



US 20050133123A1

(19) **United States**

(12) **Patent Application Publication**

Joseph et al.

(10) **Pub. No.: US 2005/0133123 A1**

(43) **Pub. Date: Jun. 23, 2005**

(54) **GLASS FIBER METAL MATRIX COMPOSITES**

Related U.S. Application Data

(75) Inventors: **Brian E. Joseph**, Wheeling, WV (US);
Brian L. Gordon, Wheeling, WV (US);
Kenneth A. Hart, Wheeling, WV (US);
Joseph A. Polsinelli, McMechen, WV (US);
James F. Witzgall, Wheeling, WV (US);
Gregg W. Wolfe, Wheeling, WV (US)

(60) Provisional application No. 60/525,848, filed on Dec. 1, 2003.

Publication Classification

(51) **Int. Cl.⁷** **C22C 21/00**

(52) **U.S. Cl.** **148/437**

Correspondence Address:

PHILIP DOUGLAS LANE

P.O. BOX 651295

POTOMAC FALLS, VA 20165-1295 (US)

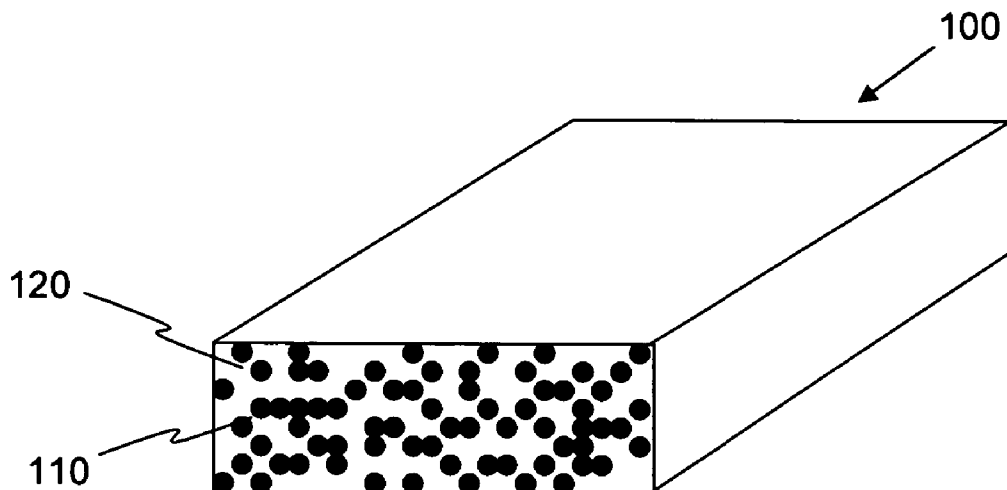
ABSTRACT

A glass fiber reinforced metal matrix composite is described. The composite includes glass fibers distributed in a metal matrix body. The fibers may be uniformly distributed in the metal matrix and may include continuous lengths of the glass fibers. The glass fibers may be glass fibers, S-glass, E-glass fibers, soda-lime-silica fibers, basalt fibers, quartz fibers, or other similar glassy fibers. The metal matrix may include aluminum or alloys of aluminum as well as other metals and alloys.

