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COMPOSITES OF BERYLLIUM-ALUMINUM-ZINC

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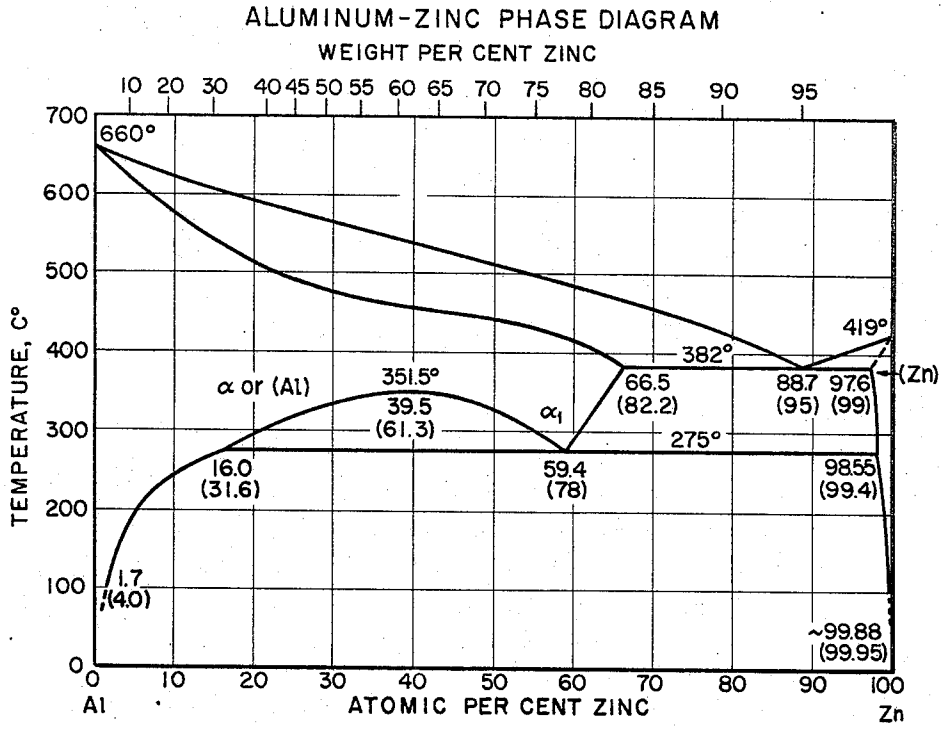



FIG. 1

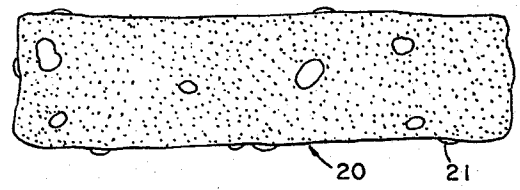



FIG. 2

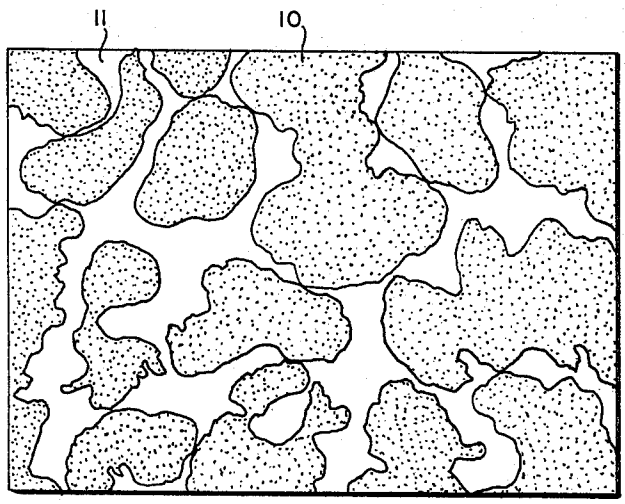



FIG. 3


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# COMPOSITES OF BERYLLIUM-ALUMINUM-ZINC

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## ABSTRACT OF THE DISCLOSURE

A two phase composite material whose microstructure consists of beryllium dispersed in an aluminum-zinc-beryllium solid solution alloy matrix was produced by liquid phase sintering pressed powder mixtures of beryllium, aluminum and zinc or powder mixtures of beryllium and prealloyed aluminum-zinc.

