United States Patent Office

3,421,862
Patented Jan. 14, 1969

1

3,421,862
HIGH STRENGTH WHISKER COMPOSITE ARTICLE

James J. Shyne, Caldwell, John V. Milewski, Saddle Brook, and Charles B. Smith, Princeton, N.J., assignors to General Technologies Corporation, Reston, Va., a corporation of Delaware
No Drawing. Filed May 17, 1965, Ser. No. 456,556
U.S. Cl. 29—182.5 2 Claims
Int. Cl. B22f *3/00; 5/00; 7/00*

ABSTRACT OF THE DISCLOSURE

A high-strength whisker composite article is provided herein. The article includes an alloyed matrix which is wetted to single crystal, non-metallic whiskers which are distributed throughout the alloy. One such article comprises a castable alloy matrix, such as aluminum or magnesium into which is incorporated a plurality of discontinuous whiskers.

This invention relates to whisker composite articles and more particularly to an article of exceedingly high strength at low whisker concentration.

Recent improvement in the technique of growing non-metallic whiskers, i.e. single crystal fibers of oxides, carbides and nitrides, have made these materials more readily available than heretofore. Accordingly, there has been considerable activity in the field of greatest commercial interest for these whiskers, namely, as a reinforcing medium for light, but structurally weak, matrix materials, such as metals, plastics and ceramics. Such articles are known as "composites," being a combination of the matrix and the whisker materials. However, the increase in strength anticipated from such composites has not been realized for such useful metals as aluminum and magnesium because of poor wetting between these metals and such whiskers. For example, the problem of incompatibility or non-wetting between a light weight metal matrix, such as aluminum or magnesium, and a single crystal, non-metallic whisker compound such as aluminum oxide whiskers, is well known in the art. Attempts to prepare such composites have not been successful. It is believed that there is a deficiency in bonding and insufficient wetting between the aluminum matrix and the aluminum oxide whiskers which would permit the formation of a stable composite. In order to overcome this difficulty aluminum oxide whiskers have been coated first with a layer of nickel. Then the nickel coated whiskers were unidirectionally oriented in a tube and the aluminum metal matrix material poured into the tube over the coated wiskers. Upon solidification a composite structure was formed in which the nickel coating served as a binder intermediate between the oriented whiskers and the aluminum matrix. This technique has not proved to be very desirable from a commercial standpoint.

Accordingly, it is an object of the present invention to provide a high-strength whisker composite article.

Another object of the invention is to provide a high-strength whisker composite of an alloy matrix and single crystal, non-metallic whiskers.

A further object is to provide such an article in which the alloy matrix is wetted to non-metallic whiskers which are substantially randomly distributed and randomly oriented throughout the alloy.

2

A more specific object is to provide a high-strength castable aluminum alloy composite article in which single crystal alpha-alumina whiskers of a predetermined concentration are wetted directly to the alloy throughout said article.

Among the other objects of the invention is to provide a technique for producing a plurality of castable alloy billets of predetermined tensile strengths in a commercial manner.

In accordance with the present invention, there is provided a high-strength whisker composite article which includes an alloy matrix wetted to a plurality of non-metallic whiskers which are substantially randomly distributed and randomly oriented throughout the alloy matrix. The whiskers are incorporated into the composite in the form of discontinuous, short fibers which are intimately mixed with the alloy matrix.

In preferred embodiments of the invention the alloy is predominately aluminum or magnesium, preferably in an amount constituting at least 80% by weight of the alloy. The secondary metal in the alloy is silicon or copper, preferably between about 6–10% by weight of the alloy. A small amount of a third constituent, such as nickel, titanium, beryllium, lithium, boron, tin, zinc or magnesium also may be included. Usually the minor constituents of the alloy comprise between 1 and 20% by weight of the alloy.

