EFFECT OF Be UPON FLOW CHARACTERISTICS OF Al–Mg2Si ALLOYS AT ROOM TEMPERATURE

- **Al–1% Mg–0.9% Si–0.5% Be**
- **Slope at 0.002 STRAIN = 1.4 x 10^6 PSI**
- **Al–1% Mg–0.9% Si**
- **Slope at 0.002 STRAIN = 4.5 x 10^5 PSI**

YIELD POINT (NORMALISED)

**FIG 1**

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CHILL CAST PARTICULATE COMPOSITES

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Continuation-in-part of Ser. No. 597,401, Nov. 11, 1966. This application Sept. 15, 1967,
Ser. No. 667,910

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ABSTRACT OF THE DISCLOSURE

A ductile and high strength chill cast beryllium com-
oposite composed essentially of beryllium particles substan-
tially surrounded by an alloy matrix of aluminum-magnesium-silicon. The composite consists essentially of about 85–60% by weight beryllium, about 39.5–15% by weight aluminum, about 3.6–0.10% by weight magnesi-
um, and about 1.5–0.08% by weight silicon. Within the ranges of proportions of elements contributing to the duc-
tility and strength of the composite, two different alloy
matrix species arise. One of the alloy matrix species con-
tains an excess of silicon to magnesium to a degree where-
by the matrix alloy may be categorized as silicon rich with
respect to the magnesium content. In the silicon rich alloy
matrix substantially all of the magnesium will combine
with the silicon. The remaining alloy matrix species con-
tains an excess of magnesium to silicon to a degree where-
by the matrix alloy may be categorized as magnesium
rich with respect to the silicon content. The mechanical
properties of the composites embodying the silicon rich
alloy matrix and the magnesium rich alloy matrix, such
as ductility and strength, are outstanding; however, the
ductility and strength characteristics of the composites
embodying the silicon rich alloy matrix are more out-
standing than the ductility and strength characteristics of
the composites embodying the magnesium rich alloy matrix.

This application is a continuation-in-part of my co-
pending application, Ser. No. 597,401, filed Nov. 11, 1966,
now abandoned.

The present invention relates to ductile composites of
beryllium, more particularly, to as-cast means and meth-
ods of providing a ductile beryllium-aluminum-magnesi-
um-silicon composite wherein the beryllium crystals and
single crystals dispersed in a matrix of aluminum-magne-
sium-silicon-beryllium.

Beryllium possesses physical properties which make the
metal attractive for use in a variety of commercial appli-
cations such as, for example, airplane parts, gears, fasten-
ers and the like. However, beryllium metal includes a
physical property which has limited its commercial ac-
ceptance. Beryllium is inherently brittle at room tempera-
ture. The brittleness of beryllium is attributed to the crystal
structure which is a hexagonal system with an extremely
small axial to basal ratio. The axial ratio of the beryllium
crystal is the smallest of any hexagonal structured metal.
The cleavage strength of beryllium is also low, a feature
which may be attributed to the crystal structure and size
through the elastic moduli. The single crystal of beryllium
is severely anisotropic with respect to its mechanical prop-
erties. As a result, the mechanical properties of poly-
crystalline beryllium are highly dependent upon grain
orientation and upon grain size. Thus during deformation
of an article fabricated from beryllium metal, 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 the beryllium article per-
pendicular to the primary fabrication direction is virtually
nonexistent.

Since fracture is known to occur on definite crystallo-
graphic planes, it is thought that fracture in beryllium arti-
cles involves a mechanism of gross crack propagation
when cracks approach grain size. Thus it appears that
fracture strength would be increased if the grain size was
reduced.

A variety of different metals and alloys have been added
to beryllium in an effort to improve the mechanical prop-
erties of beryllium, with particular emphasis on improv-
ing the mechanical property of ductility. Prior art teach-
ings have been directed toward deoxidation, grain refine-
ment, and alteration of the crystal structure of beryllium.

The above attempts did not significantly improve the duc-
tility of beryllium. Deoxidants such as zirconium, titani-
um, aluminum, and the like have been added to melts of
beryllium. However, these deoxidants did not significantly
improve the ductility of beryllium since the oxide film
on beryllium is rather stable.

