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3,445,250

PRECISION METAL CASTING MOLDS COMPRISING ALUMINA COATED SILICA AND A REFRACTORY

Richard E. Preece, Dolton, Ill., assignor to Nalco Chemical Company, Chicago, Ill., a corporation of Delaware
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ABSTRACT OF THE DISCLOSURE

A metal resistant mold for use in the precision casting of metals which is derived from a mixture of an alumina coated silica sol and a refractory which is essentially free of uncombined silica.

The precision casting of metals may be defined as a process whereby molten metal is poured into a mold wherein it solidifies to produce a cast metal object which is characterized as having close specifications as to tolerance, detail and surface quality. One of the most common methods of precision casting is precision investment casting, which is oftentimes referred to as the lost wax process.

A specific form of investment casting, which embodies the most modern form of the process, is the shell mold investment casting process. This process utilizes an expendable pattern which is a replica of the article to be produced. The pattern is coated with a ceramic slip which is made up of a granular refractory in a liquid binder vehicle. The coated pattern is stuccoed with dry granular refractory material and the stuccoed coat is allowed to dry. The process of coating and stuccoing is repeated to build up successive layers which form a ceramic shell around the expendable pattern. The ceramic shell thus formed is treated to remove the expendable pattern, leaving a thin mold capable of having many types of molten metals poured directly into its cavity to produce precision castings of high quality.

The combination of the use of slip coating and stuccoing a pattern results in extremely good reproduction of the pattern face by the mold. It can be readily seen that this process of coating a pattern is not limited to use in conjunction with expendable patterns or to the lost wax process. Precision molds can also be made wherein a shell mold as described above is reinforced by investment in a back-up material such as granular refractory, insulating material or a castable. Another method would be to produce mold sections by coating and stuccoing patterns and using the mold sections independently. More preferably, the sections could be used in conjunction with a back-up material such as sand, plaster, a granular refractory or a suitable castable.

It is essential to the production of a high quality precision metal casting that the mold surface be dimensionally correct. The mold surface must also be smooth, impermeable to the metal, and of such a chemical nature that it does not react with the metal.

The problems of control of mold dimensions and mold surface are largely mechanical. The mechanics of proper grain sizing, control of viscosity of slips and other techniques in the physical making of a mold to provide a smooth mold surface have been developed to a high degree, in full or in part, in this art. However, the problem of providing a mold which is of a chemical nature which is not reactive with the metal is a chemical problem and has caused a great degree of difficulty.

Perhaps the greatest area of difficulty in chemical incompatibility between mold and metal, which results in what is referred to as a metal-mold reaction, arises in

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the casting of metals of the group commonly classified as high melting alloys. These are alloys comprised of nickel, chrome, iron, molybdenum and rare earth metals, either by themselves or in combination. The problem can arise with any metal that is processed above approximately 2900° F., however, the problem most often arises in the casting of metals which have a tendency to form metal silicates.

The formation of metal silicates in what is known as metal-mold reactions causes irregularities upon the surface of finished metal castings which are unacceptable for most precision applications. Another source of irregularities occurs in the casting of aluminum, whereby the aluminum reduces silica and forms Al_2O_3 on the surface of the casting. The solution to these problems would be a metal mold which contained no reactive silica.

The problem has been dealt with to some degree by the use of refractories which are highly resistant to attack by molten metal and contain essentially no free silica. These refractories include alumina, zirconia, zircon and mullite. The most preferred forms of these refractories are the less reactive forms such as tabular alumina and electrically-fused mullite.

Although some advances have been made by the use of these relatively unreactive refractories with conventional vehicle binders, there is still a great need for improvement in the area of finding unreactive molds for the precision casting of high melting, highly reactive metals. This need arises due to the fact that satisfactory binders have all been found to fall in the class of siliceous materials such as colloidal silica, ethyl silicate and sodium silicate. Since the binder contributes a highly reactive portion of the mold body, these materials render the entire mold unsatisfactory.

