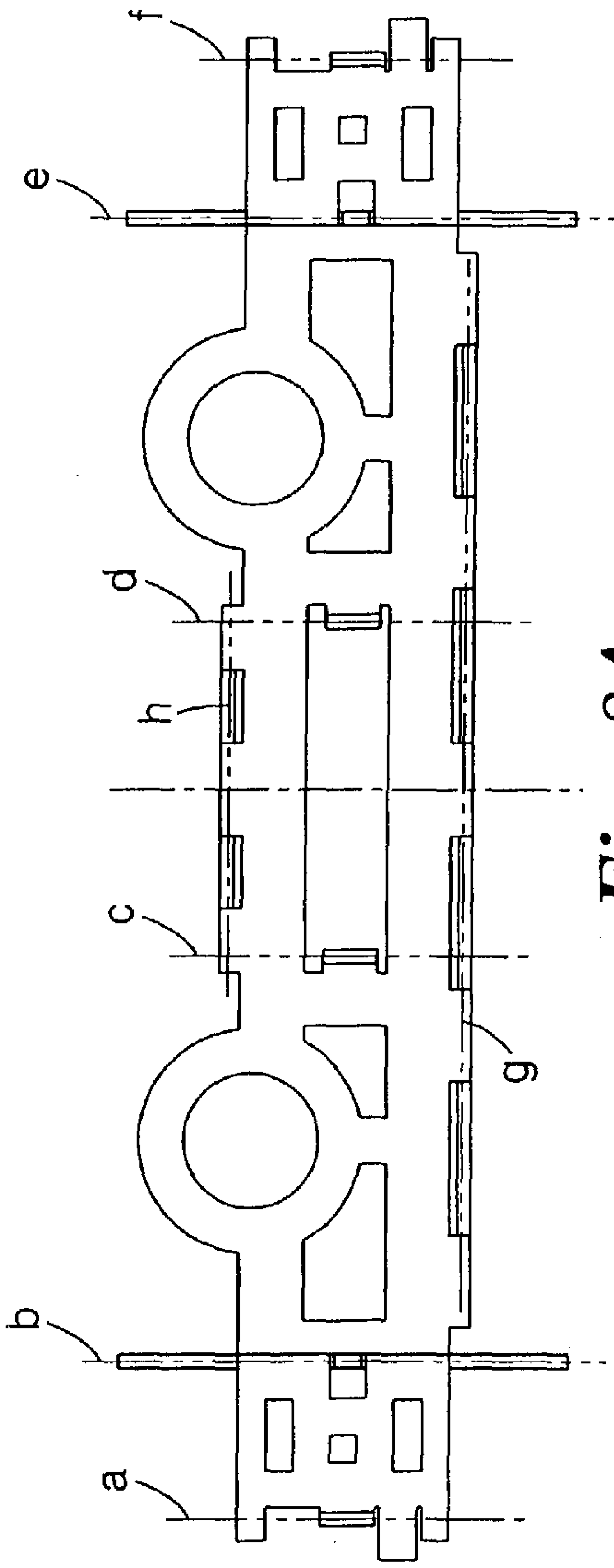


Fig. 8A

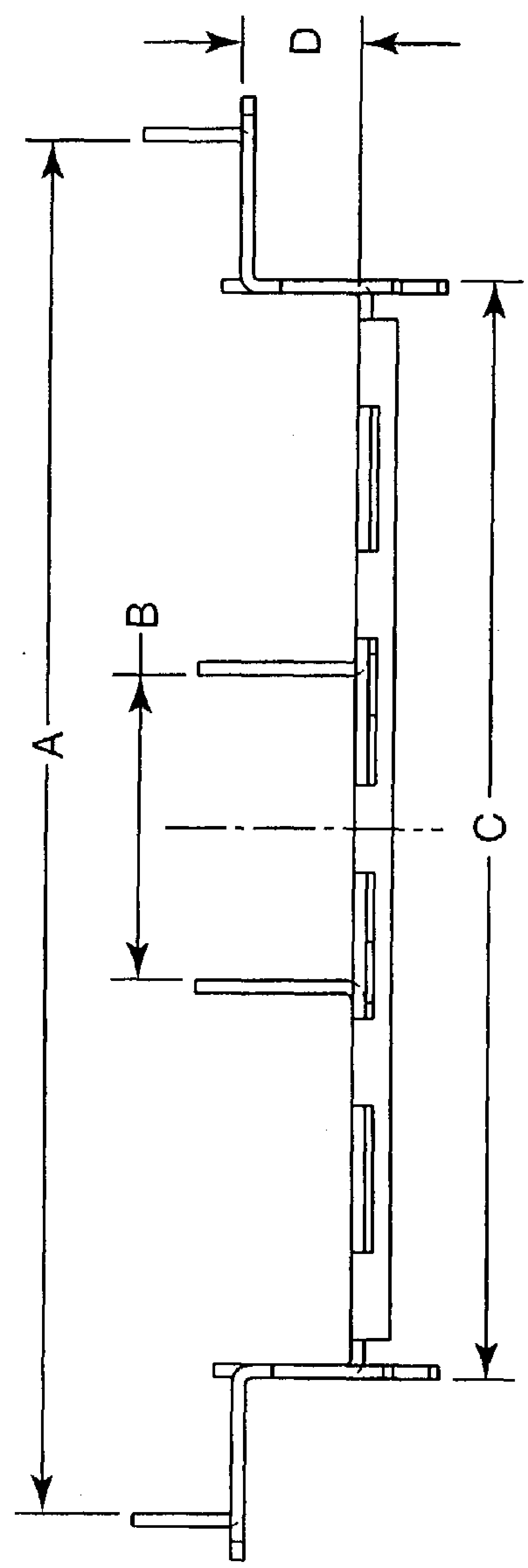


Fig. 8B

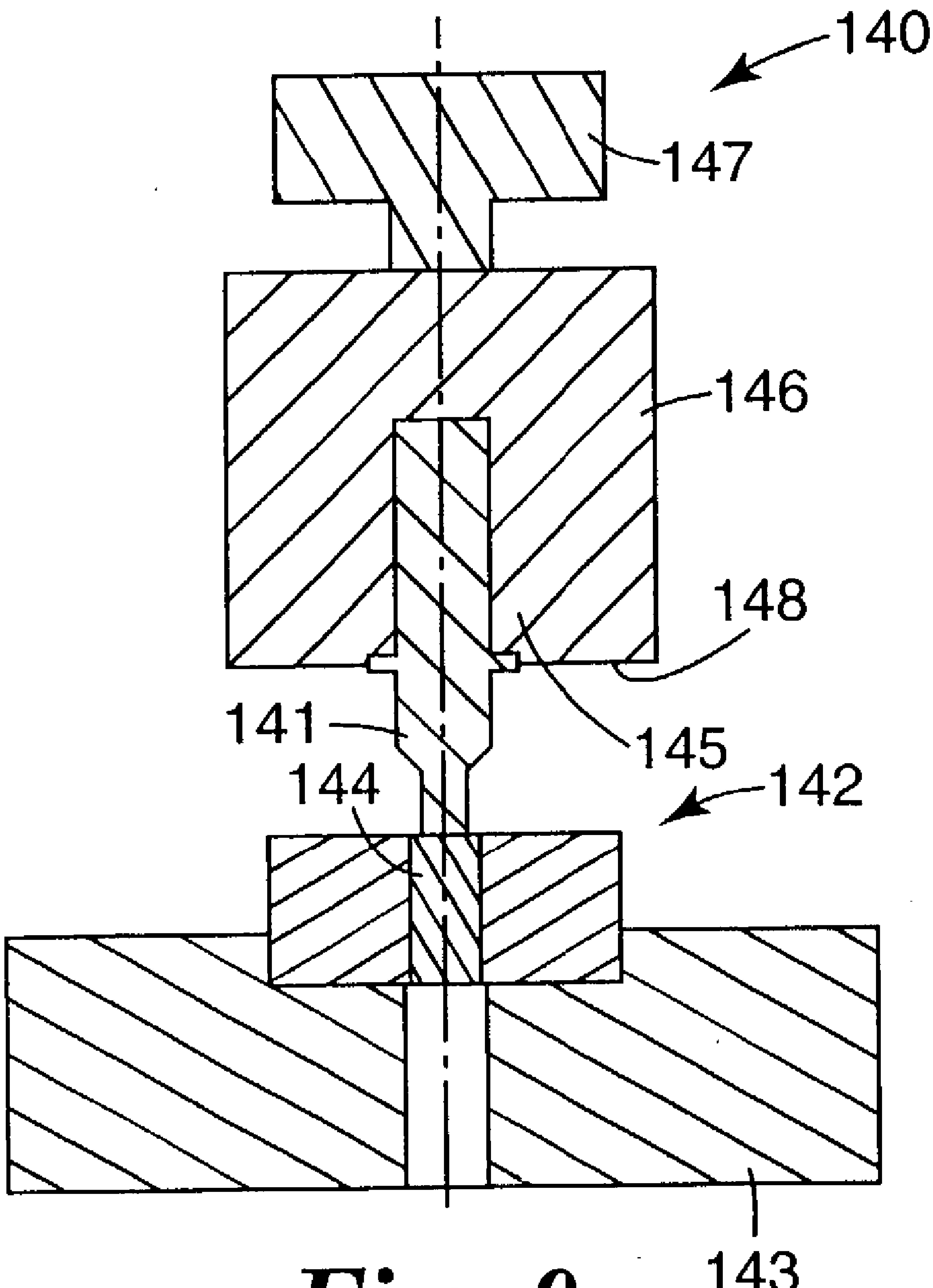


Fig. 9

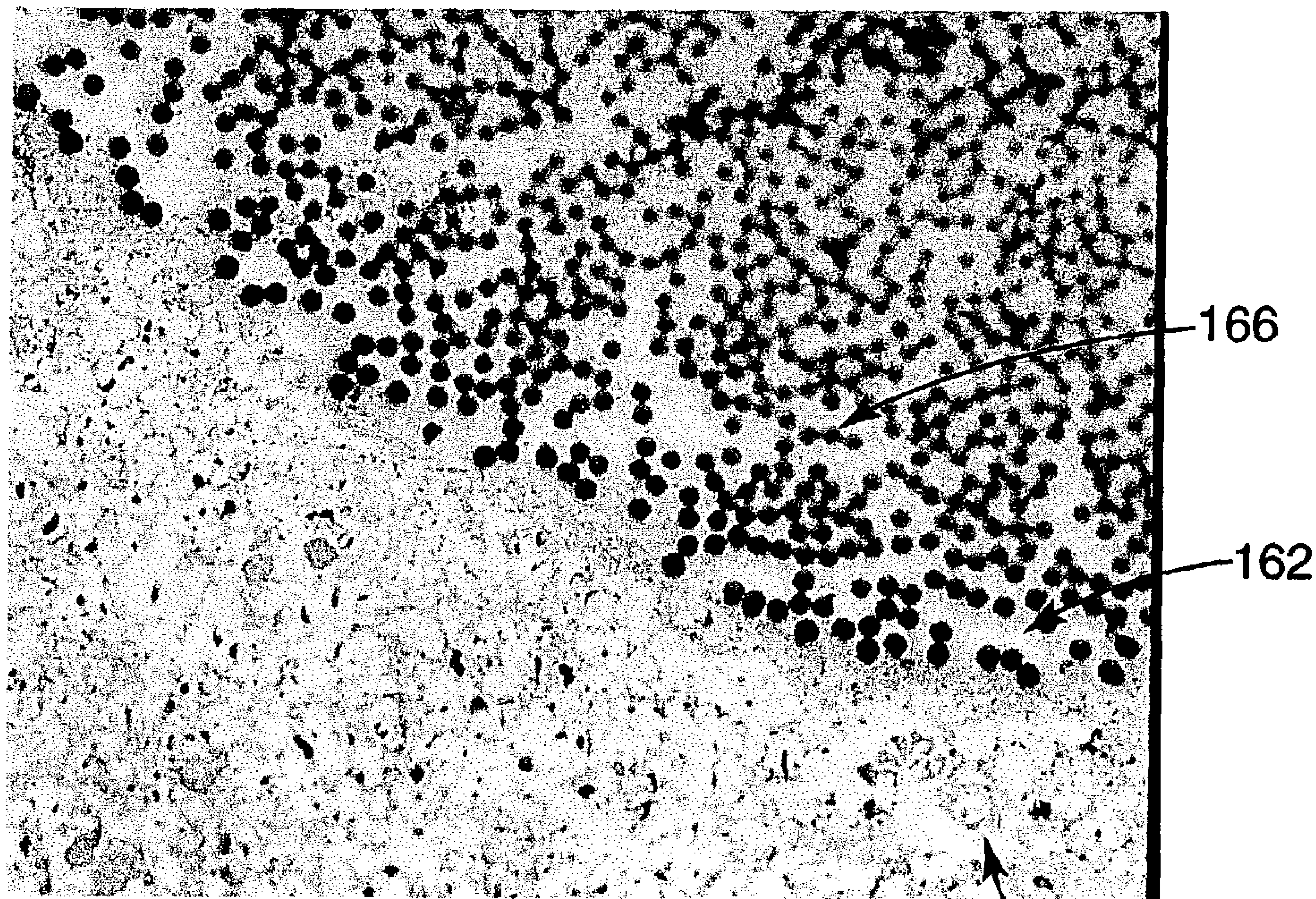


Fig. 10

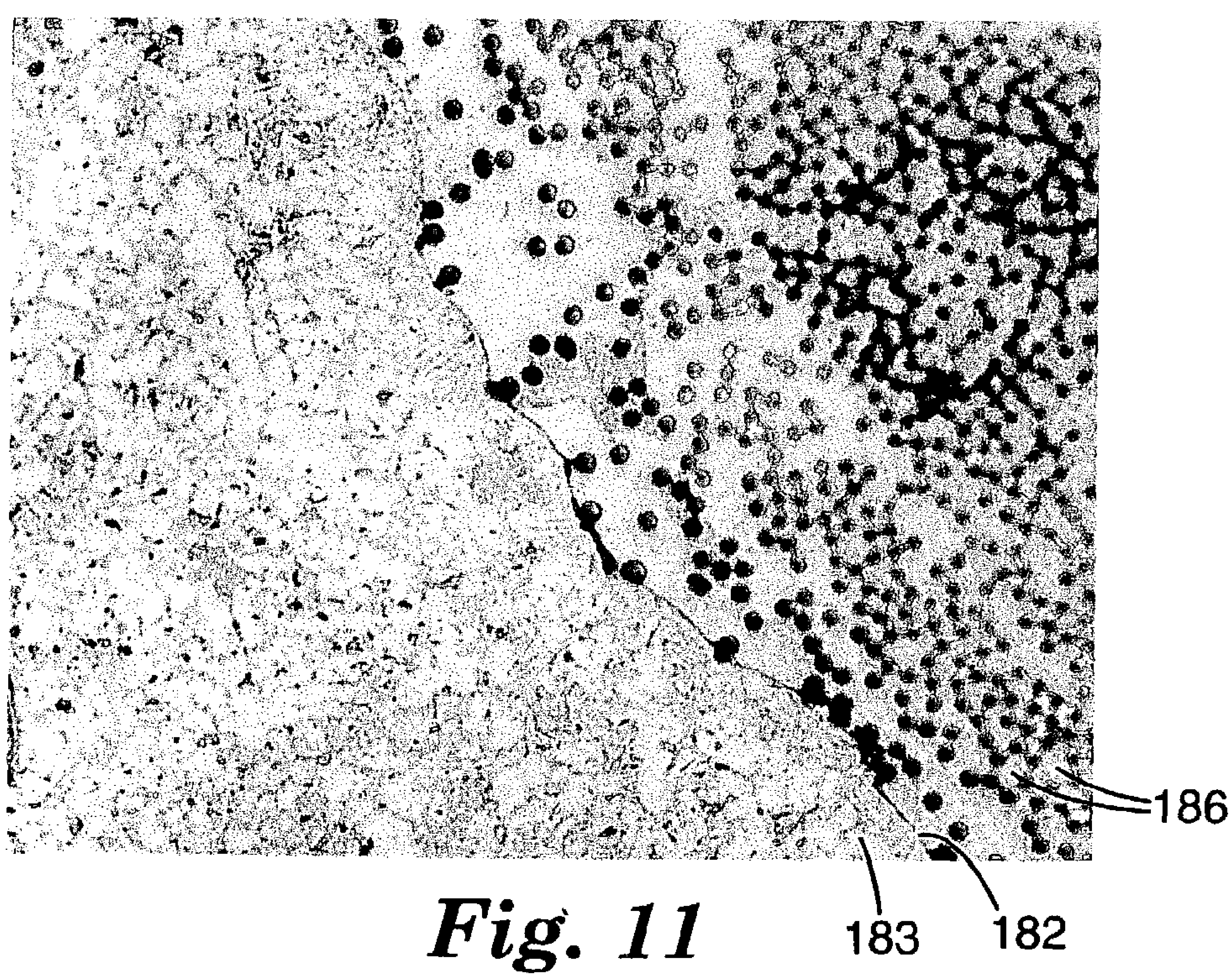


Fig. 11

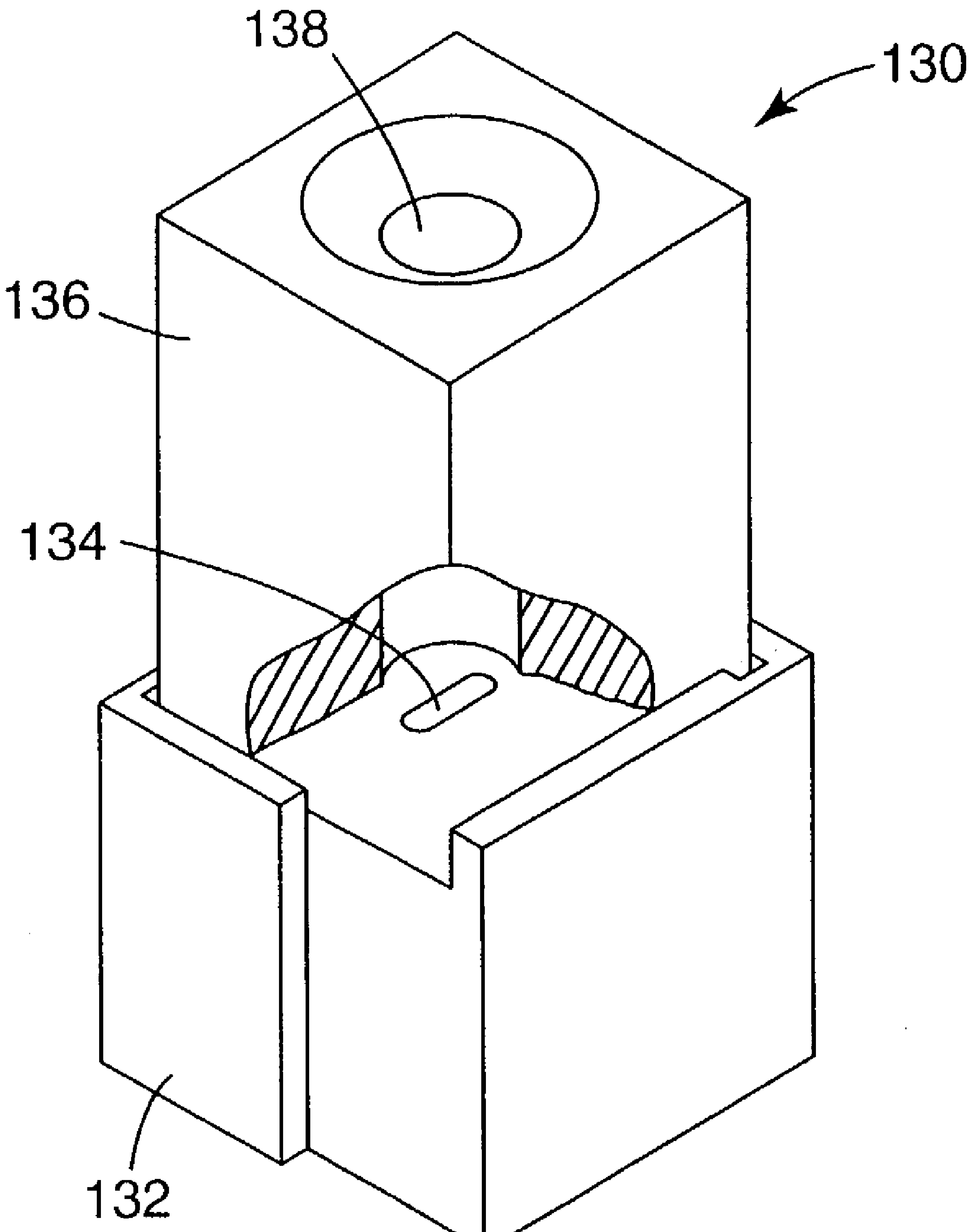


Fig. 12

METAL MATRIX COMPOSITES, AND METHODS FOR MAKING THE SAME

[0001] This application claims priority to U.S. provisional application having Serial No. 60/404,729, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to metal matrix composite insert holder and metal matrix composite articles made using metal matrix composite insert holders.

DESCRIPTION OF RELATED ART

[0003] Reinforcement of metal matrices with ceramics is known in the art (see, e.g., U.S. Pat. Nos. 4,705,093 (Ogino), 4,852,630 (Hamajima et al.), 4,932,099 (Corwin et al.), 5,199,481 (Corwin et al.), 5,234,080 (Pantale), and 5,394, 930 (Kennerknecht), Great Britain Pat. Doc. Nos. 2,182,970 A and B, published May 28, 1987 and Sep. 14, 1988, respectively, and PCT applications having publication nos. WO 02/26658, WO 02/27048, and WO 02/27049, published Apr. 4, 2002). Examples of ceramic materials used for reinforcement include particles, discontinuous fibers (including whiskers) and continuous fibers, as well as ceramic pre-forms.

[0004] Typically, ceramic material is incorporated into a metal to provide metal matrix composites (MMC) having improved mechanical properties compared to the article made of the metal without the ceramic material. For example, conventional brake calipers for motorized vehicles (e.g., cars and trucks) are typically made of cast iron. To reduce the overall weight of the vehicle, as well as in particular unsprung weight such as brake calipers, there is a desire to use lighter weight parts and/or materials. One technique for aiding in the design of MMCs, including placement of the ceramic oxide material and minimizing the amount of ceramic oxide material needed for the particular application, is finite element analysis.

[0005] A brake caliper made of cast aluminum would be about 50% by weight lighter than the same (i.e., the same size and configuration) caliper made of cast iron. The mechanical properties of cast aluminum and cast iron are not the same (e.g., the Young's modulus of cast iron is about 100-170 GPa, while for cast aluminum it is about 70-75 GPa; the yield strength of cast iron is 300-700 MPa, while for cast aluminum it is 200-3000 MPa). Hence, for a given size and shape, a brake caliper made from cast aluminum has significantly lower mechanical properties such as bending stiffness and yield strength than the cast iron caliper. Typically, the mechanical properties of such an aluminum brake caliper are unacceptably low as compared to a cast iron brake caliper. A brake caliper made of an aluminum metal matrix composite material (e.g., aluminum reinforced with ceramic fibers) that has the same configuration and at least the same (or better) mechanical properties, such as bending stiffness and yield strength, as a cast iron brake caliper is desirable.

[0006] One consideration for some MMC articles is the need for post-formation machining (e.g., adding holes or threads, or otherwise cutting away material to provide a desired shape) or other processing (e.g., welding two MMC articles together to make a complex shaped part). Many conventional MMCs typically contain enough ceramic reinforcement material to make machining or welding impractical or even impossible. It is desirable, however, to produce "net-shaped" articles that require little, if any, post-formation machining or processing. Techniques for making "net-shaped" articles are known in the art (see, e.g., U.S. Pat. Nos. 5,234,045 (Cisko) and 5,887,684 (Döll et al.)). In addition, or alternatively, to the extent feasible, the ceramic reinforcement may be reduced or not placed in areas where it may interfere with machining or other processing such as welding.

[0007] Another consideration in designing and making MMCs is the cost of the ceramic reinforcement material. The mechanical properties of continuous polycrystalline alpha-alumina fibers such as that marketed by the 3M Company, St. Paul, Minn., under the trade designation "NEXTEL 610", are high compared to low density metals such as aluminum. In addition, the cost of ceramic oxide materials such as the polycrystalline alpha-alumina fibers, is substantially more than metals such as aluminum. Hence, it is desirable to minimize the amount of ceramic oxide material used, and to optimize the placement of the ceramic oxide materials in order to maximize the properties imparted by the ceramic oxide materials. Further, it is desirable to provide the ceramic reinforcement material in a package or form that can be relatively easily used to make a metal matrix composite article therefrom.

[0008] PCT applications having publication nos. WO 02/26658, WO 02/27048, and WO 02/27049, published Apr. 4, 2002) include descriptions of embodiments that address the need for ceramic reinforcement material in a package or form that can be relatively easily used to make a metal matrix composite article therefrom. These applications also include discussions of positioning the continuous ceramic fibers used for reinforcement within a mold during the formation of a metal matrix composite article (e.g. a brake caliper).

[0009] While techniques for positioning reinforcing fibers is metal matrix composites are known in the art additional techniques are also desirable.

SUMMARY OF THE INVENTION

[0010] In one aspect, the present invention provides insert holders for holding inserts (e.g., metal comprising reinforcement inserts (e.g., metal matrix composite inserts) and/or ceramic comprising reinforcement inserts) for reinforcing a metal matrix composite article and methods of making the same.

[0011] In one embodiment, the present invention provides a first article (e.g., article for reinforcing a metal matrix composite article) comprising:

> [0012] an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy)), and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal having a positive Gibbs

oxidation free energy above at least 200° C., the second metal having a thickness of at least 8 micrometers (in some embodiments, preferably 10 micrometers, 12 micrometers, or even 15 micrometers; more preferably, in the range from 12 to 15 micrometers); and

[0013] at least one reinforcement insert (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) secured in the at least one portion for securing at least one insert. Optionally, the first metal matrix composite article further comprises a metal (e.g., Ni) between the second metal and the outer surface of the first metal. Optionally, an insert holder further comprises one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) portions for securing an insert and, correspondingly one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) positioned in the additional portion(s) for securing insert(s). Optionally, an insert holder further comprises one or more (e.g., a first, second, third, fourth, fifth, sixth, etc.) correspondingly one or more additional inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)).

[0014] In some embodiments, the present invention provides a preferred, second article comprising:

