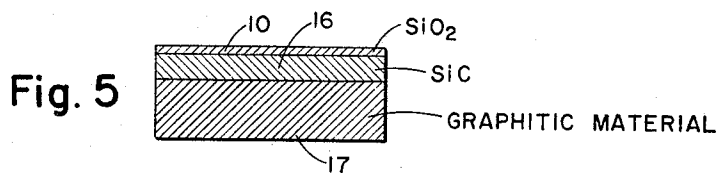
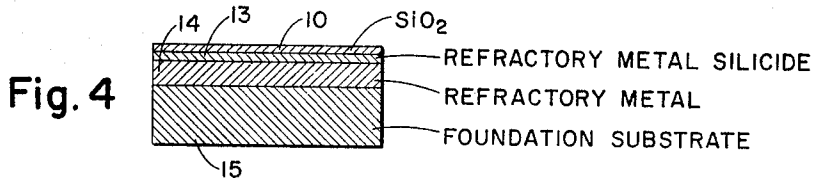
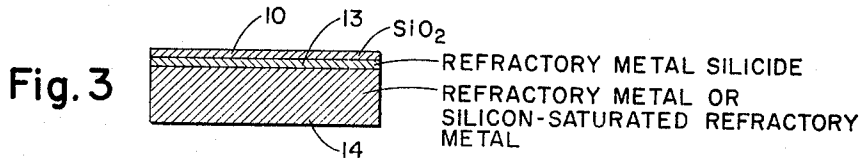
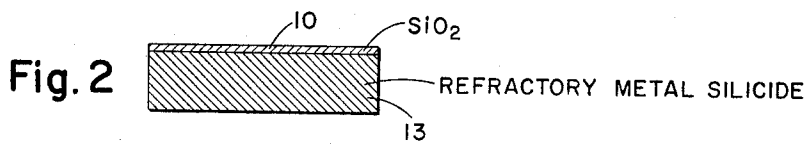
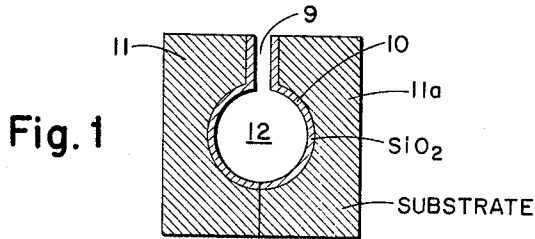


Nov. 22, 1966

R. S. DAVIS ET AL
REFRACTORY COATED CASTING MOLD

3,286,312

Filed March 29, 1965



Richard S. Davis
John L. Engelke
Joan B. Mattuck
INVENTORS

BY

Bernie A. Lygner
Attorney

1

3,286,312

REFRACTORY COATED CASTING MOLD

Richard S. Davis, Lexington, John L. Engelke, Arlington,
and Joan B. Mattuck, Boston, Mass., assignors to
Arthur D. Little, Inc., Cambridge, Mass., a corporation
of Massachusetts

Filed Mar. 29, 1965, Ser. No. 443,435

11 Claims. (Cl. 22-129)

This invention relates to molds and more particularly to a permanent mold for making a large number of castings of metals including iron and ferrous alloys.

It is customary in foundry practice to form molds of sand. Such molds are most commonly made by packing foundry-grade sand around a pattern, removing the pattern, and casting the molten metal in the sand mold thus formed. Normally, such molds must be reformed after every casting. Under some circumstances these molds may be reused for a few additional castings. Another technique for forming molds is that in which a thermosetting resin binder is added to the sand and blown against or otherwise caused to adhere to a pattern to form the mold. Such molds may be used several times, but they cannot generally be used for very heavy castings unless the resin bonded sand is built up to a substantial thickness or is supported with some suitable structural material. Moreover, the sand-resin material is not recoverable once a mold has been destroyed and is therefore more costly than sand alone. There is therefore no suitable way of making a permanent mold for ferrous alloys which can be used for repeated castings, e.g., over a thousand castings from the same mold. Even though sand is a relatively inexpensive material, the time consumed in having periodically to make new molds makes the process of casting iron and ferrous metals relatively expensive. It would therefore be desirable to have a mold for this process which would be permanent and could be reused a large number of times. Such a permanent mold can be formed of relatively expensive material and still be less expensive to use if a number of castings are to be made.

According to this invention a permanent mold can be made which is suitable for casting iron and ferrous alloys. This mold is characterized by the fact that it presents to the molten metal a substantially continuous layer of SiO_2 in a form which permits the mold to be suitably filled to produce a satisfactory casting. The silicon dioxide is most conveniently formed by oxidizing a silicon containing surface which may be a coating on a substrate or comprise the mold substrate itself.