The efficacy of these siliceous binders for use in precision metal molds, and particularly in the shell mold process of investment casting, has been proven and is well known to the art. Many alternate binders have been tested in an effort to provide an equivalent or better mold than is achieved with siliceous binders. However, without the presence of free silica, which contributes to metal-mold reactions, this problem has not been solved.

Colloidal aluminas, which are currently available in the form of fibrous particles, have been tested for use as binder vehicles for investment casting. These binders have proven unsatisfactory to date.

Due to the fibrous nature of the alumina particles, colloidal alumina sols become extremely viscous at concentrations above approximately 10%. Also, the surface area provided by a given concentration of colloidal alumina in a sol is relatively low, due to their relatively large particle size. The use of these colloidal alumina sols at viscosities which are practical for coating patterns has been unsuccessful, since, due to their low surface area and low concentration, it has been impossible to achieve sufficient binding strength for a satisfactory mold.

It is an object of the subject invention to provide an improved ceramic mold for use in precision casting of metals which is derived from a mixture of a binder which contains no silica which is free to react with molten metal and a refractory which is characterized as having essentially no free silica.

Another object is to provide a process of producing a ceramic shell mold by a lost wax process, which utilizes a binder which is essentially free of silica which is available for reaction with molten metal and a refractory which contains essentially no free silica.

An important object of the invention is to provide a method of forming metal castings, which will contain essentially no surface irregularities due to metal-mold reac-

tions, by forming the castings in a mold which is derived from a binder which contains essentially no silica which is available for reaction with the molten metal and a refractory which contains essentially no free silica.

In accordance with the invention, a unique ceramic mold for use in precision casting of metals has been discovered. In its broadest terms the mold of the subject invention can be described as deriving from a mixture of an alumina coated silica sol and a granular refractory. Production of a ceramic mold for a lost wax process, and correspondingly a method of forming precision metal castings by use of the improved mold, has been discovered.

The alumina coated sols which are referred to in the subject invention are defined as those in which all of the silica particles are coated with at least a continuous monolayer of alumina. The sols are further characterized as comprising dense spherical particles of an average particle size of from 10–30 millimicrons and an alumina-to-silica ratio of from 0.10 to 0.50. More preferably, the sols are of a particle size of from 15–20 millimicrons and have an alumina-to-silica ratio of from 0.10 to 0.30. An ideal sol, as shown below in Table 1, has an average particle size of 20 millimicrons and an alumina-to-silica ratio of 0.20.

A method of producing the alumina coated sols has been described by Mindick et al., in U.S. 3,139,406. However, it must be understood that the method of making alumina coated sols is not essential to the subject invention. It is only necessary that the finished sol have the aforementioned characteristics and most especially, that all of the silica particles be covered with at least a continuous monolayer of alumina.

The preferred sols for use in the subject invention have a total solids concentration of from 5–40% by weight. More preferably, the sols should have a solids content of from 15–30% by weight and most preferably, about 20% by weight. The sols should further have a pH range of from 0.5–6.5 and more preferably, a pH range of from about 5.0 to about 6.0.

A further important characteristic of the alumina coated sols is freedom from electrolytes, as they are essentially salt free. The finished sols have conductivities ranging from 1,000 to 5,000 micromhos. The preferred conductivities usually will not exceed 3,000. The preferred sols of the invention, e.g., those having a total solids content of between 15–30% by weight, are relatively non-viscous liquids, which may be handled without the need of using special mixing equipment or agitational devices to render them fluid and useful in forming a coating slip with the granular refractory.

Refractories which are useful in the subject invention are those which are characterized as containing little or no free silica which is capable of reacting with molten metal to form metal silicates. To meet this specification, a refractory for use in the subject invention should be characterized as having less than 4% free silica by weight and more preferably, less than 2% by weight of free silica.