[0015] an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy)), and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C.; and

[0016] at least one metal matrix composite insert secured in the at least one portion for securing at least one insert, wherein at least one of such inserts comprises:

[0017] substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 200 series) aluminum alloy)), and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the third metal having an outer surface; and

[0018] a fourth metal on the outer surface of the third metal, the fourth metal having a positive Gibbs oxidation free energy above at least 200° C., and the fourth metal having a thickness of at least 8 micrometers (in some embodiments, preferably 10 micrometers, 12 micrometers, or even 15 micrometers; more preferably, in the range from 12 to 15 micrometers).

[0019] Optionally, the second metal matrix composite article further comprises a metal (e.g., Ni) between the second metal and the outer surface of the first metal. In addition, or alternatively, optionally, the third metal matrix composite article further comprises a metal (e.g., Ni) between the fourth metal and the outer surface of the third metal. Optionally, an insert holder further comprises one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) portions for securing an insert and, correspondingly one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) positioned in the additional portion(s) for securing insert(s).

[0020] In some embodiments, the present invention provides a preferred, third article comprising:

[0021] an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy)), and combinations thereof; and

[0022] at least one metal matrix composite insert positioned in the at least one portion for securing at least one insert, the insert comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 200 series) aluminum alloy)), and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

[0023] the insert holder with the at least one insert secured in the at least one portion for securing at least one insert collectively having an outer surface, and a third metal on the outer surface, the third metal having a positive Gibbs oxidation free energy above at least 200° C., and the third metal having a thickness of at least 8 micrometers (in some embodiments, preferably 10 micrometers, 12 micrometers, or even 15 micrometers; more preferably, in the range from 12 to 15 micrometers).

[0024] Optionally, the third metal matrix composite article further comprises a metal (e.g., Ni) between the third metal and the outer surface. Optionally, an insert holder further comprises one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) portions for securing an insert and, correspondingly one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) positioned in the additional portion(s) for securing insert(s).

[0025] In some embodiments, the present invention provides a preferred, fourth metal matrix composite article comprising a first metal (e.g., aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 300 or 400 series) aluminum alloy), and combinations thereof) and an insert holder including at least one portion for securing at least one insert, wherein the insert holder comprises:

[0026] a second metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy), and combinations thereof); and

[0027] at least one reinforcement insert (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) secured in the at least one portion for securing at least one insert,

[0028] wherein there is an interface layer between the first metal and the insert holder, and wherein there is an interface layer peak bond strength value between the first metal and the insert holder of at least 100 MPa (in some embodiments, preferably at least 125 MPa, at least 150 MPa, at least 175, or even at least 180 MPa).

[0029] Optionally, the insert holder(s) further comprises one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) portions for securing an insert and, correspondingly one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) positioned in the additional portion(s) for securing insert(s).

[0030] In another aspect with regard to the fourth preferred metal matrix composite article according to the present invention, in some embodiments preferably, the interface layer is free of oxygen. In another aspect, the interface layer may include an average amount of a metal having a positive Gibbs oxidation free energy above at least 200° C. (e.g., silver, gold, alloys thereof, and combinations thereof), and wherein the average amount of such metal is (e.g., at least 15, 20, 25, 30, 35, 40, 45, or even, 50 percent by weight) higher in the interface layer than in the first metal. In another aspect, the interface layer may include an average amount of Ag and Ni (e.g., at least 15, 20, 25, 30, 35, 40, 45, or even, 50 percent by weight of each Ag and Ni) higher than that present in the first metal. In another aspect, the first and second metals may each have a melting point, wherein the melting point of the second metal is at least 10° C., 15° C., 20° C., 25° C., 30° C, 35° C., 40° C., 45° C., or even 50° C. higher than the melting point of the first metal. In another aspect, the first metal and second metals may be different (e.g., aluminum and an aluminum alloy, or different aluminum alloys).

[0031] In some embodiments, the present invention provides a preferred fifth metal matrix composite article comprising a first metal (e.g., aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 300 or 400 series) aluminum alloy), and/or combinations thereof) and an insert holder including at least one portion for securing at least one insert, wherein the insert holder comprises:

[0032] a second metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy), and combinations thereof); and

[0033] at least one metal matrix composite insert secured in the at least one portion for securing at least one insert, the metal matrix composite insert comprising:

[0034] substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 200 series) aluminum alloy), and combinations thereof), wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

[0035] wherein there is an interface layer between the first metal and the insert holder, wherein the interface layer is free of oxygen, wherein the interface layer includes an average amount of a fourth metal having a positive Gibbs oxidation free energy above at least 200° C., and wherein the average amount of the fourth metal in the interface layer is higher in the interface layer than that present in the first metal. In some embodiments, preferably the average amount of the fourth metal is at least 15, 20, 25, 20, 35, 40, 45, or even, 50 percent by weight higher in the interface layer than in the first metal. In another aspect, the interface layer may also include an average amount of Ni (e.g., at least 15, 20, 25, 20, 35, 40, 45, or even, 50 percent by weight of each Ag and Ni) higher than that present in the first metal. In another aspect, the first and second metals may each have a melting point, wherein the melting point of the second metal is at least 10° C., 15° C., 20° C., 25° C., 30° C., 35° C., 40° C., 45° C., or even 50° C. higher than the melting point of the first metal. In another aspect, the first metal and second metals may be different (e.g., aluminum and an aluminum alloy, or different aluminum alloys).