Attempts have been made to cast beryllium in a suit-
able mold; however, the resultant structure is character-
ized by a coarse grain structure that is brittle and has
strength defects. Cross-rolling and cross-forging of beryl-
lium reduces the number of basal planes along the direc-
tion of rolling and resulted in improved ductility. How-
ever, the degree of improvement is unsatisfactory and
beryllium must still be classified as brittle.

Attempts have been made also to cast alloys of ductile
metals with beryllium by ordinary casting means and by
chill-casting. However such attempts have not resulted in
products which have desirable strength characteristics and
are possessed of satisfactory ductility.

A means and method have been discovered for pre-
paring a fine grain beryllium composite having highly
desirable physical properties using chill casting techniques
wherein the individual beryllium grains are surrounded
by a ductile matrix alloy, no grain growth is experienced
during the very rapid cooling thereof and wherein the
individual beryllium grains have a diameter of between 5
and 20 microns. Subjecting a beryllium article that has
experienced grain growth to hydrostatic stress results in
shear stresses in excess of the basal plane fracture stress
generated along beryllium-beryllium grain boundaries. It
is thought that a ductile beryllium article can best be
realized by a beryllium particulate composite wherein
individual grains of beryllium are single crystals having
a determined diameter and wherein each individual grain
of beryllium is surrounded by a ductile matrix alloy.

It was found that chill casting techniques applied to a
melt of beryllium and an aluminum base alloy containing
minor amounts of magnesium and silicon provided a
ductile beryllium composite wherein the beryllium con-
tent was about 60 to 85 percent by weight of the com-
po-site. The beryllium and the matrix alloy were completely
molten when chill cast so as to obtain the high nu-
clearation rate necessary to yield an article composed of
single crystals of beryllium having a grain diameter of
5 to 20 microns embedded in a ductile matrix alloy of
aluminum-magnesium-silicon-beryllium.

It was found that within the ranges of proportions of
the constituents of the alloy matrix of aluminum-mag-
nesium-silicon contributing to the ductility and strength
of the composite, two different alloy matrix species arose.
One of the alloy matrix species may contain an excess of silicon to magnesium to a degree whereby the matrix alloy may be categorized as silicon rich with respect to the magnesium content. In the silicon rich alloy matrix it was found that substantially all of the magnesium combines with the silicon. The remaining alloy matrix species contains an excess of magnesium to silicon to a degree whereby the matrix alloy may be categorized as magnesium rich with respect to the silicon content. The mechanical properties of the composites embodying the silicon rich alloy matrix and the magnesium rich alloy matrix, such as ductility and strength, are outstanding; however, the ductility and strength characteristics of the composites embodying the silicon rich alloy matrix are more outstanding than ductility and strength characteristics of the composites embodying the magnesium rich alloy matrix.

A tough, tenacious film of beryllium oxide is present on the beryllium and must, for best results, be removed during the melting of the beryllium or the oxide film will prevent or inhibit the melt of the aluminum alloy from wetting the beryllium grains. If the oxide film is not removed from the beryllium, the beryllium and the aluminum matrix does not satisfactorily alloy. An agent must be used to either break down the oxide film on the beryllium, and lower the surface energy of the liquid alloy with respect to the beryllium oxide film so that the liquid metal progressively dissolves the beryllium as the temperature of the melt progresses toward 1300°C. It is seen that the ultimate temperature of the melt is above the 1277°C. melting point temperature of beryllium. Alkali and alkaline earth halogenide agents such as lithium fluoride-lithium chloride or lithium fluoride may be used to segregate to the solid interface of the beryllium and hence allow the matrix alloy to wet the individual beryllium grains. The agency may, in this instance, be called a fluxing agent, flux, or seizer. That is, such an agent does have other characteristics which assist in wetting the beryllium grains so as to surround the individual beryllium grains with a ductile envelope phase of aluminum-magnesium-silicon-beryllium alloy metal matrix.

The present invention is an object of the present invention to provide improved grain refinement in beryllium composites by chill casting the beryllium composites.

Another object of the present invention is to provide a beryllium composite wherein thickness reductions up to about 80 percent of the original thickness may be achieved during casting of the beryllium composite without grain boundary tearing or of cleavage cracking in beryllium grains.

Another object of the present invention is to provide a ductile composite of beryllium-aluminum-magnesium-silicon wherein the matrix alloy consists of either an excess of silicon to magnesium to a degree whereby the matrix alloy may be categorized as silicon rich or an excess of magnesium to silicon to a degree whereby the matrix alloy may be categorized as magnesium rich.