The present invention relates to ductile composites of beryllium-aluminum-zinc which can be sintered to substantially theoretical density and to means and methods for providing said composites through liquid phase sintering.

Liquid phase sintering differs from the several other types of sintering techniques in that the sintering of the compact is carried out in the presence of a liquid phase. Liquid phase sintering encompasses raising the temperature of the compressed powder metal constituents of beryllium, aluminum and zinc to a temperature wherein a predetermined amount of the liquid phase appears. In the liquid phase, one of the metal constituents, the solid, is progressively dissolved in the other metal constituent or constituents, the liquid. However, the quantities of these constituents are such that, at equilibrium, some solid phase always exists. It is thought that the liquid wets the solid so as to bring about favorable surface energies existing between the liquid and the solid thereby permitting solution into the liquid phase.

However, heretofore, when beryllium-aluminum-zinc composites were fabricated in accordance with known liquid phase sintering techniques, it was found that the solid beryllium expelled the liquid aluminum-zinc-beryllium alloy from the compact during liquid phase sintering. It is thought that the unfavorable surface energy equilibrium causing expulsion of the liquid aluminum-zinc beryllium alloy is due to a tough, tenacious film of beryllium oxide which is present on each particle of beryllium.

The present invention prevents the expulsion of the liquid aluminum-zinc-beryllium alloy from the specimen by using an agency to intervene in the sintering stage. The agency either breaks down the oxide film on the beryllium or segregates to the metal oxide interface and lowers the surface energy of the liquid metal with respect to the beryllium oxide film so that the liquid metal progressively dissolves the solid metal.

The agency can be called a fluxing agent or flux, however, the agent has other characteristics which assist in wetting beryllium so as to surround the beryllium with a ductile envelope phase of aluminum-zinc-beryllium alloy matrix metal thereby avoiding the expulsion of the liquid from the specimen.

Beryllium has several desirable physical features which make it attractive for a variety of commercial applications such as lightweight gears, lightweight fasteners, brackets,



housing, airplane parts or the like. However, beryllium has one major drawback which has seriously limited its commercial acceptance, that is, beryllium is inherently brittle at room temperature.

The lack of ductility of beryllium is attributed to the crystal structure of beryllium which is hexagonal close packed. During deformation, the basal planes of the hexagonal close packed structure, being the easiest to slip, are aligned along the working direction. Since slip is crystallographically difficult perpendicular to the basal plane, the ductility of beryllium perpendicular to the primary fabrication direction is practically nonexistent.

Several possible solutions have been advanced in an attempt to make beryllium metal sufficiently ductile so as to permit a widespread commercial acceptance of beryllium. Cross-rolling and cross-forging have been suggested as fabrication methods which might enhance the ductility of beryllium. These fabrication techniques reduced the number of basal planes along the direction of rolling and resulted in improved ductility. However, the degree of improvement was far from satisfactory. The fact remained that beryllium must be classified as brittle at room temperature even utilizing the aforementioned method when ductility perpendicular to the fabrication temperature is considered. In addition, the abovementioned technique would not be feasible where the fabrication is, by nature, solely along one axis such as swaging, drawing and extrusion.

In recent years, attention has been directed to the fabrication of beryllium alloys not having the inherent brittleness of beryllium itself but possessing various outstanding properties of the metal such as, for example, low density combined with high strength. It is thought that U.S. Patent 3,082,521 fabricated the first ductile beryllium alloy by rapidly cooling the part from a temperature at which it was liquid. However, the beryllium content of the alloy was not in excess of 86.3 atomic percent which is approximately 33 weight percent of the alloy. Although the beryllium alloy was ductile, the density of the alloy was in excess of that of aluminum and about equal to that of titanium.