The non-metallic whisker materials preferably are selected from among the following classes of compounds: oxides, carbides and nitrides. Preferred compounds are alumina oxide (alpha-alumina), silicon carbide (beta), and aluminum nitride. Other whisker compounds, such as alpha silicon carbide beryllium oxide, magnesium oxide, boron carbide and silicon nitride also may be used. Usually the preferred whiskers have an effective diameter of about 1–10 microns and length to diameter ratio of about 10:1 to 200:1. Suitable methods of preparation of the whisker materials are described in detail in our copending applications, Shyne and Milewski (TKF–1x) Ser. No. 443,153, filed Mar. 26, 1965 (preparation of alpha-alumina whiskers); Shyne and Milewski (TKF–3) Ser. No. 399,485, filed Sept. 28, 1965 (preparation of beta-silicon carbide whiskers) now abandoned Shyne and Milewski (TKF–8), Ser. No. 479,111 filed Aug. 12, 1965 (preparation of aluminum nitride whiskers). However, the methods described in the literature for these and other whisker compounds also may be used. Generally the whiskers are present in an amount between about 0.5 to 70% by weight of the composite.

The high-strength whisker composite article of the present invention is fabricated by first intimately mixing powders of the pre-alloy constituents and the whisker compound in predetermined proportions. The resultant mixture then is heated at elevated temperatures to produce the desired product. Heating may consist of hot pressing the mixture directly, or cold pressing followed by sintering. Usually a billet having a relatively high concentration of whiskers is made first from which composites of lower whisker concentration can be prepared by addition thereto of alloy material only. Suitably the billet has up to 70% by weight of whiskers. Dilution with alloy reduces the whisker concentration to 0.5% by weight.

The whisker reinforced composite article of the invention is of exceedingly high strength as compared to the alloy material per se. In a typical preparation, for example, a random addition of 10% by weight of short, fine discontinuous, single crystal alpha-alumina whiskers to an alloy composition comprising 93 parts aluminum and 7 parts silicon, produces a composite article which exhibits more than twice the tensile strength and about 1½ times the modulus of the alloy itself. These properties are attributable to the excellent wetting between the alloy composition and the whiskers throughout the structure. A further feature and advantage of this and other whisker composites of the invention is their ability to be cast readily into articles of desired shape.

The examples which follow will more specifically illustrate the invention.

Example 1

93 parts by weight of powdered aluminum metal (200 mesh) is mixed thoroughly with 7 parts by weight of powdered silicon metal (200 mesh). To 90 parts of this mixture is added 10 parts by weight of single crystal alpha-alumina whiskers. The whiskers are loose needles, 1–10 microns in diameter, with a length to diameter ratio of 10:1 to 200:1. The whisker particles are intimately dispersed with the metal powders so that a randomly distributed and randomly oriented compostion is produced. The resultant mixture is hot pressed at 1000° F. into a shaped article. The article exhibits a tensile strength of 96,000 p.s.i., and a modulus of 15 million, at room temperature. A similarly prepared alloy matrix without alpha-alumina whiskers possesses only half the tensile strength, and only two-thirds the modulus.

Example 2

The procedure of Example 1 is followed except that between 10 and 70 parts by weight of alpha-alumina whiskers is added to the alloy mixture. The resultant whisker-reinforced composite exhibits a further increase in tensile strength and modulus in accordance with the amount of whiskers present in the composite.

Example 3

The whisker-reinforced composite article prepared according to the procedure described in detail in Example 2 is then melted and cast in the form of billets having a 50% concentration of whiskers. This cast billet of high whisker concentration then is subdivided into several billets each of which has the same whisker concentration. One of these smaller size billets then is mixed thoroughly with 90 parts by weight of a molten alloy composed of 93 parts by weight aluminum and 7 parts by weight silicon to form a resultant castable aluminum-silicon alloy composite having a whisker concentration of 5 parts by weight. Another of the highly concentration billets is treated in a similar manner with 500 parts by weight of the same alloy concentration to produce a high strength composite having a whisker concentration of 1 part by weight. A third billet is diluted in the same way to a whisker concentration of 0.5 part by weight of the composite. Each of the composites thus produced exhibits an improvement in strength characteristics over the alloy itself, the degree of increase being generally proportional to the whisker concentration.

Example 4

The procedure of Examples 1–3 is followed using silicon carbide aluminum nitride, beryllium oxide, magnesium oxide, boron carbide and silicon nitride whiskers, alternately, in place of alpha-alumina whiskers, in the same concentration range, to produce similar high-strength whisker-reinforced composites of these whisker materials.