(73) Assignee: **Touchstone Research Laboratory, Ltd.**

(21) Appl. No.: **10/995,516**

(22) Filed: **Nov. 24, 2004**



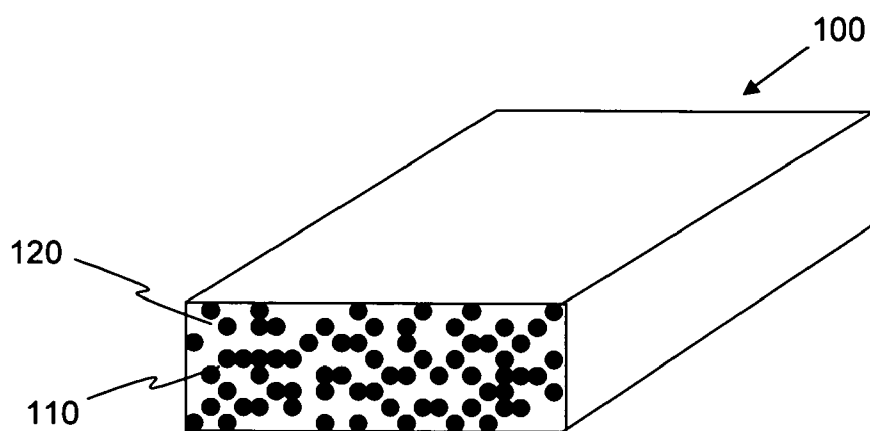


Figure 1

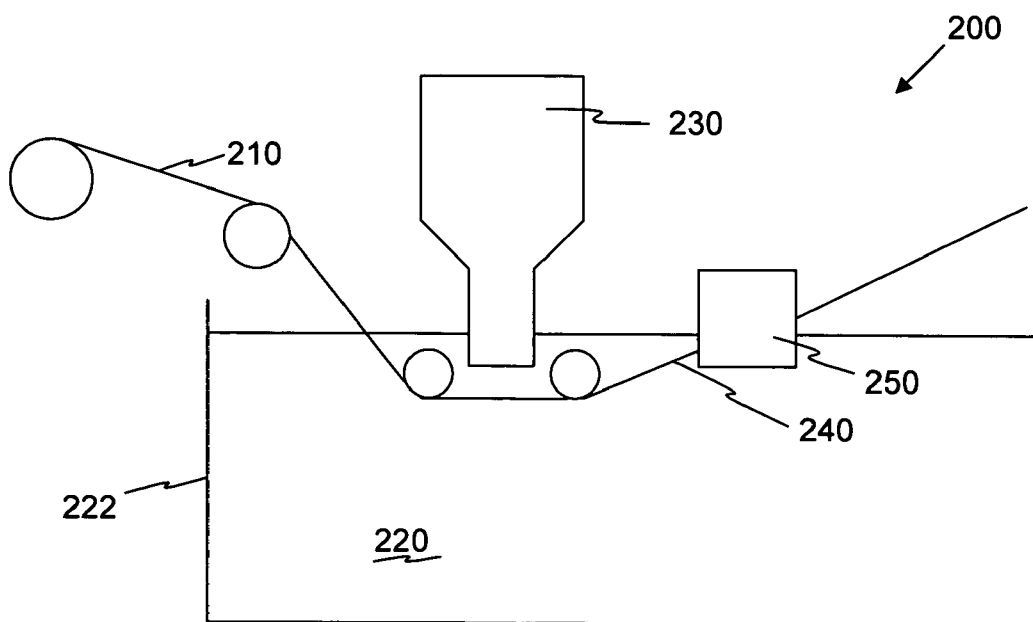


Figure 2

GLASS FIBER METAL MATRIX COMPOSITES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application No. 60/525,848, filed Dec. 1, 2003, specifically herein incorporated by reference in its entirety.

[0002] This invention was made with Government support under contract number DAAD 19-01-2-0006 awarded by the Army Research Laboratory. The Government has certain rights in the invention.

FIELD OF THE INVENTION

[0003] The invention relates to fiber reinforced metal matrix composites. More particularly, the invention relates to glass fiber reinforced metal matrix composites and methods for making the same.

BACKGROUND OF THE INVENTION

[0004] The next generation of high technology materials for use in aerospace and aircraft applications will need to possess high temperature capability combined with high stiffness and strength. Plates and shells fabricated from laminated metal matrix composites, as opposed to monolithic materials, provide the potential for meeting these requirements and thereby significantly advancing the designer's ability to meet the required elevated temperature and structural strength and stiffness specifications while minimizing weight.

[0005] Efforts to meet these challenges have produced metal matrix composites having relatively long continuous lengths of a reinforcing fibrous material, for example, a ceramic such as aluminum oxide, in a matrix of a metal such as aluminum. However, these composites are often expensive because of the costs of the fibers. In order to make metal matrix composites to be more widely accessible to various markets, there is a need to make metal matrix composites more cost effective.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to using glass fibers as the reinforcing material in fiber reinforced metal matrix composites. The invention includes a metal matrix composite having a metal matrix body portion and glass fibers distributed in the metal matrix body portion. The glass fibers may be infiltrated by the metal matrix. Additionally, the glass fibers may be distributed substantially uniformly in the metal matrix. Still further, at least a portion of the glass fibers may be continuous glass fibers. The glass fibers may be glass fibers, S-glass, E-glass fibers, soda-lime-silica fibers, basalt fibers, quartz fibers, or other similar glassy fibers. Further, the glass fibers may be in the form of woven and/or braided glass fibers, or non-woven glass fibers. The metal matrix is not particularly limited. The metal matrix may include, but is not limited to aluminum, aluminum with 12% silicon, aluminum with 2% copper, and other alloys of aluminum, zinc, and zinc alloys. The invention also includes a metal matrix composite having a plurality of continuous glass fibers substantially encapsulated in a metal matrix comprising aluminum.