It has also been suggested that beryllium alloys might be fabricated by pressing and sintering a mix of metal powders. However, such a method results in expulsion of the matrix metal or metals from the beryllium specimen and the eventual freezing of the matrix metal or metals into globs on the surface of the solid specimen. It is thought that the expulsion of the matrix metal or metals is due to the surface energies of the solid beryllium and the various liquids formed. The unfavorable surface energy equilibrium is believed to be due to a tough, tenacious film of beryllium oxide which is present on each particle of beryllium.

A means and method have been discovered for preparing a composite of beryllium, aluminum and zinc containing about 50 to 85 percent, by weight, of beryllium, a trace to about 50 percent, by weight, aluminum and a trace to about 50 percent, by weight, zinc. However, the aluminum-zinc alloy of interest are those containing about 5.5 to 6.5 percent by weight zinc relative to aluminum, thereby producing a composite having a density about the same as or less than that of aluminum, having high strength, and having good ductility. The ductility is due to the resulting microstructure of the composite. By surrounding the beryllium particles with a ductile envelope phase, a composite is formed where, under load, the

beryllium is so constrained by the ductile phase that it and the ductile phase deform continously.

The 85 percent, by weight, beryllium composite showed a considerable amount of particle contiguity and would represent, it is thought, an upper limit on the percent by weight of beryllium contained by the composite. A decrease in beryllium content below 50 percent would raise, it is thought, the density value of the composite to a value of little interest.

Alkali and alkaline earth halogenide agents such as lithium fluoride-lithium chloride or the like in a determined ratio are utilized to segregate to the solid interface of the beryllium particle and either break down the film on the particle of beryllium and/or alter the liquid-solid surface energy in the system.

Therefore, it is an object of the present invention to provide a ductile beryllium-aluminum-zinc composite having low density and high strength.

Another object of the present invention is to provide a ductile composite of beryllium-aluminum-zinc in which beryllium is the predominant ingredient.

Yet another object of the present invention is to provide a means and method of producing a ductile composite of beryllium wherein the microstructure consists of beryllium particles surrounded by a ductile envelope phase of aluminum-zinc-beryllium alloy matrix metal.

Still another object of the present invention is to provide a ductile composite of beryllium-aluminum-zinc containing about 50 to 85 percent, by weight, beryllium, a trace to about 50.0 percent, by weight, aluminum and a trace to about 50 percent, by weight, zinc.

A further object of the present invention is to provide a ductile beryllium-aluminum-zinc composite having a matrix phase that is heat treatable.

A further object of the present invention is to provide a composite of beryllium-aluminum-zinc that may be sintered to substantially theoretical density.

Another object of the present invention is to provide a ductile composite of beryllium-aluminum-zinc containing about 50 to 85 percent, by weight, beryllium and the remainder an alloy of aluminum-zinc, consisting of about 93.5 to 94.5 percent, by weight, aluminum, the remainder zinc.

Still another object of the present invention is to provide a means and method whereby a ductile beryllium-aluminum-zinc composite may be successfully fabricated in both a practical and economical manner.

Yet still another object of the present invention is to provide an agent which eliminates the expulsion of an alloy of aluminum-zinc-beryllium from a beryllium specimen.

A further object of the present invention is to provide an agent to promote liquid phase sintering of a beryllium-aluminum-zinc mixture.

Still another object of the present invention is to provide alkali and alkaline earth halogenide agents used in the fabrication of a beryllium-aluminum-zinc composite.

Another object of the present invention is to provide a lithium fluoride-lithium chloride agent for promoting liquid phase sintering in a beryllium, aluminum and zinc mix.

A further object of the present invention is to provide a lithium fluoride-lithium chloride agent wherein the constituents are used in a predetermined ratio.

The present invention, in another of its aspects, relates to novel features of the instrumentalities of the invention described herein for teaching the principal object of the invention and to the novel principles employed in the instrumentalities whether or not these features and principles may be used in the said object and/or in the said field.

With the aforementioned objects enumerated, other objects will be apparent to those persons possessing ordinary skill in the art. Other objects will appear in the following description and appended claims. The invention resides in the novel combination of elements and in the means and



method of achieving the combination as hereinafter described and more particularly as defined in the appended claims.