[0036] Optionally, the insert holder(s) further comprises one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) portions for securing an insert and, correspondingly one or more additional (e.g., a second, third, fourth, fifth, sixth, etc.) inserts (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s)) positioned in the additional portion(s) for securing insert(s).

[0037] In another aspect, the present invention provides a method of making a metal matrix composite article, the method comprising:

[0038] positioning an insert holder (e.g., a first, second, third, fourth, or fifth article according to the present invention) that includes an insert(s) (e.g., a metal comprising reinforcement insert(s) (e.g., a metal matrix composite insert(s)) and/or a ceramic comprising reinforcement insert(s));

[0039] providing molten metal selected from the group consisting of aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 300 or 400 series) aluminum alloy), and combinations thereof) into the mold; and

[0040] cooling the molten metal to provide a metal matrix composite article. Surprisingly, embodiments of the present invention can be used to make metal matrix composite articles wherein the molten metal in the mold to be in the molten state for less than 75 seconds (in some embodiments, preferably less than 60 seconds). By contrast, conventional methods tend to require the molten metal in the mold is in the molten state for 200 seconds or more. Although not wanting to be bound by theory, it is believed that the presence of the metal having a positive Gibbs oxidation free energy above at least 200° C. enables formation of a bond between the holder and/or insert, as applicable, and the metal of the metal matrix composite article (in some embodiments, preferably without an oxide layer at the interface) and hence does not require an extended period of heating of the interface by molten aluminum or aluminum alloy, as applicable to attempt to break up the oxide layer to achieve metallurgical bonding.

[0041] In this application:

[0042] "a positive Gibbs oxidation free energy above at least 200° C." refers to the quantity $\Delta G^{0}_{rxn}=\Delta H^{0}_{rxn}-T\Delta S^{0}_{rxn}$ where ΔH^{0}_{rxn} is the enthalpy of the oxidation reaction in kJ/mol, T is the temperature in degrees Kelvin, and ΔS^{0}_{rxn} is the entropy of the oxidation reaction (in kJ/mol° K.) remaining positive for temperatures greater than 200° C. (473° K.);

[0043] "peak bond strength value" refers to the peak bond strength value as determined by the "Peak Bond Strength" test described below;

[0044] "free of oxygen" means no visibly discernable continuous oxide layer at the interface when viewed at 250× with optical microscope as described in the "Oxygen Layer Test" below; and

[0045] "substantially continuous ceramic oxide fibers" refers to ceramic oxide fibers having lengths of at least 5 cm.

[0046] First, second, third, fourth, or fifth articles according to the present invention are useful, for example, to provide reinforcement material in metal matrix composite articles. One advantage of some embodiments of the present invention allow for an existing article made of (original) metal (e.g., cast iron) to be redesigned to be made from another metal (e.g., aluminum) reinforced with substantially continuous fibers such that the latter (i.e., the metal matrix composite version of the article) has certain desired properties (e.g., Young's modulus, yield strength, and ductility) at least equal to that required for the use of the original article made from the original metal. Optionally, the article may be redesigned to have the same physical dimensions as the original article.

[0047] Examples of fourth and fifth metal matrix articles according to the present invention include brake calipers and high speed mechanical arms for industrial machinery.

BRIEF DESCRIPTION OF THE DRAWING

[0048] **FIG. 1** is a perspective view of an exemplary article according to the present invention useful for making a fourth or fifth metal matrix composite article according to the present invention.

[0049] **FIG. 1A** is a cutaway view of a portion of **FIG. 1**.

[0050] **FIGS. 2 and 3** are perspective views of an exemplary insert used in an article according to the present invention.

[0051] **FIG. 4** is a perspective view of a ceramic fiber ribbon used to make an exemplary ceramic comprising insert used in an article according to the present invention.

[0052] **FIG. 5** is a perspective view of an apparatus for making an exemplary ceramic comprising insert used in an article according to the present invention.

[0053] **FIG. 6** is a perspective view of a brake caliper with an insert holder according to the present invention and exemplary inserts.

[0054] **FIG. 7** is a plan view of an exemplary brake caliper according to the present invention.

[0055] **FIGS. 8A, 8B**, and **8**C are plan views of an exemplary insert holder according to the present invention.

[0056] **FIG. 9** is a schematic of the compressive shear test equipment used to determine the peak bond strength value between an insert and the metal of a metal matrix composite article according to the present invention made using an insert holder according to the present invention.

[0057] **FIG. 10** is an optical photomicrograph of a polished cross-section of an Example 3 metal matrix composite article of copending application having U.S. Ser. No. 60/404,672, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference.

[0058] **FIG. 11** is an optical photomicrograph of a polished cross-section of a Comparative Example H metal matrix composite article of copending application having U.S. Ser. No. 60/404,672, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference.

[0059] **FIG. 12** is a schematic of a die cavity used to make the metal matrix composite article of Example 2 made using the inserts described in Example 2.

DETAILED DESCRIPTION

[0060] First, second, third, fourth, and fifth articles according to the present invention may be, and typically are, designed for the particular application to achieve an optimal, or at least acceptable balance of, desired properties, low cost, and ease of manufacture.

[0061] Typically, First, second, third, fourth, and fifth articles according to the present invention are designed for a specific application and/or to have certain properties and/or features. For example, an existing article made of one metal (e.g., cast iron) is selected to be redesigned to be made from another metal (e.g., aluminum) reinforced with metal and/or ceramic comprising inserts such that the latter (i.e., the metal matrix composite version of the article) has certain desired properties (e.g., Young's modulus, yield strength, and ductility) at least equal to that required for the use of the original article made from the first metal. Optionally, the article may be redesigned to have the same physical dimensions as the original article.

[**0062**] The desired metal matrix composite article configuration, desired properties, possible metals and ceramic oxide material from which it may be desirable for it to be made of, as well as relevant properties of those materials are collected and used to provide possible suitable constructions. In some embodiments, a preferred method for generating possible constructions is the use of finite element analysis (FEA), including the use of FEA software run with the aid of a conventional computer system (including the use of a central processing unit (CPU) and input and output devices). Suitable FEA software is commercially available, including that marketed by Ansys, Inc., Canonsburg, Pa. under the trade designation "ANSYS". FEA assists in modeling the article mathematically and identifying regions where placement of the ceramic oxide fibers, for example, would provide the desired property levels. It is typically necessary to run several iterations of FEA to obtain a more preferred design. Such results can be used to design and prepare, for example, the holder(s) and insert(s) used to make metal matrix composite articles In some embodiments, the holder may further comprises one of more (e.g., two, three, four, five, etc.) apertures. Such apertures can be helpful, for example, during casting by allowing molten metal to flow through portions of the holder.

[**0063**] The holder can facilitate the position of reinforcement inserts when making fourth and fifth metal matrix articles according to the present invention. An exemplary holder with inserts positioned therein is shown in **FIGS. 1 and 1**A. Referring to **FIG. 1**, article according to the present invention **10** comprises holder **11** portions **12**A, **12**B, **12**C, and **12**D for securing inserts **13**A, **13**B, and **13**C. Referring to **FIG. 1**A, holder **11** comprises aluminum and/or alloy(s) thereof **14**, outer surface **15**, metal having a positive Gibbs oxidation free energy above at least 200° C. **17**, and optional additional metal (e.g., Ni) **16** and outer surface **18** of optional metal **16**.

[**0064**] The holder comprises aluminum, alloys thereof (e.g., a 200, 300, 400, 700, and/or 6000 series (in some embodiments, preferably a 6000 series) aluminum alloy)), more typically an aluminum and/or alloy(s) thereof (e.g., a 200, 300, 400, 700, or 6000 series), and combinations thereof.

[**0065**] Suitable aluminum and aluminum alloys are commercially available, for example, from Alcoa of Pittsburgh, Pa. and Belmont Metals, New York, N.Y. In some embodiments, examples of preferred aluminum alloys include alloys comprising at least 98 percent by weight Al, aluminum alloy comprises at least 1.5 percent by weight Cu (e.g., aluminum alloys comprising Cu in the range from 1.5 to 2.5, preferably, 1.8 to 2.2, percent by weight Cu, based on the total weight of the alloy), and 200 (e.g., A201.1 aluminum alloy, 201.2 aluminum alloy, A206.0 aluminum alloy, and 224.2 aluminum alloy), 300 (e.g., A319.1 aluminum alloy, 354.1 aluminum alloy, 355.2 aluminum alloy, and A356.1 aluminum alloy), 400 (e.g., 443.2 aluminum alloy and 444.2 aluminum alloy), 700 (e.g., 713 aluminum alloy), and 6000 (e.g., 6061 aluminum alloy) series aluminum alloys. In some embodiments, the holders preferably comprises a 300, 400, 6000 series aluminum alloy e.g., A319.1 aluminum alloy, 354.1 aluminum alloy, 355.2 aluminum alloy, A356.1 aluminum alloy, 443.2 aluminum alloy, 444.2 aluminum alloy, and 6061 aluminum alloy).

[**0066**] The holder can be made using conventional techniques, such as cutting a sheet of aluminum and/or alloy(s) thereof and bending the cut sheet to obtain the desired holder configuration. Optionally, the sheet can comprise, for example, a combination of aluminum and an alloy thereof or two or more different aluminum alloys, etc. For example, the sheet may comprise a sheet of aluminum laminated to, co-cast with, etc. a sheet of aluminum alloy.

[**0067**] Optionally, the holder further comprises, for example, ceramic oxide fibers to aid in reinforcing the holder. For example, if the fibers can be incorporated into a sheet during its formation. The fibers may even be selectively located in the sheet such that after the sheet is cut and bent into the desired configuration, the fibers located, for example, in selected portions of the holder. Examples of suitable fibers include those described below for making inserts.

[**0068**] Although thicknesses of the metal having a positive Gibbs oxidation free energy above at least 200° C. outside of specified values may also be useful, if the thickness is too low, the coatings tend to diffuse when the holder is preheated and consequently may not protect the interface from oxidation or otherwise aid in reducing oxidation at the interface, while excess thicknesses tend to interfere with the establishment of a desirable bond strength between the metal of the holder and the metal of the metal matrix composite article. Techniques for depositing metal having a positive Gibbs oxidation free energy above at least 200° C. are known in the art and include electroplating.

[**0069**] Typically, thicknesses of the optional Ni are greater than about 1 micrometer, more typically greater than 2 micrometers, or even greater than 3 micrometers. In another aspect, typically thicknesses of such metal are less than about 10 micrometers, more typically less than about 5 micrometers. Although thicknesses outside of these values may also be useful, if the thickness is too low, the coatings tend not be as useful in aiding the adhesion of the metal having a positive Gibbs oxidation free energy above at least 200° C. to the holder, while excess thicknesses tend to interfere with the establishment of a desirable bond strength between the metal of the holder and the metal of the metal matrix composite. In some embodiments, the Ni is deposited via electroless deposition.

[**0070**] The resulting holder can be further processed (e.g., sand blasted and/or surface ground (e.g., with a vertical spindle diamond grinder), for example to remove or reduce oxidation on the surface of the holder. The holder may also be cut as needed to provide a desired shape (including being cut with a water jet). Next, the holder is coated with metal having a positive Gibbs oxidation free energy above at least 200° C. Optionally, a metal such as Ni is coated onto the holder prior to coating the metal having a positive Gibbs oxidation free energy above at least 200° C. The use of the Ni tends to aid in the adhesion of metal such as Ag to the holder.

[**0071**] Examples of reinforcement inserts for practicing embodiments of the present invention include metal comprising reinforcement inserts (e.g., a metal matrix composite inserts) and ceramic comprising reinforcement inserts.

[0072] In some embodiments, a preferred metal matrix composite insert, comprises metal (e.g. aluminum and/or an alloy(s) thereof) and substantially continuous ceramic oxide fibers. In some embodiments, a preferred ceramic comprising insert comprises ceramic (typically porous ceramic (e.g., alpha alumina)) and substantially continuous ceramic oxide fibers. Referring to **FIG. 2**, exemplary insert **20** comprises substantially continuous (as shown, longitudinally aligned) ceramic oxide fibers **22**, ceramic or metal (e.g., aluminum and/or alloy(s) thereof) **24**, metal having a positive Gibbs oxidation free energy above at least 200° C. **26** is on outer surface **25**, and optionally additional metal (e.g., Ni) **28** is positioned between outer surface **25** and metal having a positive Gibbs oxidation free energy above at least 200° C. **26**, and has outer surface **27** such that metal having a positive Gibbs oxidation free energy above at least 200° C. **26** is on outer surface **27**.

[0073] The inserts may comprise more than one groupings (e.g., two groupings, three groupings, etc.) of substantially continuous ceramic oxide fibers, wherein a grouping of substantially continuous ceramic oxide fibers is spaced apart from another grouping(s) with, for example metal or ceramic there between. For example, referring to **FIG. 3** insert **30** comprises groupings **32**A, **32**B, and **32**C of substantially continuous, substantially continuous ceramic oxide fibers **32** and metal or ceramic **34**, aluminum and/or alloy(s) thereof **35**, outer surface **36**, metal having a positive Gibbs oxidation free energy above at least 200° C. **37**, and optional additional metal (e.g., Ni) **38** and outer surface **39** of optional metal **38**.

[0074] In some exemplary embodiments of the present invention, the substantially continuous ceramic oxide fibers are substantially longitudinally aligned such that they are generally parallel to each other. While the ceramic oxide fibers may be incorporated into the metal matrix composite inserts as individual fibers, they are more typically incorporated into the metal matrix composite inserts as a group of fibers in the form of a bundle or tow. Fibers within the bundle or tow may be maintained in a longitudinally aligned (i.e., generally parallel) relationship with one another. When multiple bundles or tows are utilized, the fiber bundles or tows are also maintained in a longitudinally aligned (i.e., generally parallel) relationship with one another. In some embodiments, it is preferred that all of the continuous ceramic oxide fibers are maintained in an essentially longitudinally aligned configuration where individual fiber alignment is maintained within ±10°, more preferably ±5°, most preferably ±3°, of their average longitudinal axis.

[0075] It is also within the scope of the present invention for the ceramic oxide fibers to be curved, as opposed to straight (i.e., do not extend in a planar manner). Hence, for example, the ceramic oxide fibers may be planar throughout the fiber length, non-planar (i.e., curved) throughout the fiber length, or they may be planar at some portions and non-planar (i.e., curved) at other portions. In some embodiments, the substantially continuous ceramic oxide fibers are maintained in a substantially non-intersecting, curvilinear arrangement (i.e., longitudinally aligned) throughout the curved portion of the metal matrix composite article. In some embodiments, the substantially continuous ceramic oxide fibers are maintained in a substantially equidistant relationship with each other throughout the curved portion of the insert.

[0076] It is also within the scope of the present invention for the ceramic oxide fibers to be present as two, three, four, or more plies (i.e., a ply is at least one layer of substantially continuous ceramic oxide fibers (in some embodiments, preferably at least one layer of tows comprising the substantially continuous ceramic oxide fibers)). The plies may be oriented with respect to each other any of a variety of ways. For example, a first ply of substantially continuous ceramic oxide fibers may be positioned between 0° and 90° with respect to second ply of substantially continuous ceramic oxide fibers. In some embodiments, preferred positioning of a ply with respect to another ply(s) for some applications may be in the range from about 30° to about 60°, or even, for example, in the range from about 40° to about 50°.

