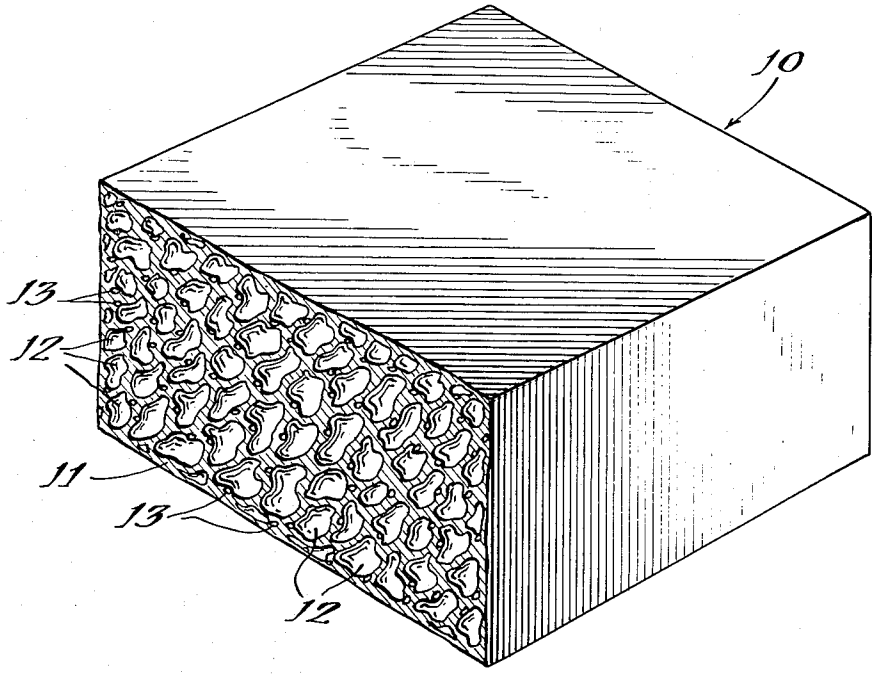
June 19, 1956 J. C. ELLIOTT 2,751,289

METHOD OF PRODUCING METAL FOAM

Filed Oct. 8, 1951



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United States Patent Office 2,751,289
Patented June 19, 1956

2,751,289

METHOD OF PRODUCING METAL FOAM

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Application October 8, 1951, Serial No. 250,346

12 Claims. (Cl. 75—20)

The invention relates to metal foams and to methods for their production.

An object of this invention is to provide a quick and economical method of producing metal foams.

Another object is to provide a closed cell metal body having improved physical characteristics.

Another object is to provide a metal body of improved structural strength having an apparent specific gravity of less than 1.

A further object is to provide a non-sinkable metal foam.

Another object is to provide a strong, light metal alloy having small gas filled closed cells.

Other objects and advantages of the invention will be apparent as the following description progresses, reference being had to the accompanying drawing showing a perspective view partly in section of a slab of the metal foam of this invention.

Referring to the drawing, the slab or body **10** is predominantly composed of a metal **11** having dispersed throughout bubbles **12** of a gas and containing small particles **13** of a solid, preferably a metal. Such small particles while desirably of macro size as shown in the drawing, may in some instances be dispersed in molecular size becoming a homogeneous part of the matrix metal.

In carrying out the process of the invention, a solid which decomposes on heating to form a gas is ground in a molten metal to produce a wetting of the solid by the metal.

The grinding may be carried out at a temperature lower than the decomposition temperature of the gas-forming solid, in which case the temperature is raised or the pressure in the system lowered to bring about gas release and resultant foaming, or the grinding is carried out in the molten metal at a temperature at which decomposition takes place. The resulting molten metal foam is quickly cooled before the foam is dissipated, producing a solid metal foam of the closed cell type such as is shown in the drawing.