A further object of the present invention is to provide a ductile composite of beryllium-aluminum-magnesium-silicon wherein up to about 0.5 percent, by weight, of the weight matrix alloy is beryllium.

Yet another object of the present invention is to provide a ductile composite of beryllium-aluminum-magnesium-silicon in which the beryllium is the predominate metal.

A further object of the present invention is to provide a fine beryllium grain structure wherein only single crystal beryllium grains having a diameter of 5 to 20 microns exist in a chill cast beryllium composite.

A further object of the present invention is to provide a chill cast fine grain beryllium composite comprising about 60 to 85 percent by weight beryllium, the remainder an alloy of aluminum-magnesium-silicon.

Still another object of the present invention is to provide a method of chill casting fine grain beryllium composites wherein a lithium fluoride-lithium chloride agent or a lithium fluoride agent is used to promote wetting between the beryllium grains and the alloy matrix.

Yet another object of the present invention is to provide a method for chill casting fine grain beryllium composites wherein beryllium grain growth does not take place during the casting of the beryllium composite.

A further object of the present invention is to provide a method for chill casting fine grain beryllium composites having low density and high strength.

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

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

With the aforementioned objectives enumerated, other objects will be apparent to those persons possessing ordinary skill in the art. Other objects and features 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 hereinbefore described and more particularly as defined in the appended claims.

In the drawings:

FIG. 1 is a graphic showing the stress-strain relationship of the aluminum-magnesium-silicon matrix and the aluminum-magnesium-silicon-beryllium matrix.

FIG. 2 is a showing of a composite of about 70 percent by weight beryllium, about 29.5 percent by weight aluminum, about 0.25 percent by weight magnesium, and the remainder silicon illustrating the fine beryllium grains surrounded by a ductile envelope phase of an aluminum-magnesium-silicon-beryllium matrix.

FIG. 3 is a showing of a 70 percent by weight beryllium composite illustrating the microstructure of the composite after heating treating before cold rolling.

FIG. 4 is a showing of the beryllium composite illustrated in FIG. 2 after the composite is cold rolled to about 12 percent of its original thickness.

Generally speaking the preferred and method of the present invention relate to a ductile beryllium-aluminum-magnesium-silicon composite fabricated by chill casting. The composite consists of 60 to 85 percent by weight beryllium, 13.0 to 39.5 percent by weight aluminum, about 0.1 to 3.6 percent by weight magnesium and about 0.05 to 1.5 percent by weight silicon. The amount of beryllium alloyed in the matrix is believed to be about 0.2 to 0.5 percent by weight of the total composite constituents. The individual grains of beryllium are thought to have a diameter of about 5 to 20 microns separated from one another by an alloy matrix of aluminum-magnesium-silicon-beryllium having a thickness between the beryllium grains thought to be about 0.1 to 2 microns on the average. The grain size of the beryllium and the thickness of the alloy matrix between the grains are important and thus optimization will achieve the best results in ductility and other mechanical properties. It will be understood that the beryllium employed in the present invention is of commercial purity. In such beryllium one encounters very small amounts of various impurities such as carbon, iron, aluminum, silicon and magnesium. The particular beryllium generally employed in the examples contained 0.01% magnesium and 0.02% silicon each by weight. Such small amounts of impurities may be ignored for they appear to have no contribution to the advantageous properties of the composites of this invention.
terminating the composite characteristics when combining commercial beryllium having the aforementioned impurities with the alloy matrix, the impurities are thought to be differentially segregable and apparently combine with the matrix metal alloy to define the final mechanical properties of the composite. Accordingly, the final composite as far as the mechanical properties such as strength, ductility and the like are concerned are thought to be obtainable only by particular combination of the materials and in the method used to combine the same. It will be understood that the percentage ranges of aluminum, magnesium and silicon which have been set forth above are those percentages which are added to ordinary beryllium deformed continuously under load.