Example 5

The procedure of Examples 1–4 is followed using copper in place of silicon, in the same concentration range, to produce high strength whisker-composites of aluminum-copper alloys wetted to these whisker materials.

Example 6

The procedure of Examples 1–5 is repeated using first 1 and then 20 parts by weight of silicon and copper in place of 7 parts by weight of the same metals to produce high strength, whisker reinforcement composite articles in which the whiskers are wetted directly to aluminum alloys of this composition.

Example 7

The procedure of Examples 1–7 is repeated using between 0.5 and 5 parts by weight of nickel, titanium, beryllium, lithium, boron, tin, zinc, or magnesium in addition to between 6–10 parts by weight of silicon or copper, to produce castable whisker composite articles of these aluminum-silicon or aluminum-copper alloys having the third metal constituent present therein.

Example 8

93 parts by weight of powdered magnesium metal (200 mesh) is mixed intimately with 7 parts by weight of powdered silicon metal (200 mesh). To this mixture is added 10 parts by weight of single crystal beta-silicon carbide whiskers. The whiskers are loose needles, 1–10 microns in diameter, with a length to diameter ratio of 10:1 to 200:1. The whisker particles are intimately dispersed with the metal powders so that a randomly distributed and randomly oriented composition is produced. The resultant mixture is cold pressed at room temperature into a shaped article, and sintered at 1000° F. The whisker-reinforced product exhibits a tensile strength of 70,000 p.s.i., and a modulus of 10 million. A similarly prepared alloy matrix without the addition of whiskers exhibits a tensile strength of only 40,000 p.s.i., and modulus of only 6 million.

Example 9

The procedure of Example 8 is repeated using 10 parts by weight of alpha-alumina in place of beta-silicon carbide to produce high-strength alpha-alumina whisker composite articles in which the whiskers are wetted directly to the magnesium-silicon alloys.

Example 10

The procedure of Example 8 is repeated using 20 and 40 parts by weight of beta-silicon carbide whiskers. A further improvement in tensile strength and modulus properties is noted with the increase in whisker concentration.

Example 11

An alloy composition is prepared by mixing 89 parts by weight magnesium, 9 parts by weight aluminum and 2 parts by weight zinc. To this mixture is added 10 parts by weight of alpha-alumina whiskers of the same dimensions as in Example 1. The resultant mixture is intimately mixed and hot pressed at 1000° F. Upon cooling, the shaped article is cast into a billet, which shows an increased tensile strength and modulus characteristics over the same alloy without the addition of whisker material.

Although the invention has been illustrated with reference to certain preferred embodiments, it will be understood that changes and modifications may be made which are within the skill of the art and the spirit and scope of the invention made herein. Accordingly we intend to be limited only by the appended claims which follow hereinafter.

What is claimed:

1. A high-strength whisker composite article consisting essentially of

(a) an alloy matrix consisting essentially of aluminum or magnesium, and at least one secondary metal selected from among silicon and copper, said aluminum or magnesium constituting at least 80 percent by weight of said alloy, and

(b) a plurality of discontinuous single crystal whiskers selected from among metallic oxides, carbides and nitrides, said whiskers constituting between 0.5–70 percent by weight of said composite, said whiskers being wetted to said alloy matrix.

2. A composite article according to claim 1 wherein said secondary metal constitutes between 6–10 percent by weight of said alloy.

References Cited

UNITED STATES PATENTS

2,953,849	9/1960	Morgan	29—419
3,038,248	6/1962	Kremer	29—419
3,070,440	12/1962	Grant	75—206
3,167,427	1/1965	Slayter	75—206 X
3,218,697	11/1965	Wainer	75—206 X
3,231,341	1/1966	Sump	29—180
3,256,596	6/1966	Fiedler	29—419
3,282,658	11/1966	Wainer	29—183.5
3,320,038	5/1967	Schulz	75—204 X
3,320,056	5/1967	Stoops	75—206 X

OTHER REFERENCES

"Fiber Composite Materials," by American Society for Metals (papers presented Oct. 10, 17 and 18, 1964) Library of Congress Catalog Card Number: 65–23128, pp. 201–213.

CARL D. QUARFORTH, *Primary Examiner.*

A. J. STEINER, *Assistant Examiner.*

U.S. Cl. X.R.

75—203, 205, 206