In the drawings:

FIGURE 1 is a phase diagram for binary alloys of aluminum-zinc.

FIGURE 2 is a photomicrograph of a beryllium specimen illustrating an aluminum-zinc-beryllium matrix metal expelled from the specimen by the forces of surface energy of solid beryllium and the aluminum-zinc-beryllium liquid.

FIGURE 3 is an enlargement showing about a 70 percent, by weight, beryllium, about 28.3 percent, by weight, aluminum, remainder zinc composite illustrating beryllium particles surrounded by a ductile envelope phase of an aluminum-zinc-beryllium alloy.

Generally speaking, the means and method of the present invention relate to a ductile beryllium-aluminum-zinc composite fabricated by liquid phase sintering to substantially theoretical density. The composite contains about 50–85 percent, by weight, of beryllium, a trace to about 50 percent, by weight, aluminum, and a trace to about 50 percent, by weight, zinc.

The method of producing the beryllium-aluminum-zinc composite by liquid phase sintering comprises the steps of mixing predetermined portions of powder beryllium and a powder alloy of aluminum-zinc or aluminum powder and zinc powder with a predetermined portion of an agent selected from the group consisting of alkali and alkaline earth halogenides. The portions are pressed in a die to form a green compact. The compact is then heated to the sintering temperature of beryllium. At this temperature the agent provides a favorable surface energy equilibrium between the beryllium and the aluminum-zinc alloy so that the alloy progressively dissolves the beryllium at the sintering temperature so as to form an aluminum-zinc-beryllium alloy matrix. Thereafter, the beryllium-aluminum-zinc composite may be heat treated and rapidly quenched so as to preserve the heat treating temperature structure and the aluminum is supersaturated with zinc. Precipitation or ageing may be carried out followed by air cooling to room temperature.

More particularly, the method of the present invention comprises mixing powder beryllium of about 50–85 percent, by weight, with a powder alloy of aluminum-zinc or the elemental powders of aluminum and zinc. An agent of lithium fluoride-lithium chloride in about 0.5 to 2.0 percent, by weight, of the total metal additions is mixed with the beryllium or with the beryllium and the alloy powder or elemental powder. The preferred ratio of the constituents of the agent is about a one to one ratio by weight. The beryllium, the alloy powder or elemental powder, and the agent are pressed so as to form a green compact. The green compact is heated in a non-oxidizing atmosphere such as argon at a temperature of about 700° C. to about 1100° C. At the aforementioned temperatures, the agent provides a favorable surface energy equilibrium between the beryllium and the alloy so that the aluminum-zinc alloy progressively dissolves the beryllium. The microstructure of the resultant composite consists of beryllium particles surrounded by a ductile envelope phase of an aluminum-zinc-beryllium alloy matrix metal. The alloy is sintered to substantially its theoretical density. The alloy may be specially heat treated and rapidly quenched so that the heat treating temperature structure is preserved and the aluminum is supersaturated with zinc. Precipitation or ageing may be carried out followed by air cooling to room temperature.

In carrying out the present invention, a beryllium base compact is fabricated by any suitable means such as powder metallurgy techniques. A suggested method utilizing this technique is to mix beryllium powder with an agent of equal parts of lithium fluoride-lithium chloride. It is seen that the ratio of lithium fluoride to lithium chloride may be varied. The milling is carried

out for about 1 hour using ceramic balls. Thereafter, a powder alloy of aluminum-zinc or the elemental powders are ball mill mixed with the beryllium and the agent for an additional hour. The blended and mixed powders are compacted to form a green compact by accepted metallurgical methods such as by compacting within the confines of a die in a hydraulic or an automatic press or by placing the powder in a rubber or plastic mold and compacting in a hydrostatic press. The green compact is sintered in a non-oxidizing atmosphere such as argon or the like at a temperature of about 700° C. to about 1100° C. It is seen that the range of the sintering temperatures is below the 1277° centigrade melting point temperature of the beryllium and is above the melting point temperature of the aluminum-zinc alloy. The aluminum-zinc alloy will dissolve smaller beryllium particles and will dissolve the surfaces of the larger beryllium powder particles so as to surround the remaining beryllium particles with a ductile envelope phase of an aluminum-zinc-beryllium alloy during sintering of the compact. The resultant composite of beryllium-aluminum-zinc had a density of about 98.5 percent of theoretical density.

