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R. H. KROCK ETAL

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BERYLLIUM-SILVER-COPPER COMPOSITE

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SILVER-COPPER PHASE DIAGRAM

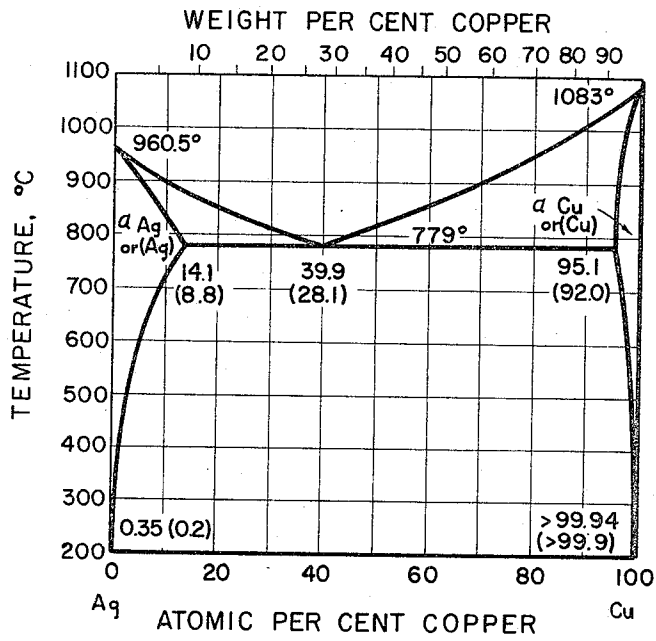


FIG 1

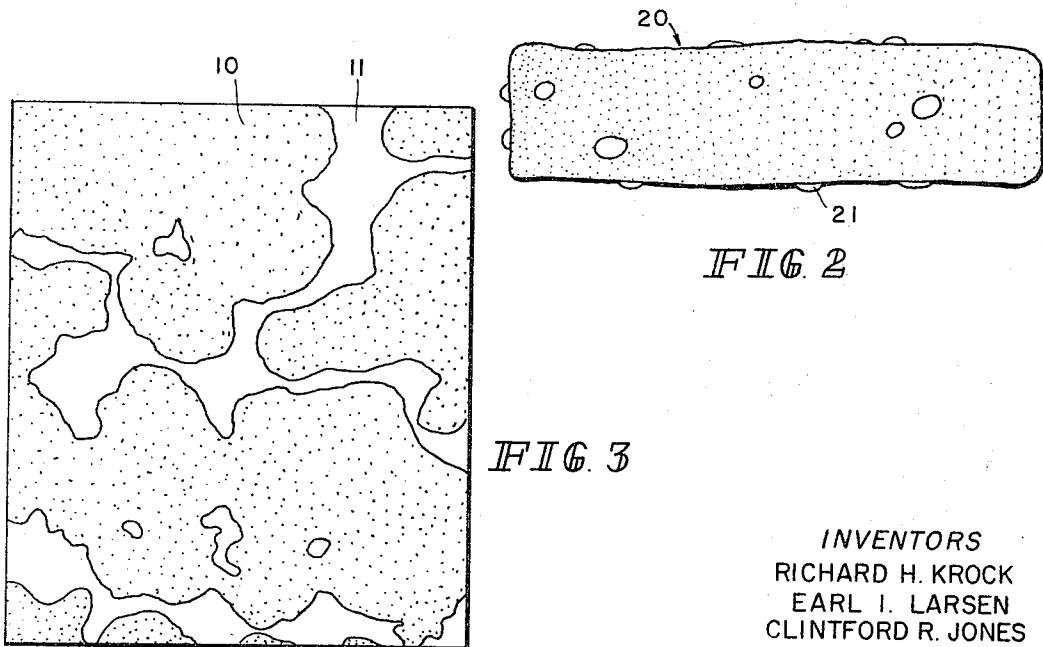


FIG 2

FIG 3

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BERYLLIUM-SILVER-COPPER COMPOSITE

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ABSTRACT OF THE DISCLOSURE

A ternary metal composite containing about 50-85 percent, by weight, beryllium and the remainder an alloy of silver-copper. The alloy contains about 72-92 percent, by weight, silver and the remainder copper.