[0077] Typically, the substantially continuous ceramic oxide fibers have lengths of at least 10 cm (frequently at least 15 cm, 20 cm, 25 cm, or more). In some embodiments of the present invention, the substantially continuous ceramic oxide fibers are in the form of tows (i.e., the tows comprise the substantially continuous ceramic oxide fibers). Typically, the substantially continuous ceramic oxide fibers comprising the tow have lengths of at least 10 cm (frequently at least 15 cm, 20 cm, 25 cm, or more).

[0078] The ceramic oxide fibers can include, or even consist essentially of, substantially continuous, longitudinally aligned, ceramic oxide fibers, wherein "longitudinally aligned" refers to the generally parallel alignment of the fibers relative to the length of the fibers.

[0079] In some embodiments, the substantially continuous reinforcing ceramic oxide fibers preferably have an average diameter of at least about 5 micrometers. In some embodiments, the average fiber diameter is no greater than about 200 micrometers, preferably, no greater than about 100 micrometers. For tows of fibers, in some embodiments, the average fiber diameter is preferably, no greater than about 50 micrometers, more preferably, no greater than about 25 micrometers. in some embodiments, preferably the substantially continuous ceramic oxide fibers have a Young's modulus of greater than about 70 GPa, more preferably, at least 100 GPa, at least 150 GPa, at least 200 GPa, at least 250 GPa, at least 300 GPa, or even at least 350 GPa.

[0080] In some embodiments, preferably the continuous ceramic oxide fibers have an average tensile strength of at least about 1.4 GPa, more preferably, at least about 1.7 GPa, even more preferably, at least about 2.1 GPa, and most preferably, at least about 2.8 GPa, although fibers with lower average tensile strengths may also be useful, depending on the particular application.

[0081] Continuous ceramic oxide fibers are available commercially as single filaments, or grouped together (e.g., as yarns or tows). Yarns or tows may comprise, for example, at least 420 individual fibers per tow, at least 760 individual fibers per tow, at least 2600 individual fibers per tow, or more. Tows are well known in the fiber art and refer to a plurality of (individual) fibers (typically at least 100 fibers, more typically at least 400 fibers) collected in an aligned untwisted form, whereas yarns imply some degree of twist or rope-like construction. Ceramic oxide fibers, including tows of ceramic oxide fibers, are available in a variety of lengths. The fibers may have a cross-sectional shape that is circular or elliptical.

[0082] Examples of useful ceramic oxide fibers include alpha alumina fibers, aluminosilicate fibers, and aluminoborosilicate fibers. Other useful ceramic oxide fibers may be apparent to those skilled in the art after reviewing the present disclosure.

[0083] Methods for making alumina fibers are known in the art and include the method disclosed in U.S. Pat. No. 4,954,462 (Wood et al.), the disclosure of which is incorporated herein by reference. In some embodiments, preferably the alumina fibers are polycrystalline alpha alumina-based fibers and comprise, on a theoretical oxide basis, greater than about 99 percent by weight Al_2O_3 and about 0.2-0.5 percent by weight SiO_2, based on the total weight of the alumina fibers. In another aspect, in some embodiments, preferable polycrystalline, alpha alumina-based fibers comprise alpha alumina having an average grain size of less than 1 micrometer (more preferably, less than 0.5 micrometer). In another aspect, in some embodiments, preferable polycrystalline, alpha alumina-based fibers have an average tensile strength of at least 1.6 GPa (preferably, at least 2.1 GPa, more preferably, at least 2.8 GPa). Alpha alumina fibers are commercially available, for example, under the trade designation "NEXTEL 610" from the 3M Company of St. Paul, Minn. Another alpha alumina fiber, which comprises about 89 percent by weight Al_2O_3, amount 10 percent by weight ZrO_2, and about 1 percent by weight Y_2O_3, based on the total weight of the fibers, is commercially available from the 3M Company under the trade designation "NEXTEL 650".

[0084] Methods for making aluminosilicate fibers are known in the art and include the method disclosed in U.S. Pat. No. 4,047,965 (Karst et al.), the disclosure of which is incorporated herein by reference. In some embodiments, preferably the aluminosilicate fibers comprise, on a theoretical oxide basis, in the range from about 67 to about 85 percent by weight Al_2O_3 and in the range from about 33 to about 15 percent by weight SiO_2, based on the total weight of the aluminosilicate fibers. In some embodiments, preferable aluminosilicate fibers comprise, on a theoretical oxide basis, in the range from about 67 to about 77 percent by weight Al_2O_3 and in the range from about 33 to about 23 percent by weight SiO_2, based on the total weight of the aluminosilicate fibers. In some embodiments, preferable aluminosilicate fibers comprise, on a theoretical oxide basis, about 85 percent by weight Al_2O_3 and about 15 percent by weight SiO_2, based on the total weight of the aluminosilicate fibers. In some embodiments, preferable aluminosilicate fibers comprise, on a theoretical oxide basis, about 73 percent by weight Al_2O_3 and about 27 percent by weight SiO_2, based on the total weight of the aluminosilicate fibers. Aluminosilicate fibers are commercially available, for example, under the trade designations "NEXTEL 440", "NEXTEL 720", and "NEXTEL 550" from the 3M Company.

[0085] Methods for making aluminoborosilicate fibers are known in the art and include the method disclosed in U.S. Pat. No. 3,795,524 (Sowman), the disclosure of which is incorporated herein by reference. In some embodiments, preferably the aluminoborosilicate fibers comprise, on a theoretical oxide basis: about 35 percent by weight to about 75 percent by weight (or even, for example, about 55 percent by weight to about 75 percent by weight) Al_2O_3; greater than 0 percent by weight (or even, for example, at least about 15 percent by weight) and less than about 50 percent by weight (or, for example, less than about 45 percent, or even less than about 44 percent) SiO_2; and greater than about 5 percent by weight (or, for example, less than about 25 percent by weight, less than about 1 percent by weight to about 5 percent by weight, or even less than, about 2 percent by weight to about 20 percent by weight) B_2O_3, based on the total weight of the aluminoborosilicate fibers. Aluminoborosilicate fibers are commercially available, for example, under the trade designation "NEXTEL 312" from the 3M Company.

[0086] Commercially available substantially continuous ceramic oxide fibers often include an organic sizing material added to the fiber during their manufacture to provide lubricity and to protect the fiber strands during handling. It is believed that the sizing tends to reduce the breakage of fibers, reduces static electricity, and reduces the amount of dust during, for example, conversion to a fabric. The sizing can be removed, for example, by dissolving or burning it away.

[0087] It is also within the scope of the present invention to have coatings on the ceramic oxide fibers. Coatings may be used, for example, to enhance the wettability of the fibers, to reduce or prevent reaction between the fibers and molten metal matrix material. Such coatings and techniques for providing such coatings are known in the fiber ceramic composite, and metal matrix composite art.

[0088] With regard to metal comprising inserts, in some embodiments, metal matrix composite inserts comprise substantially continuous ceramic oxide fibers. Typically, aluminum and/or alloy(s) thereof extends along at least a portion of the length of the substantially continuous ceramic oxide and secures the ceramic oxide fibers in place.

[0089] Although the aluminum and aluminum alloys used to make, and which comprise, metal comprising inserts, including metal matrix composite inserts, may contain impurities, in some embodiments it may be preferable to use relatively pure metal (i.e., metal comprising less than 0.1 percent by weight, or even less than 0.05 percent by weight impurities (i.e., less than 0.25 percent 0.1 percent, or even less than 0.05 percent by weight of each of Fe, Si, and/or Mg)). Although higher purity metals tend to be preferred for making higher tensile strength materials, less pure forms of metals are also useful.

[0090] Suitable aluminum and aluminum alloys are commercially available. For example, aluminum is available under the trade designation "SUPER PURE ALUMINUM; 99.99% Al" from Alcoa of Pittsburgh, Pa. Aluminum alloys (e.g., Al-2% by weight Cu (0.03% by weight impurities) can be obtained from Belmont Metals, New York, N.Y. In some embodiments, the inserts preferably comprise a 200 series aluminum alloy (e.g., A20 1.1 aluminum alloy, 201.2 aluminum alloy, A206.0 aluminum alloy, and 224.2 aluminum alloy).

[0091] In some embodiments, first, second and third articles according to the present invention that include metal matrix composite inserts comprise, in the region(s) comprising the substantially continuous ceramic fibers, in the range from about 30 to about 45 percent (in some embodiments, preferably about 35 to about 45 percent, more preferably, about 35 to about 40 percent) by volume metal and in the range from about 70 to about 55 percent (preferably about 65 to about 55 percent, more preferably, about 60 to about 65 percent) by volume of the continuous ceramic oxide fibers, based on the total volume of the region. Further, the region comprising the metal which secures the substantially continuous ceramic oxide fibers, typically comprises in the range from about 20 to about 95 percent (preferably about 60 to about 90 percent, more preferably, about 80 to about 85 percent) by volume metal and in the range from about 80 to about 5 percent (in some embodiments, preferably about 60 to about 10 percent, more preferably, about 15 to about 5 percent) by volume metal, based on the total volume of the region.

[0092] In some embodiments, inserts comprise the substantially continuous ceramic oxide fibers, in the range from about 30 to about 70 percent (in some embodiments, preferably about 35 to about 60 percent, or even about 35 to about 45 percent) by volume metal and in the range from about 70 to about 30 percent (in some embodiments, preferably about 65 to about 40 percent, or even about 65 to about 55 percent) by volume substantially continuous ceramic oxide fibers, based on the total volume of the insert. In some embodiments, preferably the inserts comprise at least 50 by volume of the substantially continuous ceramic oxide fibers, based on the total volume of the insert.

[0093] For first, second and third articles according to the present invention that include metal matrix composite inserts, the fiber and metal volume content of the inserts in the substantially continuous fiber region is generally governed by the desired to produce a homogeneous composite without significant movement of the substantially continuous ceramic oxide fibers during the metal infiltration. If the fiber content is too low, it is more difficult to prevent or minimize movement of the substantially continuous fibers during the metal infiltration. In some embodiments, the metal comprising the insert is preferably selected such that the matrix material does not significantly react chemically with the ceramic oxide material, (i.e., is relatively chemically inert with respect to the metallic, refractory material), particularly the substantially continuous ceramic oxide fibers, for example, to eliminate the need to provide a protective coating on the fiber exterior.

[0094] Metal matrix composite inserts can be made, for example, by winding a plurality of continuous ceramic oxide fibers (in some embodiments, preferably grouped together (e.g., as yarns or tows)) onto a mandrel having the desired dimension and shape for the intended metal insert design. In some embodiments, preferably the fibers being wound are sized. Exemplary sizes include water (in some embodiments, preferably deionized water), wax (e.g., paraffin), and polyvinyl alcohol (PVA). If the sizing is water, the fiber is typically wound onto the mandrel. After winding is completed, the mandrel is removed from the winder and then placed in a refrigerated cooler until the wound fiber freezes. The frozen, wound fiber can be cut as needed. For example, if the fiber is wound around a mandrel made up of four contiguous plates, the rectangular plates can be removed to provide a frozen, fiber preform. The preform can be cut into pieces to provide small preforms. Typically the sizing is removed before it is used to form a metal matrix composite insert. The sizing can removed, for example, by placing the formed fiber into a die (in some embodiments, preferably graphite), and then heating the die. The die is used to make the metal matrix composite insert.

[0095] To form the metal matrix composite insert, after the sizing is removed, if present, a die is placed in a can, typically a stainless steel can, preferably open only at one end. The interior of the can in some embodiments is preferably coated with boron nitride or a similar material to protect, minimize reaction between the aluminum/aluminum alloy and the can during the subsequent casting, and/or facilitate release of the metal matrix composite article from the mold. The can with the die within is placed inside the pressure vessel of a pressure casting machine. Subsequently, aluminum and/or aluminum alloy (e.g. pieces of aluminum and/or an aluminum alloy cut from an ingot) is placed on top of the can. The pressure vessel is then evacuated of air and heated above the melting point of the aluminum/aluminum alloy (typically about 80° C. to about 120° C. above the liquidus temperature). Upon reaching the desired temperature, the heater is turned off and the pressure vessel is then pressurized with typically argon (or a similar inert gas) to a pressure of about 8.5 to about 9.5 MPa, forcing the molten aluminum/aluminum alloy to infiltrate the preform. The pressure in the pressure vessel is allowed to decay slowly as the temperature falls. When the article solidifies (i.e., its temperature drops below about 500° C.), chamber is vented, and the cast metal matrix composite article(s) (e.g., insert(s)) is removed from the die(s), and then allowed to further cool in air.

[0096] Metal matrix composite articles (e.g., insert) can also be made, for example, by other techniques known in the art, including squeeze casting. For squeeze casting, for example, the formed ceramic oxide fiber can be placed in a die (e.g., a steel die), any sizing present burned away, molten aluminum/aluminum alloy introduced into the die cavity, and pressure applied until solidification of the cast article is complete. After cooling, the resulting metal matrix composite article insert is removed from the die.

[0097] The resulting insert can be further processed (e.g., sand blasted and/or surface ground (e.g., with a vertical spindle diamond grinder), for example to remove or reduce oxidation on the surface of the insert. The insert may also be cut as needed to provide a desired shape (including being cut with a water jet).

[0098] It is within the scope of the present invention to make metal matrix composites comprising inserts from ceramic comprising inserts, such as those described below.

[0099] In some embodiments, preferably metal matrix composite inserts are coated with metal having a positive Gibbs oxidation free energy above at least 200° C. A metal such as Ni may be coated onto the metal matrix composite article insert prior to coating the metal having a positive Gibbs oxidation free energy above at least 200° C. The use of the Ni tends to aid in the adhesion of metal such as Ag to the insert.

[0100] Although thicknesses of the metal having a positive Gibbs oxidation free energy above at least 200° C. outside of specified values may also be useful, if the thickness is too low, the coatings tend to diffuse when the insert is preheated and consequently may not protect the interface from oxidation or otherwise aid in reducing oxidation at the interface, while excess thicknesses tend to interfere with the establishment of a desirable bond strength between the two metal of the insert and the metal of the metal matrix composite article.

[0101] Typically, thicknesses of the optional Ni are greater than about 1 micrometer, more typically greater than 2 micrometers, or even greater than 3 micrometers. In another aspect, typically thicknesses of such metal are less than about 10 micrometers, more typically less than about 5 micrometers. Although thicknesses out side of these values may also be useful, if the thickness is too low, the coatings tend not be as useful in aiding the adhesion of the metal having a positive Gibbs oxidation free energy above at least 200° C. to the insert, while excess thicknesses tend to interfere with the establishment of a desirable bond strength between the metal of the insert and the metal of the metal matrix composite.

[0102] For additional details on embodiments of metal matrix composite inserts see copending application having U.S. Ser. No. 60/404,672, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference.

[0103] With regard to ceramic comprising inserts, in some embodiments, preferred embodiments include porous ceramic oxide (e.g., calcined or sintered) inserts comprising substantially continuous ceramic oxide fibers. Typically, porous ceramic oxide extends along at least a portion of the length of the substantially continuous ceramic oxide and secures the ceramic oxide fibers in place. In some embodiments, the substantially continuous ceramic oxide fibers have a first, Young's modulus, and ceramic oxide material comprising the ceramic preform has a second Young's modulus, wherein the first Young's modulus is greater than the second Young's modulus.

[0104] Continuous reinforcing fibers in the form of woven, knitted, and the like fiber constructions typically are not capable of achieving the higher fiber packing densities realized with longitudinally aligned fibers. Thus, metal infiltrated articles based on preforms utilizing woven, knitted, or the like fiber constructions typically exhibit lower strength properties than metal infiltrated articles having longitudinally aligned continuous reinforcing fibers and hence are less preferred.