Composites containing about 50 to 85 percent, by, weight, of beryllium, and the remainder an alloy of aluminum-zinc were successfully fabricated. The agent prevented the expulsion of the liquid aluminum-zinc-beryllium alloy from the compact by the forces of surface energy, that is, prevented the formation of very fine rounded droplets of the aluminum-zinc-beryllium alloy on the surface of the beryllium specimen. FIGURE 2 shows a beryllium specimen **20** having on the surface thereof an expelled alloy **21** of aluminum-zinc-beryllium. Specimens from which the aluminum-zinc-beryllium alloy has been expelled have gross porosity and as a result are weak, brittle, and of little commercial value.

The composition of the agent utilized is about 50 parts, by weight, of lithium fluoride to about 50 parts, by weight, of lithium chloride. The agent provides an action, such that, upon heating or sintering of the pressed powder mix to the temperature at which the liquid phase forms, expulsion of the melt from the specimen is eliminated. Furthermore, it was found that solution of the beryllium into the alloy was enhanced as evidenced by the rounded particles of beryllium in the microstructure.

It was found that the amount by weight of lithium fluoride-lithium chloride agent should exceed 0.5 percent, by weight, of the total of all metal additions. It would appear that the optimum range of the agent is from about 0.5 percent to about 2.0 percent, by weight, of the total of all metal additions. It is believed that the quantity of lithium fluoride-lithium chloride agent required is related to the amount necessary to cover the total beryllium surface area. Hence, the minimum amount of agent needed would be a function of the surface area of the beryllium powder. The utilization of lithium fluoride-lithium chloride agent in other than equal parts was done. It is thought, however, that an equal parts mixture achieves optimum results.

It was found during sintering that substantially 100 percent of the fluxing agent was lost during sintering. This result would seem to indicate that the flux entered into a chemical reaction whereon it decomposed and then volatilized and/or the flux volatilized as lithium fluoride-lithium chloride during the liquid phase sintering operation.

By using the methods of the present invention and the lithium fluoride-lithium chloride agent, compacts were fabricated containing up to 85 percent, by weight, of beryllium, the remainder an alloy of aluminum-zinc without the use of pressure during sintering. Using powder beryllium having a particle size of 20 microns or finer and using ceramic balls to blend the powder metals and the agent resulted in a composite having a high density. The good strength and low density characteristics of the beryllium were retained and the resulting beryllium-aluminum-zinc composite possessed good ductility. The composite was sintered to about 93 percent of its theoretical density by a single sinter and achieved about 98.5 percent of theoretical density by a repress and an intermediate reliquid phase sinter for about 1 hour.

Thus, by substantially surrounding the beryllium particles with a ductile envelope phase of an aluminum-zinc-beryllium alloy matrix metal, the beryllium and the matrix metal deform continuously under load.

An aluminum-zinc phase diagram is illustrated in FIGURE 1. Zinc strengthens aluminum by solid solution hardening and precipitation hardening. The theory of the deformation of dispersed particle composite materials states that ductility in such a composite will be enhanced when the constrained flow stress of the matrix phase can be made as equal as possible to the flow stress of the dispersed particles. Hence, zinc is used to harden aluminum. Once the composite has been cooled to room temperature, the effectiveness of the zinc is further brought into play by a subsequent heat treatment. It was found that heat treating the composite at about 460°–500° C. for about 1 hour is sufficient to completely dissolve all the zinc in the aluminum. The composite is rapidly quenched into a satisfactory medium such as water or the like, such that the high temperature structure is preserved and the aluminum is supersaturated with zinc. Hence, the solutionizing treatment contains all the zinc in solution. The zinc can be precipitated out of the supersaturated solid solution increasing the strength of the aluminum-zinc matrix. An advantage of the beryllium-aluminum-zinc composite is that the matrix phase is heat treatable.