The present invention relates to composites of beryllium-silver-copper and more particularly to means and methods for providing such 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 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, 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-silver-copper composites were developed in accordance with known liquid phase sintering techniques, it was found that the solid beryllium expelled the liquid silver-copper-beryllium alloy from the compact during liquid phase sintering. It is thought that the unfavorable surface energy equilibrium causing expulsion of the liquid 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 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 a silver-copper-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 applications such as lightweight gears, lightweight fasteners, 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 tentative solutions have been advanced in an attempt to make beryllium metal sufficiently ductile so as to permit a widespread commercial acceptance of the metal. 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 above mentioned 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 quenching the part from a temperature at which it was liquid. However, the beryllium content was not in excess of 86.3 atomic percent which is approximately 30 weight percent. 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.

Also, it has 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, silver, and copper containing 50 to 85 percent, by weight, of beryllium, 49 to 10.8 percent, by weight, silver and 14 to .3 percent, by weight, copper, thereby producing a composite having low density, 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 continuously.

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. It is thought that a decrease in beryllium content below 50 percent, by weight, would raise the density of the composite to a value of little interest. It is thought that the maximum silver to copper ratio is of the order of 49 parts silver by weight to 1 part copper as the beryllium content of the composite is modified within the hereinbefore disclosed limits. It is thought that the ratio of silver to copper may be varied without having any substantial adverse effect on the properties of the composite.

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 an agent to promote liquid phase sintering of a beryllium-silver-copper mixture.

A further object of the present invention is to provide a ductile beryllium composite having a low density and high strength.

Another object of the present invention is to provide a ductile beryllium composite having a matrix phase that is heat treatable.

A further object of the present invention is to provide a ductile composite of beryllium in which beryllium is the predominate ingredient.

Another object of the present invention is to provide a means and method of producing a ductile composite of beryllium-silver-copper whose microstructure consists of beryllium particles surrounded by a ductile envelope phase of silver-copper-beryllium alloy matrix material.

Yet another object of the present invention is to provide a ductile composite of beryllium-silver-copper containing about 50 to 85 percent, by weight, beryllium, 10.8 to 49 percent, by weight, silver, and the remainder copper.

A further object of the present invention is to provide an agent which eliminates the expulsion of a matrix metal from a beryllium specimen.

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

Another object of the present invention is to provide a composite of beryllium-silver-copper that may be sintered to substantially theoretical density.

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

A further object of the present invention is to provide a lithium fluoride-lithium chloride agent for promoting liquid phase sintering in a beryllium, silver and copper mix.

Yet still another 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 processing ordinarily 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 silver-copper.

FIGURE 2 is a photomicrograph of a beryllium specimen illustrating a matrix metal expelled from the specimen by the forces of surface energy of solid beryllium and various liquids formed.

FIGURE 3 is a photomicrograph of a 75 percent, by weight, beryllium, 18 percent, by weight, silver, remainder copper composite illustrating beryllium particles surrounded by a ductile envelope phase of a silver-copper-beryllium alloy.

Generally speaking, the means and method of the present invention relate to a ductile beryllium composite fabricated by liquid phase sintering. The composite contains about 50-85 percent, by weight, of beryllium, 10.8 to 49 percent, by weight, silver and the remainder copper.

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The method of producing the beryllium-silver copper composite by liquid phase sintering comprises the steps of mixing predetermined portions of powder beryllium and powder alloy of silver-copper, or silver powder and copper 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. At this temperature the agent provides a favorable surface energy equilibrium between the beryllium and silver-copper alloy so that the alloy progressively dissolves the beryllium at the sintering temperature. Thereafter, the composite may be heat treated and rapidly quenched so that the structure at the heat-treating temperature is preserved and the silver is supersaturated with copper.

More particularly, the method of the present invention comprises mixing powder beryllium of about 50-85 percent, by weight, with a powder alloy of silver and copper. 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 and the alloy powder or elemental powder. The constituents of the agent are in 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 1000° centigrade to about 1150° centigrade and held at the temperature for about one hour. At the aforementioned temperatures, the agent provides a favorable surface energy equilibrium between the beryllium and the alloy so that the silver-copper alloy progressively dissolves the beryllium. The micro-structure of the resultant composite consists of beryllium particles surrounded by a ductile envelope phase of a silver-copper-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 silver is supersaturated with copper.