[0105] Porous ceramic oxide comprising inserts can be made, for example, by casting a slurry of discontinuous ceramic oxide fibers (including whiskers) around the substantially continuous fibers. Typically, the substantially continuous fibers are positioned in a cavity (e.g., mold), and the slurry added to the mold. The substantially continuous fibers are positioned within the cavity such that they will be properly positioned in the resulting ceramic oxide material. The cavity is configured to provide the desired shape, although it is also within the scope of the present invention to reshape the resulting ceramic oxide material, for example, by machining, to provide the desired configuration of the ceramic oxide comprising insert.

[0106] Suitable discontinuous ceramic oxide fibers (including whiskers) include those made of alumina, including alpha alumina and transitional aluminas (such as delta alumina), aluminosilicate fibers, and aluminoborosilicate fibers, and methods of making and/or sources of such materials, are known in the art. Discontinuous fibers can be made, for example, by cutting or chopping continuous fibers (including the substantially continuous fibers discussed above). Examples of commercially available discontinuous ceramic oxide fibers include those marketed under the trade designation "SAFFIL" from J&J Dyson, Widness, UK, "KAOWOOL" from Thermal Ceramics Inc., Augusta, Ga., and "FIBERFRAX" from Unifrax, Niagara Falls, N.Y.

[0107] In some embodiments, the discontinuous fibers have a diameter in the range from about 1 micrometer to about 20 micrometers, preferably, from about 3 micrometers to about 12 micrometers, and are up to about 2.5 cm long, preferably, less than 1.2 cm long, although whiskers typically have a length in the range from about 6 micrometers to about 12 micrometers long.

[0108] Optionally, the slurry may further comprise ceramic oxide particles such as alumina (including alpha alumina) particles, aluminosilicate particles, and aluminoborosilicate particles. In some embodiments, the preferred average particle size of the particles is in the range from about 0.05 micrometer to about 50 micrometers. The slurry may further comprise ceramic oxide bonding materials such as colloidal silica, colloidal alumina, and the like which can aid in enhancing the integrity (e.g., by reaction with other components used to make the porous ceramic oxide preform to make other phases (e.g., the silica may react with alumina to form mullite)).

[0109] Suitable slurries can be formed using techniques known in the art. Typically, slurries are formed by dispersing discontinuous fibers in a liquid medium such as water. To aid in the handling and positioning of the substantially continuous fibers, a fiber insert (e.g., ribbon) can be used. A fiber insert comprises a plurality of the substantially continuous fibers held together with a binder material. Referring to **FIG. 4**, fiber ribbon **40l** comprises substantially continuous, longitudinally aligned, alpha alumina fibers **42** and fugitive binder material **44**, which serves to secure fibers **42** (as shown in tows **43)** into fiber ribbon **40**. Binder material **44** contacts the fibers only to the extent necessary to form fiber ribbon **40**, and may not necessarily be in contact with all fibers. For example, internal fibers may not be in contact with the binder material.

[0110] In selecting the binder material for making a fiber insert, consideration is given to adverse effects, if any, the binder material may have on the properties of the ceramic oxide comprising insert, as well as the impact, if any, the binder material may have on the use of the ceramic oxide comprising insert (e.g., consideration is given to adverse effects, if any, the binder material may have on the properties of a metal matrix composite article made using the ceramic oxide comprising insert).

[0111] The binder material is used to temporarily bond the substantially continuous fibers together, as well as aid in handling and ultimately placing the fibers in the ceramic oxide comprising insert. In some embodiments, the binder material may preferably be a fugitive material, which preferably bums out at relatively low temperature during the calcining stage of the pre-form fabrication process leaving no residue or ash. In some embodiments, a preferred fugitive binder material is wax (e.g., paraffin), which can be heated above its melting point, applied to the fibers, and then solidified to hold the fibers as desired. In some embodiments, a preferred fugitive binder materials include water soluble polymers such as polyvinyl alcohol (PVA), polyvinyl pyrrolidone (PVP), and combinations thereof. Other suitable fugitive binder materials may include epoxies such as that marketed by Cytec Industries, West Patterson, N.J.

(formerly marketed by the 3M Company, St. Paul, Minn., under the trade designation "SP381 SCOTCHPLY ADHESIVE").

[0112] The ceramic comprising insert is typically designed for a certain purpose, and as a result, is desired to have certain properties, have a certain configuration, and be made of certain materials. Typically, the mold is selected or made to provide the desired shape of the ceramic comprising insert. Forming a net-shaped, or near net-shaped ceramic comprising insert, can, for example, minimize or eliminate the need for and cost of subsequent machining or other post-casting processing of the insert. The cavity is selected or made to have a desired shape for the resulting ceramic comprising insert. Typically, the cavity is made or adapted to hold the substantially continuous fibers in a desired location such that the substantially continuous fibers are properly positioned in the resulting ceramic comprising insert. Techniques for making suitable cavities are known to those skilled in the art. Such cavities may be made of rigid material such as of wood, plastic, graphite, and steel (e.g., stainless steel). To facilitate the removal of liquid from the slurry, one or more apertures can be provided in the mold.

[0113] A ceramic comprising insert can be made, for example, by positioning the substantially continuous fiber in a cavity, introducing a slurry comprising discontinuous ceramic oxide fibers into the cavity, and removing liquid from slurry. Typically, the liquid is removed via apertures in the cavity. Removal of the liquid through the apertures can be enhanced by reducing the pressure outside the cavity (e.g., less than 1000 mbars, in some embodiments preferably, less than 850 mbars).

[0114] Unless the green insert is dried in the cavity, it is typically dried after removal from the cavity before calcining or sintering. In some embodiments, preferably, the green insert is dried to at least one temperature in the range from about 70° C. to about 100° C., more preferably, from about 85° C. to about 100° C., and typically most preferably, at about 100° C.

[0115] The green insert is typically calcined prior to sintering. Calcining is heating a material to a temperature(s) to eliminate free water, and in some embodiments, preferably at least about 90 wt-% of any bound volatiles constituents, but without fusion, as opposed to sintering.

[0116] Typical calcining temperatures are in the range from 400° C. to about 800° C., in some embodiments, preferably from about 600° C. to about 800° C. Typical sintering temperatures are in the range from 900° C. to about 1150° C., in some embodiments, preferably from about 950° C. to about 1100° C., more preferably from about 950° C. to about 1100° C.

[0117] The drying, calcining, and sintering times may depend, for example, on the materials involved, as well as the configuration (including size) of the ceramic comprising insert.

[0118] The orientation of the discontinuous fibers with respect to the length of the substantially continuous fibers may be adjusted by the fabrication process used to make the ceramic comprising insert. For example, the positioning apertures in the bottom of the cavity used to hold the slurry to preferentially remove the liquid from the bottom (or top) of the cavity (as opposed to the sides) may result in the largest dimension of the discontinuous fibers preferentially being more perpendicular to the length of continuous fibers positioned parallel to the lengths of the sides of the cavity than parallel. For example, referring to **FIG. 5**, fiber ribbon **51**, which comprises plurality of the substantially continuous ceramic oxide fibers **52** held together with binder material **53**, is positioned in cavity **54**. The length of continuous fibers **52** is parallel to sides of cavity **54**, and perpendicular to bottom **56** of cavity **54**. Liquid from slurry **57** is removed from via apertures **58**, such that the largest dimension of discontinuous fibers preferentially being more perpendicular to the length of continuous fibers **52** than parallel.

[0119] Preferably, removal of the liquid is aided by reducing pressure outside of the mold. For example, a fiber insert may be affixed in the mold such that it held in the desired location by clips at each end of the fiber insert. In one exemplary technique, a screen is placed on one side of the mold for water removal under reduced pressure (e.g., in some embodiments less than 1000 mbars). The placement of the screen is determined by the desired orientation of the discontinuous fibers. For example, if it is desired to preferentially align discontinuous fibers to be perpendicular to the lengths of continuous, longitudinally aligned fibers, the screen can be positioned at one of the ends of the fiber lengths, perpendicular to the length of the fibers. The slurry can be added, for example, by submersing the mold in the slurry, then removing or pumping the slurry from the mold. A reduced pressure can be applied to the screen side of the mold to draw out the liquid. When the liquid is removed, the discontinuous fibers are preferentially aligned with respect to the lengths of the substantially continuous fibers. Subsequent pressure may be applied to the fibers to force out more water, and may also aid in densifying the discontinuous fiber.

[0120] Similarly, for example, positioning apertures or holes in the sides of the cavity used to hold the slurry to preferentially remove the liquid from the sides of the cavity (as opposed to the top and bottom) may result in the largest dimension of the discontinuous fibers preferentially being more perpendicular to the length of continuous fibers positioned perpendicular to the lengths of the sides of the cavity than parallel.

[0121] For additional details regarding the formation of ceramic comprising inserts, see, for example, U.S. Pat. No. 5,394,930 (Kennerknecht) and Great Britain Pat. Doc. Nos. 2,182,970 A and B. published May 28, 1987 and Sep. 14, 1988, respectively, copending U.S. applications having Ser. Nos. 09/966,946, 09/967,401, and 09/9677,562, filed Sep. 27, 2001, and PCT applications having publication nos. WO 02/26658, WO 02/27048, and WO 02/27049, published Apr. 4, 2002, the disclosures of which are incorporated herein by reference. Other techniques and other preferred conditions may be apparent those skilled in the art after reviewing the disclosure herein.

[0122] First, second, and third articles according to the present invention can be used to make fourth and fifth metal matrix composites composite articles according to the present invention. An example of a fifth metal matrix composite article according to the present invention is brake caliper for a vehicle (e.g., a motor vehicle such as a car, sports utility vehicle, van, or truck). Referring to **FIG. 6**, exemplary brake caliper **60** comprises insert holder **61** and inserts **62**A and **62**B.

[**0123**] Typically, fourth and fifth metal matrix composite articles according to the present invention comprise, in the region comprising the substantially continuous ceramic fibers, in the range from about 30 to about 45 percent (in some embodiments, preferably about 35 to about 45 percent, more preferably, about 35 to about 40 percent) by volume metal and in the range from about 70 to about 55 percent (in some embodiments, preferably about 65 to about 55 percent, more preferably, about 60 to about 65 percent) by volume continuous ceramic oxide fibers, based on the total volume of the region. Further, the region comprising the ceramic oxide material and/or metal, as applicable, which secures the substantially continuous ceramic oxide fibers, typically comprises in the range from about 20 to about 95 percent (in some embodiments, preferably about 60 to about 90 percent, more preferably, about 80 to about 85 percent) by volume metal and in the range from about 80 to about 5 percent (in some embodiments, preferably about 60 to about 10 percent, more preferably, about 15 to about 5 percent) by volume of the ceramic oxide material and/or metal, based on the total volume of the region.

[**0124**] In some embodiments, inserts comprise the substantially continuous ceramic oxide fibers, in the range from about 30 to about 70 percent (in some embodiments, preferably about 35 to about 60 percent, or even about 35 to about 45 percent) by volume metal and in the range from about 70 to about 30 percent (in some embodiments, preferably about 65 to about 40 percent, or even about 65 to about 55 percent) by volume substantially continuous ceramic oxide fibers, based on the total volume of the insert. In some embodiments, preferably the inserts comprise at least 50 by volume of the substantially continuous ceramic oxide fibers, based on the total volume of the insert.

[**0125**] The fiber and metal volume content of the fourth and fifth metal matrix composite articles in the substantially continuous fiber region is generally governed by the desired to produce a homogeneous composite without significant movement of the substantially continuous ceramic oxide fibers during the metal infiltration. If the fiber content is too low, it is more difficult to prevent or minimize movement of the substantially continuous fibers during the metal infiltration. For inserts comprising discontinuous fibers, in the discontinuous fiber region, the fiber and metal volume content of the composite is, in general, governed by balance between increased strength and stiffness versus decreased ductility and machinability.

[**0126**] The particular fibers, matrix material(s), holder, etc. and process steps for making metal matrix composite articles are selected to provide metal matrix composite articles with the desired properties. For example, the fibers and metal matrix materials are selected to be sufficiently compatible with each other and the article fabrication process in order to make the desired article. The metal comprising the metal matrix composite in some embodiments is preferably selected such that the matrix material does not significantly react chemically with the ceramic oxide material, (i.e., is relatively chemically inert with respect to the metallic, refractory material), particularly the substantially continuous ceramic oxide fibers, for example, to eliminate the need to provide a protective coating on the fiber exterior.

[**0127**] Additional details regarding some techniques for making aluminum and aluminum alloy matrix composites are disclosed, for example, in co-pending applications having U.S. Ser. Nos. 08/492,960, filed Jun. 21, 1995 and 09/616,589, 09/616,593, and 09/616,594, filed Jul. 14, 2000, 60/404,672, filed Aug. 20, 2002, and PCT application having publication No. WO 97/00976, published Jan. 9, 1997, the disclosures of which are incorporated herein by reference.

[**0128**] The metal comprising a metal comprising insert, holder, and/or metal of a fourth or fifth metal matrix composite articles according to the present invention may be the same or different. In some embodiments, the holder preferably comprises a 6000 series aluminum alloy and the metal of the fourth or fifth metal matrix composite articles according to the present invention comprises a 6000 series aluminum alloy. If the insert is a metal comprising insert, in some embodiments, the metal comprising the insert is preferably a 200 series metal.

[**0129**] Fourth and fifth metal matrix composite articles according to the present invention can be made using first, second, and third articles according to the present invention using techniques known in the art (e.g., squeeze casting and permanent tool gravity casting). For porous inserts, such fabrication includes infiltrating the porous insert with molten metal. Finite Element Analysis (FEA) modeling can be used, for example, to identify optimal positions and quantities of the ceramic oxide fiber for meeting desired performance specifications. Such analysis can also be used, for example, to aid in selecting the configuration, composition, number, and location, for example of the first, second, and third article(s) according to the present invention used. Typically, the insert(s) and/or die is preheated prior to casting. Although not wanting to be bound by theory, it is believed that preheating the first, second, and third fourth article(s) according to the present invention facilitates desirable metallurgical bonding between the holder and/or insert(s) and the aluminum or aluminum alloy of the fourth or fifth metal matrix composite articles. In some embodiments of metal comprising inserts, preferably the insert(s) is preheated to about 500° C.-600° C. In some embodiments of ceramic comprising inserts, preferably the insert(s) is preheated to about 750° C.-800° C. In some embodiments, preferably the die is preheated to 200° C.-500° C. Although casting can typically be conducted in air, it is also within the scope of the present invention to cast in other atmospheres (e.g., argon).

[**0130**] FEA, may also be used, for example, to aid in choosing a casting technique, casting conditions, and/or mold design for casting an insert and/or metal matrix composite article according to the present invention. Suitable FEA software is commercially available, including that marketed by UES, Annapolis, Md., under the trade designation "PROCAST". As discussed above, the articles according to the present invention are typically designed for a certain purpose, and as a result, it is desired to have certain properties, to have a certain configuration, be made of certain materials, etc. Typically, the mold is selected or made to provide the desired shape of the fourth or fifth metal matrix composite articles to be cast so as to provide a net shape or near net shape. Net-shaped or near net-shaped articles, can, for example, minimize or eliminate the need for and cost of subsequent machining or other post-casting processing of a cast metal matrix composite articles. Typically, the mold is made or adapted to hold the insert(s) in a desired location(s) such that the substantially continuous ceramic oxide fibers are properly positioned in the resulting metal matrix composite articles. Techniques and materials for making suitable cavities are known to those skilled in the art. The material(s) from which a particular mold may be made depends, for example, on the metal used to make the metal matrix composite articles. Commonly used mold materials include graphite or steel.