Attention is directed to FIGURE 3, wherein a photomicrograph of about 500 magnifications shows a composite of 30 percent, by weight, aluminum-zinc alloy in beryllium after being etched by any suitable etching means such as a dilute solution of ammonium hydroxide and hydrogen peroxide. The areas **10** are beryllium particles. The areas **11** are the aluminum-zinc-beryllium alloy surrounding the beryllium particles.

As disclosed hereinbefore, the basic matrix alloys are those containing about 5.5 to 6.5 percent, zinc to aluminum. The solubility of zinc in aluminum decreases rapidly with a decreasing temperature as evidenced by the fact that solubility is 31.6 percent, by weight, zinc in aluminum at 275° C. and 4.0 percent, by weight, zinc in aluminum at 100° C. The matrix phase can be further hardened by conventional hardening techniques as applied to an aluminum-zinc alloy. Hardening is carried out after liquid phase sintering and composite densification are completed. Heat treatment in the case of aluminum–5.5 zinc consists of heating to upwards of one hour at about 460–500° C. to dissolve all the aluminum in the zinc followed by a cold water quench. Ageing or precipitation hardening is carried out by heating the composite to 120–160° C. for up to 20 hours followed by air cooling. In the case of aluminum–6.5 zinc, solution treating is carried out at 430–450° C. for up to 10 hours followed by a cold water quench. Precipitation is carried out at 130–160° C. for about 24 hours followed by air cooling.

It will be recognized by those skilled in the art that minor additions of other metals may be added to the matrix of the composite to improve one or more of the physical properties such as machinability, deoxidation, and the like. For example, an addition of a trace to about 1 percent, by weight, of either bismuth manganese, or lead to the composite improves machinability thereof. An addition of a trace to about 1 percent, by weight, of magnesium to the composite will improve the deoxidation property of the composite.

Example 1 shows the expulsion of the liquid from a beryllium specimen and Examples 2–15 are illustrative of

the preparation of beryllium-aluminum-zinc composites by liquid phase sintering.

Example 1

Expulsion of the liquid aluminum-zinc-beryllium alloy from the solid beryllium specimen occurs during liquid phase sintering when the agent of lithium fluoride-lithium chloride is not used in the preparation of a beryllium-aluminum-zinc composite.

A mixture of about 70 percent, by weight, of beryllium having a particle size of 200 mesh or finer was ball mill mixed with about 30 percent, by weight, of an alloy of aluminum-zinc or the elemental powder of suitable particle size. The alloy contained about 94.5 percent, by weight, aluminum, and about 5.5 percent, by weight, zinc. The milled mixture was pressed by any suitable means such as by an automatic press at a suitable pressure to provide a green compact sturdy enough to be handled. It was found that pressures of from about 15,000 to 20,000 pounds per square inch resulted in a green compact having a density from about 50 to 60 percent of theoretical density and sufficiently strong to be handled. Sintering of the compact was carried out in an argon atmosphere at about 1100° C. for about 1 hour. This technique, due to the surface energies of the solid beryllium and the liquid formed, resulted in the expulsion of the liquid from the specimen and its eventual freezing into rounded globs on the surface of the specimen as shown in FIGURE 2.

Example 2

A composite of about 70 percent, by weight, beryllium, about 28.3 percent, by weight, aluminum, and the remainder zinc.