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 alloy of silver-copper or the elemental powders and an agent of equal parts of lithium fluoride-lithium chloride. The powders are blended and mixed by ball milling the metal powders and the flux agent. 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 or a hydraulic or an automatic press or by placing the powders in a rubber or a 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 1000° centigrade to about 1150° centigrade. It is seen that the range of the sintering temperature is below the 1277° centigrade melting point temperature of beryllium but above the 779° centigrade melting point temperature of the silver-copper alloy. The silver-copper alloy will dissolve smaller beryllium particles and will dissolve the surfaces of the larger beryllium powder particles thereby surrounding the remaining beryllium particles with a ductile envelope phase of silver-copper-beryllium alloy during sintering of the compact.

The agent, lithium fluoride-lithium chloride, either breaks down the oxide film on the beryllium or segregates to the metal oxide interface lowering the surface energy of the liquid metal with respect to the beryllium oxide film. Simply, the agent causes the liquid to wet the beryllium.

Composites containing about 50 to 85 percent, by weight, of beryllium, and the remainder an alloy of silver-copper were successfully fabricated. The agent prevented the expulsion of the liquid silver-copper-beryllium alloy from the compact by the forces of surface energy, that is,

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prevented the formation of very fine rounded droplets of the silver-copper-beryllium alloy on the surface of the beryllium specimen. FIGURE 2 shows an enlarged beryllium specimen 20 having on the surface thereof an expelled alloy 21 of silver-copper-beryllium. Specimens from which the silver-copper-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 actuation, 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 is possible. It is thought, however, that an equal parts mixture achieves optimum results.

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 silver-copper without the use of pressure during sintering. The composite was sintered to a minimum of about 90.0 percent and up to 99.92 percent of its theoretical density by a single sinter. The good strength and low density characteristics of the beryllium were retained and the resulting beryllium-silver-copper composite possessed good ductility.

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

A silver-copper phase diagram is illustrated in FIGURE 1.

Copper is an effective material for hardening silver. 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, copper is used to harden silver. Once the composite has been cooled to room temperature, the effectiveness of the copper is brought into play by a subsequent heat treatment. In order to most effectively harden the material, the composite is heated into the complete alpha silver phase. It was found that heat treating the composite at 770° centigrade for about 1 to 2 hours is sufficient to dissolve the copper in the silver. 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 silver is supersaturated with copper. This is then followed by suitable aging to achieve a precipitation hardened alloy. A distinct advantage of the beryllium-silver-copper composite is that the matrix phase is heat treatable.

The phase diagram of FIGURE 1 shows and our experiments indicated that silver and copper form a eutectic phase diagram with considerable terminal solubility at both ends. Silver dissolves up to 8.8 percent, by weight, of copper at the eutectic temperature (779°) and copper dissolves 8 percent, by weight, of silver at the eutectic temperature. Beryllium is soluble in both copper and silver, but only slightly. Little or no solid solubility of silver into beryllium would be predicted, but beryllium

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can dissolve up to about 35 percent, by weight, of copper.

Attention is directed to FIGURE 3, wherein a photomicrograph of 500 magnifications shows a composite of 25 percent, by weight, silver-copper 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 silver-copper-beryllium alloy surrounding the beryllium particles.

Example 1 shows the expulsion of the liquid from a beryllium specimen and Examples 2-14 are illustrative of the preparation of beryllium-silver-copper composites by liquid phase sintering.

Example 1

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

A mixture of about 75 percent, by weight, of beryllium having a particle size of 200 mesh or finer was ball mill mixed with about 25 percent, by weight, of an alloy of silver-copper or the elemental powder of suitable particle size. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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° centigrade 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 75 percent, by weight, beryllium, 18 percent, by weight, silver, and the remainder copper.

A mixture of about 75 percent, by weight, of beryllium powder having a particle size of 200 mesh or finer was ball mill mixed with about 25 percent, by weight, of an alloy of silver-copper powder of suitable particle size. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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, 1.0, and 2.0 percent, by weight, of the total metal additions. 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° centigrade for about 1 hour. The composite is heat-treated at about 770° centigrade for about 1 hour so as to dissolve the copper into the silver. The composite is then rapidly quenched so that the heat-treating temperature structure is preserved and the silver is supersaturated with copper. The microstructure of FIGURE 3 was produced using the abovementioned procedure.