The chill cast beryllium composite may be produced by mixing chunks of vacuum cast crushed lump beryllium available from Brush Beryllium Corporation together with chunks of the aluminum-magnesium-silicon alloy of the desired composition together with a small portion of an agent selected from the group consisting of alkali and alkaline earth halogenides. The mix may be heated in a crucible to a temperature above the melting point temperature of beryllium to form a melt of beryllium-aluminum-magnesium-silicon. The agent substantially removes the oxide film from the beryllium so that the alloy may wet, dissolve and thereby form a homogeneous melt with the beryllium without excessive superheat being applied to the matrix which would otherwise be lost by evaporation. The melt may be chill cast in a mold so as to form a composite of beryllium grains dispersed in a matrix of aluminum-magnesium-silicon-beryllium. The composite may then be treated so as to develop its optimum properties.

In carrying out the present invention, a beryllium base composite may be fabricated by melting together a suitably crushed lump of beryllium and a pre-made alloy of aluminum-magnesium-silicon. The constituents may be placed in a suitable crucible such as a beryllium oxide crucible or the like. An agent comprising a small quantity of lithium chloride-lithium fluoride may be added to the constituents in the crucible. The constituents may be melted together by induction heating at about 1350±50°C for about 30 minutes to a homogeneous mass such as anode or the like at about 1 atmosphere of pressure. The lithium fluoride-lithium chloride agent is thought to act as flux or getter and remove the oxide film present on the beryllium. Substantially all of the lithium fluoride-lithium chloride is thought to decompose as it removes the oxide film. It is thought that the flux is lost during preparation of the melt presumably by vaporization, while the oxide will form a crustation on the top surface of the melt.

The melt may be cast directly into a split mold fabricated from any suitable material having good thermal conductivity characteristics such as a split steel mold or a split copper mold which may be equipped with water cooling. It is thought that it is important to obtain an extremely rapid rate of cooling of the melt through the solidification range thereof in order to prevent excessive grain growth of the beryllium which would lead to beryllium-beryllium continuity.

The cast composite may be heat treated by annealing at about 400°C for about 12 hours. The composite may then be quenched into a suitable quenching medium such as water or the like at substantially room temperature. Thereafter, the composite may be aged at about 200–220°C for 60 minutes. The resultant composite is thought to be desirable in order to realize optimum strength from the aluminum-based matrix alloy.

The resultant composite is thought to retain the strength and low density characteristics of the beryllium and the ductile matrix is thought to serve to constrain the beryllium so that the beryllium and the ductile matrix phase deformed continuously.

It is thought that if the beryllium content of the composite exceeded about 85 percent by weight, grain contiguity developed, resulting in undesirable brittleness, and if the beryllium content of the composite dropped below about 60 percent by weight, it is thought that the density value of the composite would be raised to a value of little interest. Employment of 68–78% beryllium is preferred.

Within the ranges of proportions of elements contributing to the ductility and strength of the composites two different species arise. This is thought to be due to the fact that magnesium combines with silicon to form Mg2Si more easily than it combines with aluminum to form Al2Mg3. Thus, whenever the atomic ratio of magnesium to silicon present in the composite is 2:1 or less, no significant amount of Al2Mg3 is present thereby providing a matrix alloy that may be classified as silicon rich. The combination of mechanical properties, particularly of strength and ductility has been found for some services to be more advantageous than in composites wherein there is present in an atomic ratio to silicon in excess of 2:1.

In the composite wherein the atomic ratio of magnesium to silicon is in excess of 2 to 1, the matrix alloy may be categorized as magnesium rich. Thus, while within the broader range of proportions set forth previously, highly useful composites are obtained, it is preferred for many purposes that the atomic ratio of magnesium to silicon not exceed 2:1. This atomic ratio of 2:1 has an approximate weight ratio of about 1.75:1. The presence of Al2Mg3 in the matrix appears to effect a decrease in strength and also probably ductility of the composite, which may be desirable for some services.