It is desirable that the gas-forming solid dissociate at a temperature at or only slightly above the melting point of the matrix metal so that the foam may be readily solidified before it comes dissipated. This may be accomplished by suitable choice of gas-forming agent and metal, or by controlling the pressure. One means of accomplishing this is to add a gas-forming solid to a metal which becomes molten at below the decomposition temperature of the solid, grind the solid wtih the molten metal to get good contact and wetting by the molten metal, and then add to this mixture another molten metal compatible with it which melts at slightly above the decomposition temperature of the solid so that on mixing the molten compositions there will be decomposition and foam at a temperature only slightly above the solidification temperature of the molten mixture. Another method is to add the gas-former to molten metal under such pressure that decomposition does not take place, maintaining the temperature

at only slightly above the solidification temperature, and then release the pressure.

The gas-forming solid is preferably a heat decomposable compound containing a metal of a type that forms an alloy with the metal to which the gas-forming solid is added, so that on decomposition of the solid into a gas and its metal there takes place an alloying of this metal with the matrix metal. This alloying action causes a speeding up of the decomposition and a more rapid formation of the metal foam, and may further cause a setting or hardening of the foam walls, thus counteracting their premature coalescence.

It is important that the gas-forming solid be made to wet the metal matrix to which it is added. It is found that grinding of the gas-forming solid in the molten metal brings about this wetting action. The ease of obtaining wetting also depends upon the choice of gas-forming solid and molten metal to which it is added. Thus good wetting and particularly satisfactory high strength, low density metal foams have been obtained by grinding powdered titanium hydride (TiH_2) into molten aluminum, magnesium, or aluminum magnesium alloys; also by grinding zirconium hydride (ZiH_2) into aluminum magnesium alloys ranging from 95% aluminum to 80% magnesium. The use of titanium or zirconium hydrides with aluminum magnesium in the process of this invention has the further advantage of improving the grain structure of the alloy. I have also been able to foam 100% aluminum, as shown in Example III below; and also 100% magnesium in analogus manner. With the latter metal an inert atmosphere is particularly essential to prevent ignition.

Other gas-formers and other metals may be used, although in some cases more extensive grinding to obtain wetting may be required to obtain good results and pressure changes may be called for in order to obtain the preferred rapid decomposition at temperatures close to the melting point of the matrix metal. Thus barium hydride, lithium hydride, lithium aluminum hydride may be used as gas-formers by simply increasing the pressure to prevent decomposition before the metal to which they are added becomes molten. Thus powdered lithium aluminum hydride may be added to and ground in an aluminum magnesium eutectic composition at 10 atmospheres pressure, the temperature brought to slightly over the solidification point, and then the pressure released with resultant rapid decomposition of the hydride and formation of foam. Also it must be borne in mind that there is a time element for decomposition so that with fast work even without pressure control a gas-forming agent can be used to produce foam up to 350° C. or more above its initial decomposition point. This is important in considering the use of the following alternative gas-formers for foaming:

	Decomposition point, °C.
Aluminum sulfate	770
Calcium carbonate	825
Zinc sulfate	740
Barium hydroxide	100
Copper phthalocyanin	approx. 425
Polymethyl siloxane	approx. 450
O-tolyl phosphate	approx. 420
Alizarin	above 430
Tetraphenyl methane	above 435
Chrysen	above 450
Picene	above 470
Di-2-naphthylamine	above 470
Oxamide	419
1 methyl uric acid	400
Sodium benzene sulfonate	450
Indanthrene	470

Gas-formers other than the metal hydrides and the others above mentioned may be used, the preferred ones

being those which readily wet the metal matrix and which decompose at normal atmospheric pressure at temperatures not more than a few degrees above the melting point of the metal, although as above pointed out compounds having higher dissociation temperatures may be used. Examples of other suitable gas-forming compounds are copper phthalocyanin, organic silicon derivatives, and other silicon-containing compounds which on heating decompose.

The amount of gas-forming solid used may be varied widely according to the amount of foaming and density of the final product desired. Particularly satisfactory high strength, low density light metal foams have been obtained using 8 through 10% of the hydride on the weight of the metal matrix. However, foamed metal may be obtained with ½% and less of hydride. Above 50% of hydride is generally not practical and at above 25% there is appreciable loss of strength and some embrittlement.