Example 3

A composite of about 75 percent, by weight, beryllium, 18 percent, by weight, silver, and the remainder copper. The procedure of Example 2 was followed using 75

percent, by weight, beryllium powder, 18 percent, by weight, silver powder, and the remainder copper powder. Individual composites were prepared using 0.5, 1.0 and 2.0 percent, by weight, of the total metal additions.

Example 4

A composite of about 75 percent, by weight, beryllium, 18 percent, by weight, silver, and the remainder copper.

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 silver-copper. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 5

A composite of about 75 percent, by weight, beryllium, 23 percent, by weight, silver, and the remainder copper.

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 silver-copper. The alloy contains 92 percent, by weight, silver and 8 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 6

A composite of about 50 percent, by weight, beryllium, 36 percent, by weight, silver, and the remainder copper.

The procedure of Example 2 was followed using 50 percent, by weight, beryllium powder, mixed with about 50 percent, by weight, of an alloy powder of silver-copper. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 7

A composite of about 50 percent, by weight, beryllium, 46 percent, by weight, silver, and the remainder copper.

The procedure of Example 2 was followed using 50 percent, by weight, beryllium powder, mixed with about 50 percent, by weight, of an alloy powder of silver-copper. The alloy contains 92 percent, by weight, silver and 8 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 8

A composite of about 60 percent, by weight, beryllium, 28.8 percent, by weight, silver, and the remainder copper.

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 silver-copper. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 9

A composite of about 60 percent, by weight, beryllium, 36.8 percent, by weight, silver, and the remainder copper.

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 silver-copper.

The alloy contains 92 percent, by weight, silver and 8 percent, by weight copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 10

A composite of about 70 percent, by weight, beryllium, 21.60 percent, by weight, silver, and the remainder copper.

The procedure of Example 2 was followed using 70 percent, by weight, beryllium powder, mixed with about 30 percent, by weight, of an alloy powder of silver-copper. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 11

A composite of about 70 percent, by weight, beryllium, 27.6 percent, by weight, silver, and the remainder copper.

The procedure of Example 2 was followed using 70 percent, by weight, beryllium powder, mixed with about 30 percent, by weight, of an alloy powder of silver-copper. The alloy contains 92 percent, by weight, silver and 8 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 12

A composite of about 85 percent, by weight, beryllium, 10.8 percent, by weight, silver, and the remainder copper.

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 silver. The alloy contains 72 percent, by weight, silver and 28 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 13

A composite of about 85 percent, by weight, beryllium, 13.8 percent, by weight silver, and the remainder copper.

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 silver-copper. The alloy contains 92 percent, by weight, silver and 8 percent, by weight, copper. 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 1000°, 1100° and 1150° centigrade using the aforementioned procedure.

Example 14

A composite of about 75 percent, by weight, beryllium, 18 percent, by weight, silver, and the remainder copper.

A mixture of beryllium powder having a particle size of 20 microns 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 steel balls for about 1 hour. Thereafter, an alloy powder of 72 percent, by weight, silver and 28 percent, by weight, copper was ball mill mixed with the beryllium for about 1 hour. The beryllium constituted about 75 percent, by weight of the blended powders and the alloy powder constituted about 25 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. 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 1150° centigrade for about 1 hour. The composite is heat-treated at about 770° centigrade for about 1 hour so as to dissolve the copper into the silver. The composite is then rapidly quenched so that the heat-treating temperature structure is preserved and the silver is supersaturated with copper. It was found that the composite had a density of about 99.92 percent of theoretical density.

The present invention is not intended to be limited to the disclosure herein, and the 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 containing about 70 percent, by weight, beryllium and the remainder an alloy of silver-copper wherein said alloy contains about 72 to 92 percent, by weight, silver and the remainder copper.

2. A ternary metal composite according to claim 1, wherein said alloy contains about 92 percent, by weight, silver and the remainder copper.

3. A ternary metal composite containing about 50-85 percent, by weight, beryllium and the remainder an alloy of silver-copper, said alloy containing about 72-92 percent, by weight, silver and the remainder copper.

References Cited

UNITED STATES PATENTS

1,816,961	8/1931	Cooper	75—150
3,082,521	3/1963	Cohen	29—497
3,264,147	8/1966	Bonfield et al.	75—150

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