Thus, keeping in mind that small proportions of beryllium, on the order of a few tenth of a percent, or less based on the matrix, are present in the matrix itself, when magnesium is present in an amount exceeding a 2:1 atomic ratio to silicon the matrix system is either

\[
\text{Al}_{x}\text{Mg}_{y} + \text{Al}_{z}\text{Mg}_{y} \text{ or } \text{Al}_{x}\text{Mg}_{y} + \text{Al}_{z}\text{Mg}_{y} + \text{Mg}_{x} \text{Si}
\]

(The notation (s) means solid solution.) However, when the magnesium is present in an amount of about 2:1 or less atomic ratio to silicon the matrix system is either \( \text{Al}_{x}\text{Mg}_{y} + \text{Mg}_{x} \text{Si} \) or \( \text{Al}_{x}\text{Mg}_{y} + \text{Mg}_{x} \text{Si} + \text{Si} \) to the extent that silico is present in excess of the stoichiometric amount required for MgSi. The excess of silicon included is desirably less than 1.0 percent, by weight and preferably less than 0.5 percent by weight of the matrix constituents. Moreover, it is preferred that each of the additions of magnesium and of silicon not exceed more than 1.0 percent by weight of the matrix constituents.

The previously mentioned small amount of beryllium present in the matrix, about 0.5 percent, by weight of the matrix, has a very important influence upon the solid state precipitation hardening process in the matrix alloy. The influence of beryllium is well developed in alloys of Al–Mg–Si (with or without excess Si). In a "pure" Al–Mg–Si alloy (say Al-1% wt. Mg-0.5% wt. Si) the MgSi phase precipitates from quenched solid solution via an intermediate, partially, coherent, stage. Establishment of this quasi-equilibrium configuration is dependent upon the excess vacant lattice sites which are present in the "as-quenched" structure. However, with beryllium as solid solution this stage does not occur to the same extent (because the beryllium atoms associate with the vacant lattice sites) and the equilibrium MgSi structure forms directly. Under these circumstances the particle size of MgSi is very small and the alloy then deforms in a manner typical of a dispersion strengthened rather than a precipitation hardened alloy.

The rate of work hardening is very much higher especially in the early stages of plastic yielding. FIG. 1 serves to illustrate these effects. It is important in a particulate composite that the matrix work hardening rate be as high as possible since this leads to better load transfer and, therefore (in general), better ductility.

The resultant microconfiguration of the beryllium com-
posite 10 is illustrated in FIG. 2. The beryllium grain size should be about 5 to 20 microns and the beryllium 11 should be uniform and dispersed throughout the composite. The aluminum-base matrix alloy 12 should have a thickness between the beryllium grains of about 0.1 to 2 microns.

FIG. 3 shows a beryllium composite 15 having beryllium 16 uniformly dispersed throughout an aluminum-magnesium-silicon alloy matrix 17 prior to cold rolling. FIG. 4 shows the composite of FIG. 3 after subjection to cold rolling which, it is thought, will reduce the thickness of the composite by about 88 percent. The cold rolling demonstrates the fabricability of the composite. It should be noted that the composite should experience no grain boundary tearing or cleavage cracking in the beryllium grains as a result of cold rolling.

The following example is illustrative of the preparation of a beryllium-aluminum-magnesium-silicon composite by chill casting.

EXAMPLE 1

A composite of about 70 percent by weight beryllium, about 29.5 percent by weight of aluminum, about 0.25 percent by weight magnesium and the remainder silicon. Chunks of beryllium and an alloy of aluminum-magnesium-silicon having a purity of at least 99.99 percent may be placed together in a beryllium-oxide crucible. About 2 percent by weight of the total metal additions of about 3 parts lithium chloride to 1 part lithium fluoride may be added to the contents of the crucible. The elements in the crucible may be melted by induction heating in an argon atmosphere at about 1300° C. for about 30 minutes. The melt may be cast directly into a split copper mold that was water cooled. The chill cast beryllium composite may be removed from the mold and the composite may be heat treated by annealing at about 480-500° C. for about to 2 to 12 hours, quenched in water at room temperature and aged at about 200-220° C. for about 30 minutes.

EXAMPLE 2

A composite of about 70 percent by weight beryllium, about 26.7 percent aluminum, about 3.0 percent by weight magnesium and the remainder silicon. Chunks of beryllium and an alloy of aluminum-magnesium-silicon having a purity of at least 99.99 percent were melted together in a beryllium crucible. About 2 percent by weight of the total metal additions of about 3 parts lithium chloride to 1 part lithium fluoride was added to the contents of the crucible. The elements in the crucible were melted by induction heating in an argon atmosphere at about 1300° C. for about 30 minutes. The melt was cast directly into a split copper mold that was water cooled. The chill cast beryllium composite was removed from the mold and the composite was heat treated by annealing at about 400° C. for about 12 hours, quenched in water at room temperature and aged at about 220° C. for about 2 hours.