[0131] Again, surprisingly, first, second, and third articles according to the present invention can be used to make metal matrix composite articles wherein the molten metal in the mold is in the molten state for less than 75 seconds (in some embodiments, preferably, less than 60 seconds). Although longer times for keeping the molten metal in the mold in the molten state may also be useful, the shorter times (i.e., less than 75 seconds), and although not wanting to be bound by theory, it is believed that the longer times may lead to deformation of the holder and/or metal comprising insert(s). In some embodiments, preferably the holder and insert do not significantly deform during the casting of a metal matrix composite article (i.e., the holder and insert(s) have first outer dimensional configuration (i.e., size and shape) prior to casting, and second outer dimensional shapes after casting, wherein the respective first and second outer dimensional configurations are the same, and wherein it is understood that the metal having a positive Gibbs oxidation free energy above at least 200° C. and optional metal such as Ni tend to diffuse into the metal of the casting metal (and possibly the metal of the insert)).

[0132] For metal matrix composite article having a higher than desired amount of oxidation at the interface between the insert(s) and the metal cast around the insert, the article may be further processed using hot isostatic pressing (HIPing) to reduce or remove the undesired oxidation. HIPing may also be used to reduce the porosity, if any, in the metal matrix composite article. Techniques for HIPing are well known in the art. Examples of HIPing temperatures, pressures, and times that may be useful for embodiments of the present invention include 500° C. to 600° C., 25MPa to 50 MPa, and 4 to 6 hours, respectively. Temperatures, pressures, and times outside of these ranges may also be useful. Lower temperatures tend, for example, to provide less densification and/or increase the HIPing time, whereas higher temperatures may deform the metal matrix composite article. Lower pressures tend, for example, to provide less densification and/or increase the HIPing time, whereas higher pressures tend, for example, to be unnecessary or in some cases, may even damage the metal matrix article. Shorter times tend, for example, to provide less densification, whereas longer times may, for example, be unnecessary.

[0133] For additional details on exemplary inserts and techniques for making metal matrix composite articles see copending application having U.S. Ser. No. 60/404,704, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference.

[0134] Other techniques for making metal matrix composite articles may be apparent to those skilled in the art after reviewing the instant disclosure.

[0135] Additional details regarding making metal matrix composites can be found, for example, in U.S. Pat. Nos. 4,705,093 (Ogino) and 5,234,080 (Pantale), and 5,394,093 (Kennerknecht), the disclosures of which are incorporated herein by reference.

[0136] Further, for additional details regarding the formation of ceramic comprising inserts, and metal matrix composite article made from ceramic oxide pre-forms see, for example, U.S. applications having Ser. Nos. 09/966,946; 09/967,401; and 09/9677,562; filed Sep. 27, 2001 (and claiming priority to provisional applications nos. 60/236, 091; 60/236,092; and 60/236,110; respectively, all filed Sep. 28, 2000), and PCT applications having publication nos. WO 02/26658, WO 02/27048, and WO 02/27049, published Apr. 4, 2002), the disclosures of which are incorporated herein by reference.

[0137] Embodiments of some metal matrix composite articles according to the present invention have a "Peak Bond Strength Value" between the insert or holder, as applicable (i.e., depending on which one is being tested), and the aluminum or aluminum alloy cast around the insert as determined by the following "Peak Bond Strength Value Test" of at least 100 MPa (in some embodiments, preferably at least 125 MPa, at least 150 MPa, at least 175, or even at least 180 MPa). A schematic of the compressive shear test equipment is shown in **FIG. 9**, wherein compressive shear test equipment **140** includes pushout tool **141**, test sample **142**, support block **143**, and 100,000 Newton (22,482 pounds) compressive load cell **147**. The metal matrix composite to be tested is cross-sectioned perpendicular to the longitudinal axis of the insert or holder, as applicable; the thickness of the cross-section for the insert is 1.16 cm (0.46 inch), the thickness of the cross-section for the holder is 0.4 cm, and the diameter of either 2.5 cm (1 inch).

[0138] Pushout tool **141** has a corresponding cross-section at the point of contact with insert or holder, as applicable, **144** with test sample **142**, except the cross-sectional area of pushout tool **141** is 10 percent less (i.e., the shape of the cross-section of pushout tool **141** and insert or holder, as applicable, **144** is the same, but the size of the cross-section of pushout tool **144** is less). Pushout tool **141** is clamped in upper jaws **145** of the hydraulic chuck with a hydraulic pressure of 10.34 MPa (1500 pounds per square inch). Support block **143** has a 2.54 cm (1.0 inch) diameter by 0.15 cm (0.06 inch) deep counterbore. A 1.1 cm (0.435 inch) diameter through hole is placed on top of the open jaws **145** of the bottom of hydraulic chuck **146**.

[0139] Sample to be tested **142** is placed on top of support block **143** and nested in the counterbore for centering of the insert or holder, as applicable, over the through hole. Bottom **148** of hydraulic chuck support **146** is raised until the gap between the upper pushout tool **141**, and the insert or holder, as applicable, to be pushed out (i.e., sample to be tested **144**), is 0.025 cm. (0.01 inch). The exposed insert or holder, as applicable, in the test specimen is then visually positioned with the matching tip of pushout tool **141** by manually sliding support block **143** horizontally and rotationally until the cross-sections of the two elements match.

[0140] The test is then conducted by moving the lower hydraulic support chuck up toward fixed pushout tool **141** at a rate of 0.05 cm (0.020 inch) per minute while simultaneously monitoring the load and deflection. The insert or holder, as applicable, is thereby brought into contact with the fixed pushout tool face and the contact force between the two recorded as a function of displacement. The test is discontinued shortly after the peak force is reached and a total deflection of about 0.05 cm (0.020 inch) is obtained.

[0141] After completion of the test, the specimen is examined under an optical microscope at 100× magnification to verify that the test insert or holder, as applicable, and pushout tip were properly aligned such that their cross-sections were overlapping.

[0142] The average shear stress is calculated using the following formula:

$$\text{Average Shear Stress} = \frac{\text{Load at first slippage, } N \text{ lbs.)}}{\text{Area of contact between insert and aluminum alloy, m}^2 \text{ (in}^2\text{).}}$$

[0143] The loads are plotted as a function of the insert displacement. The load at which the pushout curve has a discontinuity (i.e., where there is initial slippage at the interface between the insert or holder and the aluminum or aluminum alloy cast around the insert or holder, as applicable) is a peak bond strength value.

[0144] The Peak Bond Strength is calculated using Finite Element Analysis (FEA). Finite Element Analysis (FEA) software (available under the trade designation "ANSYS" from Ansys Inc., Canonsburg, Pa.) is used to model the insert or holder, as applicable, and show that the ratio of peak bond strength to measured average shear stress is approximately 3.0.

[0145] The FEA calculation is done as follows. A finite element model of the test specimen geometry is created. The insert or holder, as applicable, is meshed with elements of dimension 0.02 cm by 0.02 cm by 0.05 cm (0.01 inch by 0.01 inch by 0.02 inch) cubes, except at the top of the insert or holder, as applicable, where the mesh size is 0.02 cm in all dimensions. The aluminum/aluminum alloy cast around the insert or holder, as applicable, is meshed with cubes having sides of 0.05 cm (0.02 inch) near the insert or holder, as applicable, and 0.10 cm (0.04 inch) elsewhere in the modeled test specimen. The FEA software computes the shear stress at points along the surface of the insert or holder, as applicable, for an applied pressure of 533.3 MPa (corresponding to a pushout test load of 2900 pounds). The calculation determines that the peak shear stress across all points of the surface of the insert or holder, as applicable, and the average across the insert surface or holder surface, as applicable. The ratio of Peak Bond Strength to average shear stress is thus about 3 to 1.

[0146] Embodiments of some metal matrix composite articles according to the present invention are free of oxygen at the interface between the insert or holder and the aluminum or aluminum alloy cast around the insert or holder as determined by the following "Oxygen Layer Test". A portion of a metal matrix composite article is cut to obtain a cross-section of the insert or holder and the aluminum or aluminum alloy cast around the insert or holder. Then cross-section is polished with semi-automatic metallographic grinding/polishing equipment (obtained under the trade name "ABRAMIN" from Struers, Inc, Cleveland, Ohio). The polishing speed is 150 rpm. The polishing is done in the following successive 6 stages. The polishing force is 150 N, except in Stage 6 it is 250 N:

[0147] Stage 1

[0148] The sample is polished for 45 seconds using 120 grit silicon carbide paper (obtained from Pace Technologies, Northbrook, Ill.) while continuously, automatically dripping water onto abrasive pad during polishing. After polishing, the sample is thoroughly rinsed with water.

[0149] Stage 2

[0150] The sample is polished for 45 seconds using 220 grit silicon carbide paper (obtained from Pace Technologies) while continuously, automatically dripping water onto abrasive pad during polishing. After polishing, the sample is thoroughly rinsed with water.

[0151] Stage 3

[0152] The sample is polished for 45 seconds using 600 grit silicon carbide paper (obtained from Pace Technologies) while continuously, automatically dripping water onto abrasive pad during polishing. After polishing, the sample is thoroughly rinsed with water.

[0153] Stage 4

[0154] The sample is polished for 4.5 minutes using polishing pad (obtained under the trade designation "DP-MOL" from Struers, Inc.), wetted lightly with periodic droplets of lubricant (obtained under the trade designation "PURON, DP-LUBRICANT" from Struers) and sprayed for 1 second with 6 micrometer diamond grit (obtained under the trade designation "DP-SPRAY, P-6 μm" from Struers). After polishing, the sample is thoroughly rinsed with water.

[0155] Stage 5

[0156] The sample is polished for 4.5 minutes using polishing pad ("DP-MOL"), wetted lightly with periodic droplets of lubricant (obtained under the trade designation "PURON, DP-LUBRICANT" from Struers) and sprayed for 1 second with 3 micrometer diamond grit (obtained under the trade designation "DP-SPRAY, P-3 μm" from Struers). After polishing, the sample is thoroughly rinsed with water.

[0157] Stage 6

[0158] The sample is polished for 4.5 minutes using a porous synthetic polishing cloth (obtained under the trade designation "OP-CHEM" from Struers), wetted first with water and colloidal silica suspension (obtained under the trade designation "OP-S SUSPENSION" from Struers) poured by hand on the cloth. The sample is washed with water during the last 5 seconds of polishing. After polishing, the sample is dried.

[0159] The resulting polished sample is viewed at 250× with optical microscope to determine if a visibly discernable continuous oxide layer is present between the insert or holder and the aluminum or aluminum alloy cast around the insert or holder. For reference purposes, Example 3 (see **FIG. 10**) of copending application having U.S. Ser. No. 60/404,672, filed Aug. 20, 2002, the disclosure of which is incorporated herein by reference, when evaluated with this test did not have a visibly discernable continuous oxide layer at the interface, whereas Comparative Example H (see **FIG. 11**) from the same application did. Referring to **FIG. 10**, the polished cross-section of Example 3 showed no abrupt boundary at interface **162** between insert matrix **166** and casting alloy **163**. Referring to **FIG. 11**, the polished cross-section of Comparative Example H showed an abrupt boundary, believed to be an oxide layer, at interface **182** between insert matrix **186** and casting alloy **183**.

[**0160**] An example of a disk brake for a motor vehicle comprises a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and a brake caliper comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

[**0161**] Referring to **FIGS. 7A and 7B**, disc brake assembly **70** comprises brake caliper housing **71** formed of body member **72**, arm member **73**, and bridge **74** connected at one end to body member **72** and at other end to arm member **73**. Body member **72** has a generally cylindrical recess **75** therein which slideably receives piston **76** to which is pressed inner brake pad **77**. Inner face **78** of arm member **73** supports outer brake pad **79** which faces inner brake pad **77**. Brake rotor **701**, connected to a wheel (not shown) of a vehicle, lies between inner and outer brake pads **77, 79**, respectively. Brake caliper housing **71** includes inserts **200**A and **200**B with interfaces **202**A and **202**B. Hydraulic, or other, actuation of piston **76** causes inner brake pad **77** to be urged against one side of rotor **701** and, by reactive force, causes caliper housing **71** to float, thereby bringing outer brake pad **79** into engagement with the other side of rotor **701**, as is well known in the art.

[**0162**] This invention is further illustrated by the following example, but the particular materials and amounts thereof recited in this example, as well as other conditions and details, should not be construed to unduly limit this invention. Various modifications and alterations of the invention will become apparent to those skilled in the art. All parts and percentages are by weight unless otherwise indicated.

EXAMPLE 1

[**0163**] An insert holder was made as follows. Aluminum sheet stock, 1.5 mm in thickness, consisting of 6061 aluminum alloy that had been heated-treated with a standard T4 heat treatment (obtained under the trade designation "6061-T4" from Vincent Brass and Aluminum, St. Paul, Minn.) was laser-cut to obtain the configuration shown in **FIG. 8**. The laser used for cutting the aluminum sheet stock was a 1500 Watt, numerically controlled CO_2 laser (obtained from Coherent, Inc., Santa Clara, Calif., and integrated into a numerically controlled laser cutting system by Laser Manufacturing, Inc., Somerset, Wis.). The insert holder was designed to hold three inserts, two with dimensions 72 mm by 15.5 mm by 5 mm and one with dimensions 82 mm by 35 mm by 5 mm.

[**0164**] The cut sheet was bent with pliers along the fold lines a, b, c, d, e, f, g, and h shown in **FIG. 8A** to make the shape shown in **FIGS. 8A and 8B** to provide an insert holder. Dimension A is 158.2 mm, B is 35 mm, C is 126.2 mm, D is 13.6 mm, and E is 28 mm. The insert holder was then coated by Co-Operative Plating Co., St. Paul, Minn. to provide an electroless deposition of about 3 micrometers of nickel followed by an electroplating of about 12 micrometers of silver.

[**0165**] Inserts **13**A, **13**B, and **13**C were placed in the holder and fastened into place by bending clamps **12**A, **12**B, **12**C, and **12**D shown in **FIG. 1** until they were just in contact with the inserts. Inserts **13**A, **13**B, and **13**C were made as follows.

[**0166**] Tows of continuous alpha alumina fibers (available under the trade designation "NEXTEL 610" from the 3M Company, St. Paul, Minn.; 3,000 denier; Young's modulus of about 370 GPa; average tensile strength of about 3 GPa; average diameter 11 micrometers) were wound using a deionized water sizing, wherein the tows of fiber were dipped in a water bath immediately before being wound onto a four-faced 20.3 cm. (8-inch) square mandrel to produce a fiber preform having a 65% volume loading of fiber. The fiber was wound under tension (about 75 grams, as measured by a tension meter (obtained under the trade designation "CERTEN" from Tensitron, Boulder Colo.)) to form four rectangular preform plates (10.2 cm (4 inches) by 20.3 cm (8 inches) by 0.29 cm (0.115 inches) thick). The mandrel was then placed in a −40° C. (−40° F.) cooler to freeze the water and stabilize the resulting preform. When frozen, the plates were cut into 7.6 cm by 15.2 cm (3 inch by 6 inch) preforms.

[**0167**] A graphite die assembly (obtained from Schunk Graphite Technology, Inc., Menomonie Falls, Wis.) was used to cast the aluminum matrix composite plates. The width of the graphite die was 9.64 cm, the length 15.24 cm and the height 4.90 cm. The die included four slots for inserts with 0.89 cm center-to-center spacing between the slots. The graphite die assembly was coated with an aqueous graphite particle dispersion (obtained under the trade designation "AQUADAG" from Acheson Colloids Company, Port Huron, Mich.). Four of the frozen 7.6 cm by 15.2 cm preforms were placed in the graphite die assembly, one preform in each of the four cavities. The die assembly with the preforms positioned therein was then placed in an oven at 120° C. (250° F.) for about 16 hours until the water in the preforms evaporated.