A mixture of about 70 percent, by weight, of beryllium powder having a particle size of 200 mesh or finer was ball mill mixed using ceramic balls with about 30 percent, by weight, of an alloy of aluminum-zinc powder of suitable particle size. The alloy contained about 94.5 percent, by weight, aluminum and about 5.5 percent, by weight, zinc. Also ball mill mixed with the beryllium and alloy powders was about 1.0 percent, by weight, of the total metal additions equal parts of an agent of lithium fluoride-lithium chloride. Mixtures of the beryllium and alloy powders were also prepared with the agent having 0.5 and 2.0 percent, by weight, of the total metal additions using varying ratios of lithium fluoride-lithium chloride. The milled mixture was pressed by any suitable means such as by an automatic press at a suitable pressure to provide a green compact sturdy enough to be handled. It was found that pressures of from about 15,000 to 20,000 pounds per square inch resulted in a green compact having a density of from 50 to 60 percent of theoretical density and sufficiently strong to be handled. Sintering of the compact was carried out in an argon atmosphere at about 1100° C. for about 1 hour. A second press followed by a second sinter at about 1100° centigrade for about 1 hour raised the density of the composite to about 98.5 percent of theoretical density. The composite was heat treated at about 460–500° C. for about 1 hour so as to completely dissolve all the zinc into the aluminum. The composite was then rapidly quenched so that the heat treating temperature structure was preserved and the aluminum was supersaturated with zinc. The zinc can be precipitated from the supersaturated solid solution thereby precipitation hardening the composite by heating the composite to about 120°–160° C. for about 20 hours followed by air cooling.

Example 3

A composite of about 70 percent, by weight, beryllium, about 28 percent, by weight, aluminum, and the remainder zinc.

A mixture of beryllium powder having a particle size of 20 micron or finer was ball mill mixed with about 2.0 percent, by weight, of the total metal additions equal parts of an agent of lithium fluoride-lithium chloride. The milling was carried out with ceramic balls for about 1 hour. Thereafter, an alloy powder of about 93.5 percent, by weight, aluminum and 6.5 percent, by weight, zinc was ball mill mixed with the beryllium for about 1 hour. Ceramic balls were used to mix the powders. The beryllium constituted about 70 percent, by weight of the blended powders and the alloy powder constituted about 30 percent of the blended powders. Mixtures of the beryllium and alloy powders were also prepared with the agent having 0.5 and 1.0 percent, by weight, of the total metal additions using varying ratios of lithium chloride to lithium fluoride. The milled mixture was pressed by any suitable means such as by an automatic press at a suitable pressure to provide a green compact sturdy enough to be handled. It was found that pressures of from about 15,000 to 20,000 pounds per square inch resulted in a green compact having a density of from about 50 to 60 percent of theoretical density and sufficiently strong to be handled. Sintering of the compact was carried out in an argon atmosphere at about 1100° C. for about 1 hour. After a repress and resinter a composite was yielded having a density of about 98.5 percent of theoretical density. Another composite was prepared using the above procedure but sintering for ½ hour. Each composite was heat treated at about 430–450° C. for about 10 hours so as to dissolve the zinc into the aluminum. Each composite was then rapidly quenched so that the heat treating temperature structure was preserved and the aluminum was supersaturated with zinc. The zinc can be precipitated from the supersaturated solid solution thereby precipitation hardening the composite by heating to about 130–160° C. for about 24 hours followed by air cooling. A sintering temperature as low as 700° C. may be used.

Example 4

A composite of about 70 percent, by weight, beryllium, 28 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 3 was followed using about 70 percent, by weight, beryllium, about 28 percent, by weight, aluminum powder, and the remainder zinc powder. Individual composites were prepared using 0.5, 1.0 and 2.0 percent, by weight, of the total metal additions at temperatures of about 700°, 800°, 900°, 1000° and 1100° C.

Example 5

A composite of about 70 percent, by weight, beryllium, 28.3 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 3 was followed using about 70 percent, by weight, beryllium powder, mixed with about 30 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contains about 94.5 percent, by weight, aluminum and about 5.5 percent, by weight, zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride in equal proportions and in unequal proportions at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and 1 hour using the aforementioned procedure.

Example 6

A composite of about 50 percent, by weight, beryllium, about 50 percent, by weight, aluminum, and a trace of zinc.

The procedure of Example 3 was followed using 50 percent, by weight, beryllium powder, mixed with about 50 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contained about 100 percent, by weight, aluminum and a trace of zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium

chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 7

A composite of about 50 percent, by weight, beryllium, about 50 percent, by weight, zinc and a trace of aluminum.