It is therefore a primary object of this invention to provide an improved mold form suitable for making castings of iron and ferrous alloys. It is another object of this invention to provide a mold form of the character described which is essentially permanent and reusable for making a large number of castings over an extended period of time. It is yet another object of this invention to provide a mold which has a surface coating which is regenerative or self-healing. It is still another object of this invention to provide a mold of the character described which presents a surface which is readily wetted by the molten metal and which at the same time permits easy removal of the solidified casting therefrom. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

2

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the article possessing the features, properties and relation of elements which are exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings in which

FIG. 1 shows a typical mold in cross-section constructed in accordance with this invention, and

FIGS. 2-5 illustrate in cross-section various composites which may make up the mold form of this invention.

FIG. 1 is a cross-sectional representation of a typical enclosed mold form made of two sections 11 and 11a and constructed in accordance with this invention. The mold illustrated is suitable for casting a spherical metal piece by introducing molten metal through gate 9 into a cavity 12. The complete mold may be considered to be comprised of two components, namely a silicon dioxide surface layer 10 which lines the surface defining cavity 12 and the gate 9, and the supporting substrate 11.

FIGS. 2-5 illustrate various forms which this supporting substrate may take. Generally the substrate material must be one which retains its structural integrity at temperatures approaching the melting point of the cast metal or alloy. It should also have a relatively high thermal conductivity at the temperatures involved in casting in order to achieve the cooling of the cast metal.

In FIGS. 2-5 no attempt has been made to show a contoured cavity which may assume any suitable configuration. Neither has any attempt been made to indicate the relative thickness of the various layers making up the components of the mold.

In FIGS. 2 the entire supporting substrate is a refractory metal silicide 13. The most commonly used refractory metals are molybdenum and tungsten, although metals such as niobium (columbium), tantalum, titanium, zirconium and hafnium may also be considered to be refractory metals suitable for the practice of this invention. It is also, of course, within the scope of this invention to use alloys which contain such refractory metals. As an example we may cite the well-known alloy designated TZM which is an alloy of titanium, zirconium and molybdenum. These refractory metals form a number of different silicides. For example, molybdenum forms three silicides, MoSi_2 , Mo_5Si_3 , and Mo_3Si . Tungsten forms two silicides namely WSi_2 and W_5Si_3 . When these refractory metal silicides are exposed to an oxidizing atmosphere such as air, the surface oxidizes to form a thin layer of SiO_2 . This layer is somewhat glassy in appearance and serves as an excellent surface for molds since it is readily wetted by the molten metal and at the same time is readily separated from the solidified casting.

Several techniques are available for making the refractory metal silicide substrate for the mold system of FIG. 2. These techniques include, but are not limited to, powder metallurgy compounding, mixing metal and silicon powders and hot pressing, and diffusion of silicon vapor into the refractory metal substrate.

It may be desirable to form a substrate such as that illustrated in FIG. 3 in which the refractory metal silicide 13 is used only as a layer on a refractory substrate 14 which may be silicon-saturated. Silicide coatings are

known to be protective coatings for refractory metals. However, when a metal silicide is used as a coating on a refractory metal, the silicon may tend to diffuse into the refractory metal thus eventually destroying the protective coating of metal silicide. In order to prevent the diffusion of silicon into the substrate and the subsequent disintegration of the coating, the refractory metal substrate may be saturated with silicon thus establishing equilibrium conditions which prevent diffusion of the silicon into the substrate. The system of a silicon-saturated refractory metal having a metal silicide coating is the subject of a co-pending application Serial No. 443,432 filed in the names of Paul E. Blackburn and Joan B. Mattuck and assigned to the same assignee as the present application. In this system sufficient silicon is incorporated into the refractory substrate to provide therein a silicon content equivalent to the equilibrium solution concentration of the silicon in the metal or alloy substrate for the temperature at which it is to be exposed. For example in the case of molybdenum the amount of silicon will range between about 1 and 5 atomic percent while in the case of tungsten this will be from about 4 to 8 atomic percent. As in the case of the mold system of FIG. 2, exposure to an oxidizing atmosphere at elevated temperatures, e.g., air or oxygen will form a thin layer or coating of SiO_2 10 on the refractory metal silicide 13.

FIG. 4 illustrates a mold system similar to that of FIG. 3 except that it includes a foundation substrate 15 which may be any suitable refractory material having relatively high thermal conductivity at the temperatures to which it is to be exposed in the casting process. This may be a metal or an alloy. In this case, as in the case of FIG. 3, the refractory metal may or may not contain silicon.

FIG. 5 illustrates another system which differs from that of FIGS. 2-4 in that the substrate is non-metallic, i.e., graphite, or a graphitic or carbonaceous material. On the graphite substrate 17 there is built up a layer of silicon carbide 16 which, like the refractory metal silicides will oxidize to form a thin layer of SiO_2 . As an example of constructing such a mold we may cite the following. A substrate is formed of graphite and the silicon carbide layer is deposited thereon by hot pressing or sintering silicon on the surface, by coating with molten silicon or by sintering in the presence of a silicon source, e.g., silicon tetrafluoride.