[**0168**] The die assembly was then placed in a stainless steel can (length 102 mm, width 53 mm, and height 500 mm) open at one end, and having its interior coated with a boron nitride suspension (obtained under the trade designation "RS 1000" from ZYP Coatings Inc., Oak Ridge, Tenn.). Although not wanting to be bound by theory, it is believed that the boron nitride coating inhibits reaction between the stainless steel and the molten aluminum during the subsequent casting operation.

[**0169**] After the coating was dry, 2500 grams of an aluminum-2% copper alloy ingot (cut into two pieces, each 5.1 cm by 2.5 cm by 30.5 cm (I inch by 2 inch by 12 inch)) (obtained under the trade designation "1980-A" from Belmont Metal, New York, N.Y.) were then placed in the stainless steel can on top of the assembly. A type-K thermocouple (obtained from Omega Engineering Inc., Stamford, Conn.) was placed at the top of the die assembly to monitor the temperature of the aluminum-2% copper melt during the casting process. A hold-down rod was also affixed to the top of the graphite assembly to prevent that assembly from floating in the molten aluminum during the casting.

The stainless steel can was then placed inside the pressure vessel of the pressure casting machine (obtained from Process Engineering Technologies, Plaistow, N.H.), and the pressure vessel closed. The size of the pressure casting vessel was about 16.9 cm (inner diameter) by 88.9 cm (in length).

[0170] The closed casting vessel was then evacuated of air with a vacuum pump until a pressure of less than one torr was achieved. The power to the electrical furnace of the pressure caster was then turned on, and the graphite die assembly and Al-2%Cu alloy ingot were heated to a temperature of 710° C. (about 100° C. above the melting point of the alloy). The average heating rate was about 340° C. per hour. After a melt temperature of 710° C. was reached, the furnace power was turned off, and the vacuum valve to the vessel closed, thereby isolating the vessel from the vacuum pump.

[0171] A low pressure valve connected to pressurized, bottled argon tanks was then opened to back-fill the vessel with argon to an initial low pressure of 1.79 MPa (260 psi). When this pressure was reached, the low-pressure valve was closed and a high-pressure argon valve was opened until a pressure of 8.96 MPa (1300 psi) was reached. The pressure was maintained at 8.96 MPa±1% (1300 psi±15 psi) for 15-20 minutes forcing the molten aluminum-2% copper alloy to infiltrate the preforms completely.

[0172] Next, the pressure was allowed to decay with the temperature to 500° C. When the temperature fell below 500° C., the vessel exhaust valve was opened, and the argon was vented to the atmosphere. The vessel was then opened, and the stainless steel can was removed. The die assembly was separated from the can, and the four cast aluminum matrix composite plates were removed from the graphite mold.

[0173] The cast plates were surface ground with a vertical spindle diamond grinder (#11 Blanchard grinder obtained from Precision Instruments, Minneapolis, Minn.) to a thickness of 0.25 cm (0.1 inch). The plates were then sliced lengthwise to a width of 0.94 cm (0.37 inch) to make 15.2 cm (6 inch) by 0.95 cm (0.375 inch) by 0.25 cm (0.1 inch) plates.

[0174] Three plates were then surface treated/coated as follows. All plates were abraded with a 100 grit grinder wheel (obtained under the trade designation "DIAMOND WHEEL, ASD100" from Norton Company, Worcester, Mass.), and cleaned with a standard lacquer thinner (available as Grade 401 from HCI, St. Paul, Minn.) by rubbing with paper towels until no visible residue could be removed from the surface.

[0175] The two resulting plates were coated (by Co-Operative Plating Co., St. Paul, Minn.), via electroless deposition, with about 3 micrometers of nickel, followed by electroplating about 12 micrometers of silver. The holder and inserts were provided by the 3M Company to THT Presses, Inc., Dayton Ohio for them to use to squeeze cast, using 354 aluminum alloy, the resulting brake caliper shown in **FIG. 6**.

EXAMPLE 2

[0176] A portion of an exemplary holder according to the present invention was prepared as follows. A piece of sheet stock of 6061 aluminum (obtained under the trade designation "6061-T4" from Vincent Brass and Aluminum, St. Paul Minn.) was cut by Eagle Tool (Spring Lake Park, Minn.) using a water-jet cutting process. The resulting sheet was 0.095 inch (0.24 cm) in thickness. The cutout piece had dimensions 0.367 inch by 0.095 inch by 6.00 inch (0.93 cm by 0.24 cm by 15.24 cm). The edges of the aluminum piece were smoothed using **150** grit sandpaper to remove the slight ripples from water-jet cutting. To facilitate later insertion of the portion into a die, one end of the aluminum piece was tapered using **150** grit sandpaper (available from 3M Company, St. Paul, Minn. under the trade designation "WETORDRY") to a 0.327 inch by 0.055 inch (0.83 cm by 0.14 cm) section over the final 0.40 inch (1.0 cm) of its length.

[0177] The resulting aluminum piece was then plated (by Co-Operative Plating Co, St. Paul, Minn.) with an electroless coating of nickel followed by electroplating with silver). The thickness of the nickel coating was about 3 micrometers, and the silver coating about 17 micrometers.

[0178] The resulting exemplary holder portion was heated in air by placing the holder portion for 20 minutes in a furnace preheated to about 550° C. The heated holder portion was then placed in a steel die cavity. Referring to **FIG. 12**, die **130** included base **132** (9.8 cm by 9.8 cm by 14 cm (3.9 in. by 3.9 in. by 5.5 in.)) with rectangular slot **134** (1.3 cm by 0.25 cm (0.5 in. by 0.1 in.)) for the holder portion, and upper part 136 (7.3 cm by 7.3 cm by 12.7 cm (29 in by 2.9 in by 5.0 in)). Upper part **136** includes cavity **138** having diameter 2.54 cm (1 inch) and depth 10.2 cm (4 inch). Upper part **136** was coated with a boron nitride release agent (obtained under the trade designation "COMBAT BORON NITRIDE AEROSOL SPRAY CC-18" from The Carborundum Corp., Amherst, N.Y.) and then preheated to about 400° C. Within four seconds after the heated holder portion was placed in the die, a molten aluminum alloy (obtained under the trade designation "A356" from Alcan Inc., Montreal, Quebec) at a temperature of about 760° C. was poured into the steel die cavity around the pre-heated holder portion and allowed to solidify. When the temperature cooled to about 500° C., the holder portion and casting assembly were removed from the die cavity.

[0179] The resulting cast sample was heat-treated by placing it in an oven for 8 hours at 535° C., followed by a water quench, and concluding with 12 hours in an oven at 160° C.

[0180] The resulting heat-treated sample was sectioned into four 0.27 cm (0.106 inch) by 2.5 cm (1 inch) diameter sections. These four sections were cut perpendicular to the longitudinal axis of the exemplary portion of the holder. For each of the four sections, an "L"-shaped piece of aluminum (cut from the sheet stock aluminum ("6061-T4") 0.040 inch (0.10 cm) thick was adhered (marketed under the trade designation "PRONTO CA8" from 3M Company, St. Paul, Minn.) to each section to mark the boundary between the exemplary portion of the holder and the surrounding 356 aluminum alloy to facilitate alignment during the pushout test.

[0181] A schematic of the compressive shear test equipment is shown in **FIG. 9**, wherein compressive shear test equipment **140** included pushout tool **141**, test sample **142**, support block **143**, and 100,000 Newton (22,482 pounds) compressive load cell **147**. Pushout tool **141** had a corresponding cross-section at the point of contact with the exemplary portion of the holder, **144** with test sample **142**, except the cross-sectional area of pushout tool **141** was 10 percent less (i.e., the shape of the cross-section of pushout tool **141** and exemplary portion of the holder, **144** was the same, but the size of the cross-section of pushout tool **144** is less). Pushout tool **141** was clamped in upper jaws **145** of the hydraulic chuck with a hydraulic pressure of 10.34 MPa (1500 pounds per square inch). Support block **143** had a 2.54 cm (1.0 inch) diameter by 0.15 cm (0.06 inch) deep counterbore. A 1.1 cm (0.435 inch) diameter through hole was placed on top of the open jaws **145** of the bottom of hydraulic chuck **146**.

[0182] Sample to be tested **142** was placed on top of support block **143** and nested in the counterbore for centering of the exemplary portion of the holder over the through hole. Bottom **148** of hydraulic chuck support **146** was raised until the gap between the upper pushout tool **141**, and the exemplary portion of the holder to be pushed out (i.e., sample to be tested **144**), was 0.025 cm. (0.01 inch). The exposed exemplary portion of the holder in the test specimen was then positioned to line up with the alignment strip previously glued to the sample with the matching tip of pushout tool **141** by manually sliding support block **143** horizontally and rotationally until the cross-sections of the two elements match.

[0183] The test was then conducted by moving the lower hydraulic support chuck up toward fixed pushout tool **141** at a rate of 0.025 cm (0.010 inch) per minute while simultaneously monitoring the load and deflection. The exemplary portion of the holder was thereby brought into contact with the fixed pushout tool face and the contact force between the two was recorded as a function of displacement. The test was discontinued shortly after a total deflection of about 0.05 cm (0.020 inch) was obtained.

[0184] After completion of the test, the specimen was examined under an optical microscope at 100× magnification to verify that the exemplary portion of the holder and pushout tip were properly aligned such that their cross-sections were overlapping.

[0185] The average shear stress is calculated using the following formula:

$$\text{Average Shear Stress} = \frac{\text{Load at first slippage, } N \text{ lbs.)}}{\text{Area of contact between holder portion and aluminum alloy, m}^2\text{ (in}^2\text{).}}$$

[0186] The loads were plotted as a function of the displacement of the exemplary portion of the holder. The load at which the pushout curve showed significant nonlinear deflection (i.e., where there was initial slippage at the interface between the exemplary portion of the holder and the aluminum or aluminum alloy cast around the exemplary portion of the holder) was a peak bond strength value.

[0187] The Peak Bond Strength was calculated using Finite Element Analysis (FEA). Finite Element Analysis (FEA) software (obtained under the trade designation "ANSYS" from Ansys Inc., Canonsburg, Pa.) was used to model the exemplary portion of the holder, and show that the ratio of peak bond strength to measured average shear stress was about 1.86.

[0188] The FEA calculation was done as follows. A finite element model of the test specimen geometry was created. The exemplary portion of the holder was meshed with cube-shaped elements 0.025 cm (0.01 inch) in size. The aluminum/aluminum alloy cast around the exemplary portion of the holder was meshed with cubes having sides of 0.025 cm (0.01 inch) near the exemplary portion of the holder and 0.10 cm (0.04 inch) elsewhere in the modeled test specimen. The FEA software computed the shear stress at points along the surface of the exemplary portion of the holder for an applied pressure of 228 MPa (corresponding to a pushout test load of 1144 pounds). The calculation then determined the peak shear stress across all points of the surface of the exemplary portion of the holder and the average across the exemplary portion of the holder surface, as applicable. The ratio of Peak Bond Strength to average shear stress thus obtained was about 1.86 to 1 for an exemplary portion of a holder surface. The load at first slippage, the average shear stress, and the peak bond strength for the four samples (Examples 2A, 2B, 2C, and 2D) are reported in the Table below.

TABLE

Example	Load at first slippage, N, (lbs.)	Average Shear Stress, MPa, (psi)	Peak Bond Strength, MPa, (psi)
2A	4466 (1004)	70.8 (10,266)	131.7 (19,095)
2B	5418 (1218)	85.9 (12,454)	159.7 (23,165)
2C	5218 (1173)	83.7 (12,131)	155.6 (22,564)
2D	4942 (1111)	79.7 (11,567)	148.3 (21,515)

[0189] Various modifications and alterations of this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention, and it should be understood that this invention is not to be unduly limited to the illustrative embodiments set forth herein.

What is claimed is:

1. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C., the second metal having a thickness of at least 8 micrometers; and

at least one metal comprising reinforcement insert secured in at least one portion for securing at least one insert.

2. The article according to claim 1 comprising two portions for securing respectively an insert, and two of the metal comprising reinforcement inserts positioned respectively in the portions for securing respectively an insert.

3. The article according to claim 1 further comprising a third metal between the second metal and the outer surface of the first metal.

4. The article according to claim 1 wherein the second metal has a thickness of at least 10 micrometers.

5. The article according to claim 1 wherein the second metal is one of gold or silver.

6. The article according to claim 1 wherein the first metal is an aluminum alloy, and wherein the metal of the metal comprising reinforcement insert is an aluminum alloy.

7. The article according to claim 1 wherein the first metal is a 6000 series aluminum alloy and wherein the metal of the metal comprising reinforcement insert is a 200 series aluminum alloy.

8. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C., the second metal having a thickness of at least 8 micrometers; and

at least one crystalline ceramic comprising reinforcement insert secured in at least one portion for securing at least one insert.

9. The article according to claim 8 wherein the second metal has a thickness of at least 10 micrometers.

10. The article according to claim 8 wherein the second metal is one of gold or silver.

11. The article according to claim 9 wherein the crystalline ceramic comprising reinforcement insert comprises porous, sintered ceramic oxide material and substantially continuous ceramic oxide fibers having lengths of at least 5 cm, the porous, sintered ceramic oxide material securing the substantially continuous ceramic oxide fibers in place, wherein the porous, sintered ceramic oxide material extends along at least a portion of the length of the substantially continuous fibers.

12. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers; and

at least one metal comprising reinforcement insert secured in the at least one portion for securing at least one insert.

13. The article according to claim 12 wherein the Ni has a thickness of at least 1 micrometer.

14. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers; and

at least one crystalline ceramic comprising reinforcement insert secured in the at least one portion for securing at least one insert.

15. The article according to claim 14 wherein the Ni has a thickness of at least 1 micrometer.

16. The article according to claim 14 wherein the crystalline ceramic comprising reinforcement insert comprises porous, sintered ceramic oxide material and substantially continuous ceramic oxide fibers having lengths of at least 5 cm, the porous, sintered ceramic oxide material securing the substantially continuous ceramic oxide fibers in place, wherein the porous, sintered ceramic oxide material extends along at least a portion of the length of the substantially continuous fibers.

17. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C.; and

at least one metal matrix composite insert secured in at least one portion for securing at least one insert, wherein at least one of such inserts comprises:

substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the third metal having an outer surface; and

a fourth metal on the outer surface of the third metal, the fourth metal having a positive Gibbs oxidation free energy above at least 200° C., and the fourth metal having a thickness of at least 8 micrometers.

18. The article according to claim 17 further comprising another metal between the second metal and the outer surface of the first metal, and, further comprising another metal between the fourth metal and the outer surface of the third metal.

19. The article according to claim 17 wherein the second and fourth metals each have a thickness of at least 10 micrometers.

20. The article according to claim 17 wherein the second and fourth metals are one of gold or silver.

21. The article according to claim 17 wherein the first metal is an aluminum alloy, and wherein the third metal is an aluminum alloy.

22. The article according to claim 17 wherein the first metal is a 6000 series aluminum alloy and wherein the third metal is a 200 series aluminum alloy.

23. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal matrix composite insert positioned in the at least one portion for securing at least one insert, the insert comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

the insert holder with the at least one insert secured in the at least one portion for securing at least one insert collectively having an outer surface, and a third metal on the outer surface, the third metal having a positive Gibbs oxidation free energy above at least 200° C., and the third metal having a thickness of at least 8 micrometers.

24. The article according to claim 23 further comprising another metal between the third metal and the outer surface.

25. The article according to claim 24 wherein the third metal has a thickness of at least 10 micrometers.

26. The article according to claim 24 wherein the third metal is one of gold or silver.

27. The article according to claim 24 wherein the first metal is an aluminum alloy, and wherein the second metal is an aluminum alloy.