[0007] The invention also includes a method for producing a glass fiber reinforced metal matrix composite. The method includes the steps of providing a plurality of glass fibers and embedding the plurality of glass fibers in a metal matrix. The step of embedding may include infiltrating the glass fibers with the metal matrix. The plurality of glass fibers may be supplied in a multifiber tow. The method may also include the step of pulling the glass fibers through a partially or fully molten metal bath.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a diagrammatic view of a glass fiber reinforced metal matrix composite in accordance with an embodiment of the invention.

[0009] FIG. 2 is a diagrammatic view of an apparatus for making a glass fiber reinforced metal matrix composite in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0010] With reference now to FIG. 1, there is shown a glass fiber reinforced metal matrix composite in accordance with an embodiment of the invention designated with the general reference numeral 100. The glass fiber reinforced metal matrix composite includes a plurality of glass fibers, representative glass fibers being represented by the reference numeral 110. The glass fibers 110 are embedded in a metal matrix 120. The glass fibers 110 may be substantially uniformly distributed in the metal matrix 120. Further, the glass fibers 110 may be continuous lengths of fibers extending through the composite 100. The glass fibers 110 may be infiltrated with the matrix metal such that there is substantially no void space between the glass fibers and the metal matrix 120.

[0011] The shape of the glass fiber reinforced metal matrix composite 100 is not particularly limited and may have any number of cross-sectional shapes. Such shapes may include, but are not limited to, circular, elliptical, oval, square, rectangular, triangular, polygonal, irregular polygonal, and the like.

[0012] Generally, the glass fiber 110 may be any type of glass fiber that can maintain some characteristics of a fiber when exposed to the process temperatures and contact with the selected metal. Preferably, the glass fiber improves the mechanical and/or physical properties of the resulting metal matrix composite compared to those of the matrix metal alone. Fibers, depending on the selected matrix metal, may include, but are not limited to, glass fibers, S-glass fibers, E-glass fibers, soda-lime-silica fibers, basalt fibers, quartz fibers, other similar glassy fibers. The diameter of the glass fibers is not particularly limited provided that they may be encapsulated in the metal matrix. In certain embodiments, the diameter of the glass fibers may range from about 5 μm to about 30 μm .

[0013] The matrix metal 120 is not particularly limited, as long as the matrix metal is capable of embedding the selected glass fibers such that the glass fibers retain some characteristic of a fiber during the formation of the composite. Matrix metals, depending on the selected fibers, may include, but are not limited to, aluminum, aluminum with 12% silicon, aluminum with 2% copper, zinc, and zinc

alloys including alloys and combinations thereof, as well as other metals and metal alloys. In certain embodiments, the matrix metal becomes fluid enough for processing at temperatures below those temperatures at which the selected glass fibers are too soft for processing.

[0014] A method for making a glass fiber reinforced metal matrix composite will be described. Glass fibers are provided for embedding in a metal matrix composite. The glass fibers may be in the form of continuous lengths of individual fibers. Further the glass fibers may be a plurality of fibers in the form of continuous lengths of tows, yarns, or the like. Further, the glass fibers may be in the form of a woven material where one or more glass fibers are woven in an arrangement to form a fabric like structure. Additionally, the

metal matrix composite may be taken up on a reel, spool, or provided in continuous lengths.

[0017] Without intending to limit the scope of the invention the following example is provided to illustrate certain embodiments of the invention.

EXAMPLE

[0018] High strength S-2 glass fibers listed in Table I were infiltrated with a metal matrix by passing the glass fibers into an aluminum bath, passing the fibers near an ultrasonic waveguide, and removing the infiltrated fibers from the aluminum bath. The glass fibers were supplied from Advanced Glassfiber Yarns.

TABLE I

ID	Glass Fibers					
	Loss on Ignition (LOI) (%)	Yield (yds/lb)	Tex	Denier	Filament Count	Filament Diameter (μm)
721B-AA-750	0.65	750	660	5940	1730	14
365-225-TRL288	0.7	225	2200	19,800	1730	23
933-AA-375	0.23	375	1325	11,880	16,320	9
933-AA-750	0.23	750	660	5940	8160	9
463-AA-750	1.0	750	660	5940	8160	9
449-AA-250	0.65	250	1980	17820	24,480	9

glass fiber may be in the form of a non-woven material. Such non-woven material may include a sheet, mat, batting, and the like.