The SiO_2 layer formed on that surface of the mold which is to contact the molten metal is preferably relatively thin, i.e., of the order of about 1 to 5 mils. It is only necessary to form a thin layer or coating since the SiO_2 coating is in effect self-healing or self-regenerating. This is due to the fact that the SiO_2 film is formed on a silicon containing substrate which can be readily oxidized to form the SiO_2 coating. Thus if the film of SiO_2 should crack, spall, or otherwise be removed it is a relatively easy procedure to expose the mold surface to an oxidizing atmosphere at elevated temperatures to regenerate the SiO_2 layer. In fact it could automatically be formed when the mold is opened to the air at elevated temperatures.

In some cases, e.g., in the case of where the refractory metal silicide is subject to "pest" failure during use it will be preferable to keep the mold at an elevated temperature between metal pourings to prevent destruction of silicide brought about through temperature cycling. However, if maintaining the mold at elevated temperatures is not feasible, it may be rendered essentially impervious to "pest" failure by forming the silicide least likely to undergo this form of destruction. For example, in the use of a molybdenum-based mold if the molybdenum silicide is primarily Mo_3Si , the chance of pest failure is materially reduced.

In making the mold of this invention the substrate may be formed in the shape of a block and the cavity then machined out of the desired configuration. Alternative-

ly, the substrate may be formed around a pattern by flame spraying the metal or metal silicide onto a pattern. The substrate may also be formed around a pattern by known techniques of powder metallurgy, the pattern removed, and the substrate containing the mold cavity sintered with heating at a temperature determined by the material from which the substrate is formed. Once the cavity is formed within the substrate having an exposed surface containing chemically bonded silicon, the cavity surface is exposed to an oxidizing atmosphere, e.g., heated in air or oxygen and the surface is chemically changed to form a thin, glass-like layer of SiO_2 . If any of the SiO_2 layer cracks off or is chipped, re-exposure of the cavity surface to oxidizing conditions regenerates the SiO_2 layer, thus making the surface self-healing.

It has been found that the SiO_2 layer surface is easily wetted by the molten metal to be cast and hence makes it possible to form accurate and intricate castings. Moreover, the mold form of this invention does not undergo any appreciable shrinkage at any stage of its making or use. This in turn eliminates the need for any costly compensation for dimensional changes from pattern to final casting. Finally, the SiO_2 surface readily releases the casting once it has solidified, thus retaining the mold shape and preserving the cavity surface for making a large number of castings.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and since certain changes may be made in carrying out the above method and in the article set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language might be said to fall therebetween.

We claim:

1. A permanent mold for casting molten metals, comprising

(a) a cavity suitable for receiving the molten metal to be cast;

(b) a thin layer of SiO_2 covering that portion of the cavity surface which is contacted by said molten metal; and

(c) a substrate in which said cavity is defined, at least that portion of said substrate directly in contact with said layer of SiO_2 being of a material containing chemically bonded silicon in a form which is readily oxidized to SiO_2 in an oxidizing atmosphere, said material being one which retains its structural integrity at the melting temperature of the metal to be cast.

2. A mold in accordance with claim 1 wherein said substrate is a refractory metal silicide.

3. A mold in accordance with claim 2 wherein said refractory metal silicide is molybdenum silicide.

4. A mold in accordance with claim 3 wherein said molybdenum silicide is Mo_3Si .

5. A mold in accordance with claim 3 wherein said molybdenum silicide is Mo_5Si_3 .

6. A mold in accordance with claim 3 wherein said molybdenum silicide is MoSi_2 .

7. A mold in accordance with claim 1 wherein said substrate is a refractory metal silicide in contact with a refractory body containing said refractory metal.

8. A mold in accordance with claim 1 wherein said substrate is a refractory metal silicide in contact with a refractory body containing said refractory metal and having dispersed through said refractory body a quantity of silicon in an amount substantially no greater than the

5

equilibrium solution concentration of silicon in said refractory metal.

9. A mold in accordance with claim 8 further characterized by having a foundation substrate supporting said refractory body.

10. A mold in accordance with claim 1 wherein said substrate is silicon carbide.

11. A mold in accordance with claim 10 further characterized by having a foundation substrate of graphitic material.

5

10

6

References Cited by the Examiner

UNITED STATES PATENTS

2,358,157	9/1944	Gardner	-----	106—38.27	X
2,429,946	10/1947	Roach	-----	106—38.27	
2,448,903	9/1948	Miller	-----	106—38.27	
2,618,032	11/1952	Traenkner	-----	117—5.1	

J. SPENCER OVERHOLSER, *Primary Examiner*.

E. MAR, *Assistant Examiner*.