The temperature of the molten metal is preferably maintained during the mixing and decomposition of the hydride at close to the solidification point both because a higher temperature would require more rapid and greater cooling in order to solidify the molten foam before dissipation of the gas but also because the higher the temperature the more rapid the dissociation of the hydride and the greater tendency for non-uniform and large gas spaces.

The gas-former is preferably added to the molten metal in powdered form. The size of the particle is not particularly important, the smaller particle, however, giving greater speed of dissociation due to greater surface area. Furthermore, the small particles give small metal particles which more readily disperse and where soluble in the base metal, more readily dissolve in this metal.

The grinding of the solid gas-former in the molten metal may be done in various ways. A steel roller heated to the temperature of the surrounding molten metal containing the solid gas-former may be used. Also ball milling of the composition can be carried out to give the grinding action and resultant wetting of the gas-former by the molten metal. The term "grinding" as used in the specification and claims is used in the generic sense to include any wiping action under substantial pressure. Other means of effecting wetting of the solid gas-former by the molten metal may be used such as, for example, intensive mixing such as high speed mixing and the like.

While it is not desired to be restricted to any theory, the following is a theory which conforms with the facts and which is believed to be correct: The grinding of the gas-forming solid such as the metal hydride in the molten metal brings about a wetting of the hydride by the molten-metal and allows the dispersion of the hydride much as pigment is dispersed in paint.

As the hydride becomes heated to the temperature of its dissociation there is a rapid formation of gas which is particularly rapid when the metal of the hydride is of the type which alloys with the other metal, and there is an apparent increase in viscosity similar to that in which the apparent viscosity of cream is increased when it is whipped. This apparent increase in viscosity is due to the entrapped gas producing a molten metal foam which on cooling becomes the solid metal foam of this invention.

The molten foam may be poured into molds and cast into various shapes although it is preferred to generate the foam within the mold. Sheets of foamed metal may be made by feeding a pre-mixed and wetted hydride molten metal mixture to a heated moving belt or through a series of heated rollers which bring about decomposition of the hydride and the formation of a sheet of foam which is then quenched to give a solid metal foam sheet.

The solid metal foam may vary greatly in strength and apparent specific gravity, depending upon the type of metal used and upon the size and extent of the gas bubbles which, in turn depends upon the amount of gas-former used, the temperature during dissociation and the rapidity of cooling the molten foam. The gas bubbles or cells may vary from one-sixteenth inch and less to one inch and more in diameter. With light metals, apparent specific gravities of less than 1 are readily attained.

The foam metal bodies of this invention are particularly useful for the manufacture of boats, life preservers, and other light weight, strong articles.

The following examples are used to illustrate this invention:

Example I

Powdered TiH_2 of a fineness such that most of the powder would pass through a 325 mesh screen, was added to a molten alloy consisting of 80% by weight aluminum and 20% magnesium at a temperature of 600° C. to give a mixture containing 10% by weight of TiH_2. The powdered TiH_2 was ground into the molten alloy by means of a heated steel pestle, the composition being maintained at the temperature of 600° C. This produced a molten foam which was then poured into a mold and allowed to cool and solidify. The resultant product was a closed cell metal body consisting of a dispersion of hydrogen bubbles of approximately one-quarter inch diameter in a solid matrix of the aluminum magnesium alloy containing minute particles of dispersed titanium metal alloyed at their interface with the aluminum magnesium.

Example II

60 grams powdered zirconium hydride was ground into 60 grams of a low melting eutectic alloy of magnesium and zinc having a melting point of 341° C. This composition containing the ground and wetted zirconium hydride was allowed to cool and solidify. 5 grams of the above alloy were then mixed into 50 grams molten aluminum 90% magnesium 10% alloy at a temperature of about 650° C. The mixture melted immediately and dispersed quickly in the aluminum magnesium alloy. There was a violent evolution of hydrogen gas with production of molten foam metal which was immediately cooled before dissipation of the foam forming a solid metal foam.