Typical refractories which are commercially available and useful in the subject invention are alumina, zircon, zirconia, and mullite. More preferable, commercially available forms of the aforementioned refractories are known as tabular alumina, fused alumina, washed zircon, fused zircon, stabilized zirconia and fused mullite. It is not intended to limit the scope of the invention to include only those refractories specifically named, as the art of purifying refractory granular materials is undergoing a rapid development. Other materials within the broad category of refractories containing essentially no free silica could be equally useful.

The most preferred refractory for use in the practice of the subject invention is tabular alumina. Tabular alumina is defined as a massive, sintered alumina that has been thoroughly shrunk and has coarse well-developed alpha alumina crystals. Tabular alumina has been converted to the corundum form by heating to a temperature

slightly below 3700° F., the fusion point of aluminum oxide. The name tabular is applied because the material is composed predominately of tablet-like crystals. Tabular alumina is distinctly different from fused alumina which is produced by an electro-thermal process in which alumina is fused at a temperature of above 4000° F. in an electric arc furnace. Fused alumina is as acceptable for use in the subject invention as tabular alumina; however, tabular alumina is more economical and more readily available commercially.

In a typical process for preparing the ceramic mold of the subject invention, a slip is first made by suspending a granular refractory powder in the alumina coated silica sol binder. The granular refractory for use in the slip is preferably finer than 200 mesh, based on the U.S. Standard Sieve Series. The slip is mixed with constant agitation with the refractory and the sol in proportions such that the viscosity of the slip is suitable for providing a continuous coating to a dipped pattern. A typical viscosity which is suitable for this purpose is from 8–14 seconds as measured with a No. 5 Zahn cup, and more preferably, from 10–12 seconds. However, it is not meant to limit the scope of this invention to any given viscosity, as the viscosity can vary as long as a continuous coating can be maintained upon the pattern.

In order to form the molds of the subject invention, patterns are normally coated with a slip which has been prepared according to the above method. The coating is most preferably accompanied by dipping; however, the same result can be achieved by spraying or pouring the slip over the pattern. After the pattern has been coated with the slip, it is stuccoed with a granular refractory by any of a number of suitable methods.

The most preferred method for applying stucco to the coated patterns is by submerging the coated pattern into a fluidized bed of a granular refractory. Another preferred method is by sifting the granular refractory onto the coated pattern. Other methods may also be used.

The granular refractory for use in stuccoing should be substantially coarser than is necessary to be retained on an 80 mesh screen of the U.S. Standard Sieve Series. However, the exact mesh size for any particular application is governed by considerations such as availability of refractory, viscosity of the slip used in coating the pattern, drying time available and desired finished mold strength.

After stuccoing, the resultant stuccoed coating is allowed to dry thoroughly, after which the coating, stuccoing and drying process is repeated until a mold of the desired thickness and strength is built up. Most commonly the number of layers necessary for a mold will be between 1 and 9, and more usually, between 3 and 7.

It should be noted that for purposes of the subject invention, the ceramic mold is considered to be formed by the first two stuccoed layers. It must be understood that additional layers of stuccoed coatings or other types of back-up materials such as sand, castable, granular refractory or insulating material are merely to give the mold more support. These support materials may be of various chemical compositions and may contain free silica without changing the unreactive nature of the mold. The unreactive metal mold of the subject invention exists in the first two layers even though these layers need additional back-up for strength considerations.

The method of forming precision metal castings is one of pouring metals into a mold wherein no metal mold reactions take place at the metal mold interface. This method of forming is achieved by having a mold which consists of two unreactive layers, regardless of what back-up or strengthening materials may be used in conjunction with these layers.

The invention will be better understood by reference to the following examples.

EXAMPLE I

A slip was made up using 2½ gallons of an alumina

coated silica sol having the physical characteristics given below, and 50 lbs. of —325 mesh tabular alumina.