The procedure of Example 3 was followed using 50 percent, by weight, beryllium powder, mixed with about 50 percent, by weight, zinc powder and the remainder aluminum powder. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of an agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 8

A composite of about 50 percent, by weight, beryllium, about 46.7 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 3 was followed using 50 percent, by weight, beryllium powder, mixed with about 50 percent, by weight of an alloy powder of aluminum-zinc. The alloy contained about 93.5 percent, by weight, aluminum, the remainder zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 9

A composite of about 50 percent, by weight, beryllium, about 47.2 percent by weight, aluminum, and the remainder zinc.

The procedure of Example 2 was followed using 50 percent, by weight, of an alloy powder of aluminum zinc. The alloy contained about 94.5 percent, by weight, aluminum, the remainder zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 10

A composite of about 60 percent, by weight, beryllium, 37.8 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 2 was followed using 60 percent, by weight, beryllium powder, mixed with about 40 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contains 94.5 percent, by weight, aluminum and 5.5 percent, by weight, zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 11

A composite of about 75 percent, by weight, beryllium, 23.6 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 2 was followed using 75 percent, by weight, beryllium powder, mixed with about 25 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contained 94.5 percent, by weight, aluminum and 5.5 percent, by weight, zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and for 1 hour using the aforementioned procedure.

Example 12

A composite of about 85 percent, by weight, beryllium, about 15 percent, by weight, aluminum, and the remainder a trace of zinc.

The procedure of Example 3 was followed using 85 percent, by weight, beryllium powder, mixed with about 15 percent, by weight of an alloy powder of aluminum-zinc. The alloy contained about 100 percent, by weight, aluminum, the remainder a trace of zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and 1 hour using the aforementioned procedure.

Example 13

A composite of about 85 percent, by weight, beryllium, about 15 percent, by weight, zinc, and the remainder a trace of aluminum.

The procedure of Example 3 was followed using 85 percent, by weight, beryllium powder, mixed with about 15 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contained about 100 percent, by weight, zinc, the remainder a trace of aluminum. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and 1 hour using the aforementioned procedure.

Example 14

A composite of about 85 percent, by weight, beryllium, about 14 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 3 was followed using 85 percent, by weight, beryllium powder, mixed with about 15 percent, by weight of an alloy powder of aluminum-zinc. The alloy contained about 93.5 percent, by weight, aluminum, and the remainder zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and 1 hour using the aforementioned procedure.

Example 15

A composite of about 85 percent, by weight, beryllium, about 14.2 percent, by weight, aluminum, and the remainder zinc.

The procedure of Example 2 was followed using 85 percent, by weight, beryllium powder, mixed with about 15 percent, by weight, of an alloy powder of aluminum-zinc. The alloy contained about 94.5 percent, by weight, aluminum, and the remainder zinc. Individual composites were prepared using 0.5, 1.0 and 2.0 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride at temperatures of about 700°, 800°, 900°, 1000° and 1100° C. for ½ hour and 1 hour using the aforementioned procedure.

The present invention is not intended to be limited to the disclosure herein, and changes and modifications may be made in the disclosure by those skilled in the art without departing from the spirit and scope of the novel concepts of this invention. Such modifications and variations are considered to be within the purview and scope of this invention and the appended claims.

Having thus described our invention, we claim:

1. A ternary metal composite consisting essentially of about 50–85 percent, by weight, of beryllium, and the remainder an alloy of aluminum-zinc.

2. A ternary metal composite according to claim 1, wherein said beryllium particles are surrounded by a matrix of an alloy of aluminum-zinc-beryllium.

3. A metal composite according to claim 1, wherein said composite consisting essentially of a trace to about 50 percent, by weight, aluminum, and a trace to about 50 percent, by weight, zinc.

4. A metal composite according to claim 1, wherein said alloy of aluminum-zinc consisting essentially of about 93.5–94.5 percent, by weight, aluminum, the remainder zinc.

5. A metal composite according to claim 1, wherein said alloy of aluminum-zinc consisting essentially of about 14 to 47.2 percent, by weight, aluminum and about 0.8 to 3.3 percent, by weight, zinc.



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