Example III

8% of powdered zirconium hydride (particle size 95% through 325 mesh) was ground into 92% of molten high purity (99.75%) aluminum at 670° C. The mixture was maintained at this temperature until maximum volume was attained by decomposition of the hydride (about 30 seconds) at which time it was quenched. A solid foam, having average cell size about ¼–⅜" diameter resulted.

The foregoing examples illustrate the production of metal bodies having an apparent specific gravity of less than 1. Such bodies may be obtained by using magnesium, aluminum, lithium, or mixtures thereof as the major constituent of the composition. Other metals or increased proportions of other metals may be used with or in place of the light metals to produce heavier metal foam bodies.

It is thus seen that the invention is broad in scope and is not to be restricted excepting by the claims, in which it is my intention to cover all novelty inherent in the invention as broadly as possible in view of the prior art.

I claim:

1. The method of producing a composition suitable for the production of metal foam which comprises grinding zirconium hydride in a molten metal selected from the group consisting of magnesium, aluminum and mixtures thereof, said grinding being carried out at a temperature below the temperature at which the zirconium hydride decomposes to form hydrogen.

2. The method of producing a metal foam which comprises grinding zirconium hydride in a molten metal selected from the group consisting of magnesium, aluminum and mixtures thereof, bringing the ground mixture to a temperature and for a time sufficient to decompose the hydride and produce a foam, and cooling the composition to the solid state before the foam has dissipated.

3. The method of producing a metal foam which comprises grinding powdered zirconium hydride in molten aluminum, bringing the ground mixture to a temperature of approximately 670° C. to decompose the hydride and produce a foam, and quenching the composition to cool the composition to the solid state before the foam has dissipated.

4. The method of producing a composition suitable for the production of metal foam which comprises grinding in a molten metal a solid compound which decomposes to form as gas at below the volatilization temperature of the metal, said grinding being carried out at a temperature below the temperature at which the solid compound decomposes to form a gas.

5. The method of producing metal foam which comprises grinding in a molten metal a solid compound which decomposes to form a gas at below the volatilization temperature of the metal, bringing the ground mixture to a temperature and for a time sufficient to decompose the solid compound and product a foam, and cooling the composition to the solid state before the foam has dissipated.

6. The method of producing a composition suitable for the production of metal foam which comprises grinding a metal hydride in a molten light metal, said grinding being carried out at a temperature below the temperature at which the metal hydride decomposes to form hydrogen.

7. The method of producing a metal foam which comprises grinding a metal hydride in a molten light metal, bringing the ground mixture to a temperature and for a time sufficient to decompose the hydride and produce a foam, and cooling the composition to the solid state before the foam has dissipated.

8. The method of producing a composition suitable for the production of metal foam which comprises grinding a heavy metal hydride in a molten light metal, said grinding being carried out at a temperature below the temperature at which the heavy metal hydride decomposes to form hydrogen.

9. The method of producing a metal foam which comprises grinding a heavy metal hydride into a molten light metal, bringing the ground mixture to a temperature and

for a time sufficient to decompose the hydride and produce a foam, and cooling the composition to the solid state before the foam has dissipated.

10. The method of producing a composition suitable for the production of metal foam which comprises grinding at least one hydride selected from the group consisting of zirconium and titanium hydride in a molten metal selected from the group consisting of magnesium, aluminum and mixtures thereof, said grinding being carried out at a temperature below the temperature at which the hydride decomposes to form hydrogen.

11. The method of producing a metal foam which comprises grinding at least one hydride selected from the group consisting of zirconium and titanium hydride in a molten metal selected from the group consisting of magnesium, aluminum and mixtures thereof, bringing the ground mixture to a temperature and for a time sufficient to decompose the hydride and produce a foam, and cooling the composition to the solid state before the foam has dissipated.

12. A method of producing a metal foam which comprises grinding a heavy metal hydride in a molten metal composition of 80% by weight of aluminum and 20% by weight of magnesium, bringing the ground mixture to a temperature of approximately 600° C. for a time sufficient to produce a metal foam and cooling the composition to the solid state.

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