Table 1

Aluminum coated sol:

Solids	20%.
pH	5.5.
Al ₂ O ₃ /SiO ₂ Ratio	0.20.
Viscosity at 77° F.	5 c.p.s.
Specific gravity at 68° F.	1.14.
Specific surface area	150 m. ² /gm.
Average particle size	20 millimicrons.
Particle charge	Positive.
Density of sol at 68° F.	9.5 lbs./gal.
Freezing point	32° F.
Na ₂ O content	Less than 0.01%.
Chloride content	0.3%.

The viscosity of the slip was adjusted by adding tabular alumina until a No. 5 Zahn cup viscosity of 10 seconds was obtained. The slip was allowed to stand overnight with continuous agitation in order to reduce the number of air bubbles contained therein. Three wax patterns were dipped in the slip and stuccoed with +70 mesh tabular alumina. The stuccoed coatings were allowed to dry whereupon the procedure was repeated, again using +70 mesh tabular alumina as stucco. Three back-up coats were applied in the same manner, except that a +100 mesh calcined alumina-silicate grog was used as a stucco material. The dry stuccoed patterns were given a pre-wet by dipping into a tank containing only the alumina coated sol before being dipped into the slip for each successive coat.

After the three coated patterns were allowed to dry, the wax was burned out of the patterns and stainless steel was poured into the molds. The resultant stainless steel castings showed excellent surfaces with a complete absence from metal mold reactions. The same stainless steel exhibited a roughened surface with evidences of a severe metal mold reaction when cast into a prior art mold of fused silica and colloidal silica.

EXAMPLE II

Three wax patterns were coated in the same manner as the patterns in Example I, except that three primary coats were backed up by five secondary coats using the same calcined alumino-silicate grog as was used on the patterns of Example I. The molds were again dewaxed as in Example I.

A high nickel chrome alloy steel which had suffered extremely severe metal mold reactions in the molds of fused silica was used. After pouring the alloy into the three patterns the resultant castings showed extremely good surface properties and a complete absence of evidence of any metal mold reaction.

It can be seen by the foregoing examples that the objects of the invention, to provide an improved ceramic mold for use in precision casting and to provide a process

for producing a ceramic mold by the lost wax process which is essentially free of reactive silica, has been substantially achieved. Accordingly, a method of forming metal castings which contain essentially no surface irregularities due to metal mold reactions has been discovered.

The invention is hereby claimed as follows:

1. A ceramic mold for use in precision casting of metals which is derived from a mixture comprising an alumina coated silica sol and a granular refractory, said refractory being characterized as containing less than 2% by weight of free silica.

2. The mold of claim 1 which is further characterized as a ceramic shell mold for use in a lost wax process.

3. The mold of claim 1 in which the refractory is tabular alumina.

4. The process of producing a ceramic shell mold by a lost wax process which comprises coating an expendable pattern with a ceramic slip comprising an alumina coated sol vehicle having suspended therein a granular refractory, said refractory being characterized as containing less than 2% by weight of free silica, stuccoing the treated pattern with a granular form of the refractory, drying the coating, forming a plurality of superimposed similar coatings on the pattern and removing the expendable pattern from the ceramic shell.

5. The process of claim 4 in which the refractory is tabular alumina.

6. The method of forming precision metal castings which comprises the steps of forming a mold by coating a pattern with a ceramic slip comprising an alumina coated silica sol vehicle having suspended therein a granular refractory, said refractory being characterized as containing less than 2% by weight of free silica, stuccoing the coated pattern with a granular form of the refractory, drying the stuccoed coating, forming a plurality of superimposed similar coatings on the pattern and removing the pattern from the mold, pouring molten metal into the mold, allowing the metal to solidify and removing the mold.

7. The method of claim 4 wherein the mold is a ceramic shell mold for use in a lost wax process which is formed by coating an expendable pattern.

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JULIUS FROME, *Primary Examiner*.

T. MORRIS, *Assistant Examiner*.

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