The percent by weight of the ingredients of the composite may be varied considerably while still retaining the advantages of the invention. The materials contemplated by the invention suitable for most purposes will generally fall within the following range of percent by weight:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent by wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>60-85</td>
</tr>
<tr>
<td>Aluminum</td>
<td>130-39.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.10-3.6</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.08-1.2</td>
</tr>
</tbody>
</table>

Preferably the metal composite contains about 12.75 to 28.8 weight percent aluminum, 0.45 to 3.6 weight percent magnesium, and about 0.15 to 0.9 weight percent silicon.

Composites of beryllium may also be prepared using 0.5 and 1 percent by weight of the total metal additions of the agent lithium fluoride-lithium chloride or of the agent lithium fluoride used in the aforementioned procedure. In addition, composites may be prepared using 0.5, 1.0 and 2.0 percent by weight of lithium fluoride-lithium chloride having a ratio of 1 part to 1 part and 3 parts to 1 part.

It is thought that the foregoing method is applicable to other beryllium composite compositions with the matrix based on aluminum. However, it is thought that the choice of the matrix is controlled by the chemistry of the system and the ability to strengthen the matrix by solid state heat treatment. These factors, it is thought have little to do with the ability to chill cast a fine grain structure. Having thus described my invention, I claim:

1. A metal composite which consists essentially of about 60 to 85 percent by weight beryllium, about 13.0 to 39.5 percent by weight aluminum, about 0.10 to 3.6 percent by weight magnesium and about 0.08 to 1.5 percent by weight silicon.

2. A metal composite according to claim 1, wherein the magnesium to silicon content is magnesium rich.

3. A metal composite according to claim 1, wherein the magnesium to silicon content is silicon rich.

4. A metal composite according to claim 1, wherein the atomic ratio of magnesium to silicon in said composite is not greater than about 2 to 1.

5. A metal composite according to claim 1, wherein substantially no AlMg is present.

6. A metal composite according to claim 1, wherein the weight ratio of magnesium to silicon in said composite is not greater than about 1.75 to 1.

7. A metal composite according to claim 1, wherein said magnesium and said silicon constituents combined to form magnesium silicide with a trace of free silicon remaining in said aluminum alloy.

8. A metal composite according to claim 7, wherein said trace of said free silicon is not greater than about 1.0 percent by weight of the alloy constituents of said composite.

9. A metal composite according to claim 7, wherein said trace of said free silicon is not greater than about 0.5 percent by weight of the alloy constituents of said composite.

10. A metal composite according to claim 1, wherein said aluminum is about 12.75 to 28.8 percent by weight, said magnesium is about 0.45 to 3.6 percent by weight, and said silicon about 0.15 to 0.9 percent by weight of the total metal constituents of said composite; said aluminum, magnesium and silicon constituting essential ingredients of a matrix alloy in which are embedded segregated grains of the beryllium with said matrix alloy containing MgSi and AlMg.

11. A metal composite according to claim 1, wherein said composite consists essentially of about 68 to 78 percent by weight beryllium and the remainder an alloy consisting of about 98.5 percent by weight aluminum, about 0.8 percent by weight magnesium and the remainder silicon.

12. A metal composite according to claim 1, wherein said beryllium is about 70 percent by weight, said aluminum is about 24.5 percent by weight, said magnesium is about 0.25 percent by weight, and the remainder silicon.

13. A metal composite according to claim 1, wherein said beryllium is individual grains having a diameter of about 5 to 20 microns substantially surrounded by said aluminum-magnesium-silicon alloy, the thickness of said alloy between said beryllium grains being about 0.1 to 2 microns.

14. A metal composite according to claim 1, wherein said beryllium is individual grains substantially surrounded by said alloy of aluminum-magnesium-silicon, the ratio of said beryllium grain diameter to the thickness of said alloy between said beryllium grains being not greater than about 200 to 1.
15. A metal composite according to claim 14, wherein the ratio of said beryllium grain diameter to the thickness of said alloy between said beryllium grains being not greater than about 20 to 1 and not less than about 5 to 2.

16. A metal composite according to claim 4, wherein not greater than about 0.5 percent by weight of said beryllium of the total weight of the alloy matrix is dissolved by said matrix thereby increasing the matrix work hardening coefficient.