[0015] With reference now to FIG. 2, there is shown an apparatus for forming a glass fiber reinforced metal matrix composite, the apparatus being represented by the reference numeral 200. The apparatus 200 may be used to form continuous lengths of composite material through an infiltration process. As shown in FIG. 2, glass fibers 210 are provided and submersed in a metal bath 220 containing the metal will become the metal matrix. The metal bath is typically contained in a furnace 222 sufficient to maintain the temperature of the metal above its softening point. The submersed glass fibers 210 may be infiltrated with the metal from the metal bath 220 by passing the glass fibers near a sonic waveguide 230. The waveguide 230 directs sonic energy from a sonic processor 235 to the fibers and the metal bath surrounding the fibers. The sonic processor 235 may provide ultrasonic energy. The metal wets the fibers so that each individual fiber of the fiber bundle is substantially surrounded or encapsulated by the metal, preferably leaving no or minimal void spaces and forms a softened metal matrix infiltrated glass fiber bundle 240.

[0016] The softened metal matrix infiltrated glass fiber bundle 240 may then be pulled through an optional shaping die 250 to shape the infiltrated glass fiber bundle and control the fiber density in the infiltrated fiber bundle. In certain embodiments, the softened metal infiltrated glass fiber bundles may be continuously drawn through the shaping die 250. The fibers may be drawn through the apparatus 200 manually or by mechanically means. The shaping die 250 provides a glass fiber reinforced metal matrix composite having a desired cross-sectional shape. Once the matrix metal has sufficiently solidified, the glass fiber reinforced

[0019] A pure aluminum bath and an aluminum with 12% silicon bath were used in the process. The aluminum bath temperature was held constant at 1350° C. The ultrasonic probe positioned was varied between 0.125 and 0.250 inches from the glass fibers. The ultrasonic amplitude was varied between settings of 30 and 60 and the processing speed was varied between 36 inches per minute and 294 inches per minute. Under certain conditions, ultrasonic amplitudes below 30 did not achieve infiltration and amplitudes above 60 began to damage the fibers. All fibers produced a glass fiber reinforced metal matrix composite. Micrographs showed good infiltration of the glass fibers. Samples produced ultimate tensile strengths of 46.8 ksi and an elastic modulus of 8.8 Msi.

[0020] The above examples are not to be considered limiting and are only illustrative of a few of the many types of composites that may be prepared. The present invention may be varied in many ways without departing from the scope of the invention and is only limited by the following claims.

What is claimed is:

1. A metal matrix composite comprising:
a metal matrix body portion; and
glass fibers distributed in said metal matrix body portion.
2. The metal matrix composite of claim 1, wherein said glass fibers are infiltrated by the metal matrix.
3. The metal matrix composite of claim 1, wherein said glass fibers are distributed substantially uniformly in said metal matrix.
4. The metal matrix composite of claim 1, wherein at least a portion of said glass fibers are continuous glass fibers.

5. The metal matrix composite of claim 1, wherein said glass fibers are glass.

6. The metal matrix composite of claim 1, wherein said glass fibers are E-glass.

7. The metal matrix composite of claim 1, wherein said glass fibers are basalt fibers.

8. The metal matrix composite of claim 1, wherein said glass fibers are quartz fibers.

9. The metal matrix composite of claim 1, wherein said metal matrix comprises aluminum.

10. The metal matrix composite of claim 1, wherein said metal matrix is selected from the group consisting of aluminum, aluminum with 12% silicon, aluminum with 2% copper, alloys of aluminum, zinc, and zinc alloys.

11. The metal matrix composite of claim 1, wherein said glass fibers are in the form of woven glass fibers.

12. The metal matrix composite of claim 1, wherein said glass fibers are in the form of non-woven glass fibers.

13. The metal matrix composite of claim 1, wherein said glass fibers are selected from the group consisting of, S-glass and soda-lime-silica fibers.

14. A metal matrix composite comprising a plurality of continuous glass fibers substantially encapsulated in a metal matrix comprising aluminum.

15. A method for producing a glass fiber reinforced metal matrix composite, the method comprising the steps of:

providing a plurality of glass fibers; and

embedding said plurality of glass fibers in a metal matrix.

16. The method of claim 15, wherein the step of embedding includes infiltrating said glass fibers with said metal matrix.

17. The method of claim 15, wherein said plurality of glass fibers are supplied in a multifiber tow.

18. The method of claim 15, wherein said plurality of glass fibers are selected from the group consisting of glass fibers, S-glass, E-glass fibers, soda-lime-silica fibers, basalt fibers, quartz fibers, or other similar glassy fibers.

19. The method of claim 15, wherein said metal matrix comprises aluminum.

20. The method of claim 15, wherein said metal matrix is selected from the group consisting of aluminum, aluminum with 12% silicon, aluminum with 2% copper, and alloys of aluminum.

21. The method of claim 20, further comprising the step of pulling said glass fibers through a metal bath.

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