28. The article according to claim 24 wherein the first metal is a 6000 series aluminum alloy and wherein the second metal is a 200 series aluminum alloy.

29. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni; and

at least one a metal matrix composite insert secured in the at least one portion for securing at least one insert, at least one of such inserts comprising:

substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the second metal having an outer surface;

Ni on the outer surface of the second metal, the Ni having an outer surface; and

Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers.

30. The article according to claim 29 wherein the Ni has a thickness of at least 1 micrometer.

31. An article comprising:

an insert holder including at least one portion for securing at least one insert, the insert holder comprises a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal matrix composite insert positioned in the at least one portion for securing at least one insert, the insert comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

the insert holder with the at least one insert secured in the at least one portion for securing at least one insert collectively having an outer surface, Ni on the outer surface of the metal, the Ni having an outer surface of the insert holder, and Ag on the outer surface of the Ni.

32. The article according to claim 31 wherein the Ni has a thickness of at least 1 micrometer.

33. A metal matrix composite article comprising a first metal and an insert holder including at least one portion for securing at least one insert, wherein the first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the insert holder comprises:

a second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal comprising reinforcement insert secured in the at least one portion for securing at least one insert,

wherein there is an interface layer between the first metal and the insert holder, and wherein there is an interface layer peak bond strength value between the first metal and the insert holder of at least 100 MPa.

34. The metal matrix composite article according to claim 33 wherein the peak bond strength value is at least 130 MPa.

35. The metal matrix composite article according to claim 33 comprising two portions for securing respectively an insert, and two of the metal comprising reinforcement inserts positioned respectively in the portions for securing respectively an insert.

36. The metal matrix composite article according to claim 33 wherein the first metal is an aluminum alloy, wherein the second metal is an aluminum alloy, and wherein the metal of the metal comprising reinforcement insert is an aluminum alloy.

37. The metal matrix composite article according to claim 33 wherein the first metal is one of a 300 or 400 series aluminum alloy, wherein the second metal is a 6000 series aluminum alloy, and wherein the metal of the metal comprising reinforcement insert is 200 series aluminum alloy.

38. The metal matrix composite article according to claim 33 which is a brake caliper.

39. A disc brake for a motor vehicle comprising a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and the brake caliper according to claim 38 comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

40. A metal matrix composite article comprising a first metal and an insert holder including at least one portion for securing at least one insert, wherein the first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the insert holder comprises:

a second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one crystalline ceramic comprising reinforcement insert secured in the at least one portion for securing at least one insert, wherein there is an interface layer between the first metal and the insert holder, and wherein there is an interface layer peak bond strength value between the first metal and the insert holder of at least 100 MPa.

41. The metal matrix composite article according to claim 40 wherein the peak bond strength value is at least 130 MPa.

42. The metal matrix composite article according to claim 40 comprising two portions for securing respectively an insert, and two of the crystalline ceramic comprising reinforcement inserts positioned respectively in the portions for securing respectively an insert.

43. The metal matrix composite article according to claim 40 wherein the first metal is an aluminum alloy and wherein the second metal is an aluminum alloy.

44. The metal matrix composite article according to claim 40 wherein the first metal is one of a 300 or 400 series aluminum alloy, and wherein the second metal is a 6000 series aluminum alloy.

45. The metal matrix composite article according to claim 44 wherein the crystalline ceramic comprising reinforcement insert comprises porous, sintered ceramic oxide material and substantially continuous ceramic oxide fibers having lengths of at least 5 cm, the porous, sintered ceramic oxide material securing the substantially continuous ceramic oxide fibers in place, wherein the porous, sintered ceramic oxide material extends along at least a portion of the length of the substantially continuous fibers.

46. The metal matrix composite article according to claim 40 which is a brake caliper.

47. A disc brake for a motor vehicle comprising a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and the brake caliper according to claim 46 comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

48. A metal matrix composite article comprising a first metal and an insert holder including at least one portion for securing at least one insert, wherein the first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the insert holder comprises:

a second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal matrix composite insert secured in the at least one portion for securing at least one insert, the metal matrix composite insert comprising:

substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

wherein there is an interface layer between the first metal and the insert holder, wherein the interface layer is free of oxygen, wherein the interface layer includes an average amount of a fourth metal having a positive Gibbs oxidation free energy above at least 200° C., and wherein the average amount of the fourth metal in the interface layer is higher in the interface layer than that present in the first metal.

49. The metal matrix composite article according to claim 48 comprising two portions for securing respectively an insert, and two of the metal matrix composite inserts positioned respectively in the portions for securing respectively an insert.

50. The metal matrix composite article according to claim 48 wherein the first metal is an aluminum alloy, wherein the second metal is an aluminum alloy, and wherein the third metal is an aluminum alloy.

51. The metal matrix composite article according to claim 48 wherein the first metal is one of a 300 or 400 series aluminum alloy, wherein the second metal is a 6000 series aluminum alloy, and wherein the third metal is a 200 series aluminum alloy.

52. The metal matrix composite article according to claim 48 which is a brake caliper.

53. A disc brake for a motor vehicle comprising a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and the brake caliper according to claim 52 comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

54. A metal matrix composite article comprising a first metal and an insert holder including at least one portion for securing at least one insert, wherein the first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the insert holder comprises:

a second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal matrix composite insert secured in the at least one portion for securing at least one insert, the metal matrix composite insert comprising:

substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

wherein there is an interface layer between the first metal and the insert holder, and wherein there is an interface layer peak bond strength value between the first metal and the insert holder of at least 100 MPa.

55. The metal matrix composite article according to claim 54 wherein the peak bond strength value is at least 130 MPa.

56. The metal matrix composite article according to claim 54 comprising two portions for securing respectively an insert, and two of the metal matrix composite inserts positioned respectively in the portions for securing respectively an insert.

57. The metal matrix composite article according to claim 54 wherein the first metal is an aluminum alloy, wherein the second metal is an aluminum alloy, and wherein the third metal is an aluminum alloy.

58. The metal matrix composite article according to claim 54 wherein the first metal is one of a 300 or 400 series aluminum alloy, wherein the second metal is a 6000 series aluminum alloy, and wherein the third metal is a 200 series aluminum alloy.

59. The metal matrix composite article according to claim 54 which is a brake caliper.

60. A disc brake for a motor vehicle comprising a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and the brake caliper according to claim 59 comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

61. A metal matrix composite article comprising a first metal and an insert holder including at least one portion for securing at least one insert, wherein the first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the insert holder comprises:

a second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof; and

at least one metal matrix composite insert secured in the at least one portion for securing at least one insert, the metal matrix composite insert comprising:

substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers,

wherein there is an interface layer between the first metal and the insert holder, wherein the interface layer is free of oxygen, and wherein the interface layer includes an average amount of Ag and Ni higher than that present in the first metal.

62. The metal matrix composite article according to claim 61 wherein the peak bond strength value is at least 130 MPa.

63. The metal matrix composite article according to claim 61 comprising two portions for securing respectively an insert, and two of the metal matrix composite inserts positioned respectively in the portions for securing respectively an insert.

64. The metal matrix composite article according to claim 61 wherein the first metal is an aluminum alloy, wherein the second metal is an aluminum alloy, and wherein the third metal is an aluminum alloy.

65. The metal matrix composite article according to claim 61 wherein the first metal is one of a 300 or 400 series aluminum alloy, wherein the second is a 6000 series aluminum alloy, and wherein the third metal is a 200 series aluminum alloy.

66. The metal matrix composite article according to claim 61 which is a brake caliper.

67. A disc brake for a motor vehicle comprising a rotor; inner and outer brake pads disposed on opposite sides of the rotor and movable into braking engagement therewith; a piston for urging the inner brake pad against the rotor; and the brake caliper according to claim 66 comprising a body member having a cylinder positioned on one side of the rotor and containing the piston, an arm member positioned on the other side of the rotor and supporting the outer brake pad, and a bridge extending between the body member and the arm member across the plane of the rotor.

68. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes a metal comprising reinforcement insert, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C., the second metal having a thickness of at least 8 micrometers, and the metal comprising reinforcement insert being secured in the at least one portion for securing at least one insert;

providing molten third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten third metal to provide a metal matrix composite article.

69. The method according to claim 68 wherein the molten third metal in the mold is in the molten state for less than 75 seconds.

70. The method according to claim 68 wherein the molten third metal in the mold is in the molten state for less than 75 seconds.

71. The method according to claim 68 comprising two portions for securing respectively an insert, and two of the metal comprising reinforcement inserts positioned respectively in the portions for securing respectively an insert.

72. The method according to claim 68 wherein the first metal is an aluminum alloy, wherein the third metal is an aluminum alloy, and wherein the metal of the metal comprising reinforcement insert is an aluminum alloy.

73. The method according to claim 68 wherein the first metal is a 6000 series aluminum alloy, wherein the metal of the metal comprising reinforcement insert is a 200 series aluminum alloy, and wherein the third metal is one of a 300 or 400 series aluminum alloy.

74. The method according to claim 68 wherein the metal matrix composite article is a brake caliper.

75. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes a crystalline ceramic comprising reinforcement insert, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C., the second metal having a thickness of at least 8 micrometers, and the crystalline ceramic comprising reinforcement insert being secured in the at least one portion for securing at least one insert;

providing molten third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten third metal to provide a metal matrix composite article.

76. The method according to claim 75 wherein the molten third metal in the mold is in the molten state for less than 75 seconds.

77. The method according to claim 75 wherein the molten third metal in the mold is in the molten state for less than 60 seconds.

78. The method according to claim 75 comprising two portions for securing respectively an insert, and two of the crystalline ceramic comprising reinforcement inserts positioned respectively in the portions for securing respectively an insert.

79. The method according to claim 75 wherein the first metal is an aluminum alloy and wherein the third metal is an aluminum alloy.

80. The method according to claim 75 wherein the first metal is a 6000 series aluminum alloy, and wherein the third metal is one of a 300 or 400 series aluminum alloy.

81. The method according to claim 75 wherein the crystalline ceramic comprising reinforcement insert comprising porous, sintered ceramic oxide material and substantially continuous ceramic oxide fibers having lengths of at least 5 cm, the porous, sintered ceramic oxide material securing the substantially continuous ceramic oxide fibers in place, wherein the porous, sintered ceramic oxide material extends along at least a portion of the length of the substantially continuous fibers.

82. The method according to claim 75 wherein the metal matrix composite article is a brake caliper.

83. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes a metal comprising reinforcement insert, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers, and the metal comprising reinforcement insert being secured in the at least one portion for securing at least one insert;

providing molten second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten second metal to provide a metal matrix composite article.

84. The method according to claim 83 wherein the molten second metal in the mold is in the molten state for less than 75 seconds.

85. The method according to claim 83 wherein the molten second metal in the mold is in the molten state for less than 60 seconds.

86. The method according to claim 83 wherein the metal matrix composite article is a brake caliper.

87. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes a crystalline ceramic comprising reinforcement insert, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers;

providing molten second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten second metal to provide a metal matrix composite article.

88. The method according to claim 87 wherein the molten second metal in the mold is in the molten state for less than 75 seconds.

89. The method according to claim 87 wherein the molten second metal in the mold is in the molten state for less than 60 seconds.

90. The method according to claim 87 wherein the metal matrix composite article is a brake caliper.

91. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes an insert in a mold, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, and a second metal on the outer surface of the first metal, the second metal having a positive Gibbs oxidation free energy above at least 200° C., the insert being secured in the at least one portion for securing at least one insert and comprising substantially continuous ceramic oxide fibers and third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the third metal secures the substantially continuous ceramic oxide fibers in place, and wherein the third metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the third metal having an outer surface; and a fourth metal on the outer surface of the third metal, the fourth metal having a positive Gibbs oxidation free energy above at least 200° C., and the fourth metal having a thickness of at least 8 micrometers;

providing molten fifth metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten fifth metal to provide a metal matrix composite article.

92. The method according to claim 91 wherein the molten fifth metal in the mold is in the molten state for less than 75 seconds.

93. The method according to claim 91 wherein the molten fifth metal in the mold is in the molten state for less than 60 seconds.

94. The method according to claim 91 comprising two portions for securing respectively an insert, and two of the inserts positioned respectively in the portions for securing respectively an insert.

95. The method according to claim 91 wherein the first metal is an aluminum alloy, wherein the third metal is an aluminum alloy, and wherein the fifth metal is an aluminum alloy.

96. The method according to claim 91 wherein the first metal is a 6000 series aluminum alloy, wherein the third metal is a 200 series aluminum alloy, and wherein the fifth metal is one of a 300 or 400 series aluminum alloy.

96. The method according to claim 91 wherein the metal matrix composite article is a brake caliper.

97. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes an insert in a mold, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, the insert being secured in the at least one portion for securing at least one insert and comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the insert holder and the insert collectively having an outer surface, and a third metal on the outer surface, the third metal having a positive Gibbs oxidation free energy above at least 200° C., and the third metal having a thickness of at least 8 micrometers;

providing molten fourth metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten fourth metal to provide a metal matrix composite article.

98. The method according to claim 97 wherein the molten fourth metal in the mold is in the molten state for less than 75 seconds.

99. The method according to claim 97 wherein the molten fourth metal in the mold is in the molten state for less than 60 seconds.

100. The method according to claim 97 comprising two portions for securing respectively an insert, and two of the inserts positioned respectively in the portions for securing respectively an insert.

101. The method according to claim 97 wherein the first metal is an aluminum alloy, wherein the second metal is an aluminum alloy, and wherein the fourth metal is an aluminum alloy.

102. The method according to claim 97 wherein the first metal is a 6000 series aluminum alloy, wherein the second metal is a 200 series aluminum alloy, and wherein the fourth metal is one of a 300 or 400 series aluminum alloy.

103. The method according to claim 97 wherein the metal matrix composite article is a brake caliper.

104. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes an insert in a mold, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, Ni on the outer surface of the insert holder, the Ni having an outer surface; and Ag on the outer surface of the Ni, the insert being secured in the at least one portion for securing at least one insert and comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the second metal having an outer surface; and Ni on the outer surface of the second metal, the Ni having an outer surface; and Ag on the outer surface of the Ni, the Ag having a thickness of at least 8 micrometers;

providing molten third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten third metal to provide a metal matrix composite article.

105. The method according to claim 104 wherein the molten third metal in the mold is in the molten state for less than 75 seconds.

106. The method according to claim 104 wherein the molten third metal in the mold is in the molten state for less than 60 seconds.

107. The method according to claim 104 wherein the metal matrix composite article is a brake caliper.

108. A method of making a metal matrix composite article, the method comprising:

positioning an insert holder that includes an insert in a mold, the insert holder including at least one portion for securing at least one insert, the insert holder comprising a first metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, the insert holder having an outer surface, the insert being secured in the at least one portion for securing at least one insert and comprising substantially continuous ceramic oxide fibers and second metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof, wherein the second metal secures the substantially continuous ceramic oxide fibers in place, and wherein the second metal extends along at least a portion of the length of the substantially continuous ceramic oxide fibers, the insert holder and the insert collectively having an outer surface, Ni on the outer surface of the metal, the Ni having an outer surface of the insert holder, and Ag on the outer surface of the Ni;

providing molten third metal selected from the group consisting of aluminum, alloys thereof, and combinations thereof into the mold; and

cooling the molten third metal to provide a metal matrix composite article.

109. The method according to claim 108 wherein the molten third metal in the mold is in the molten state for less than 75 seconds.

110. The method according to claim 108 wherein the molten third metal in the mold is in the molten state for less than 60 seconds.

111. The method according to claim 108 wherein the metal matrix composite article is a brake caliper.

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