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CONDENSATION OF MAGNESIUM VAPORS

Walther Schmidt, Richmond, Va., assignor to Reynolds Metals Company, Richmond, Va., a corporation of Delaware

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5 Claims

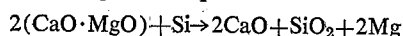
ABSTRACT OF THE DISCLOSURE

A method is disclosed for condensing magnesium vapors by contacting the vapors with an aluminum base magnesium alloy at a temperature below about 600° C. The alloy preferably contains 75% aluminum and 25% magnesium before the condensation and 72–85% magnesium after condensation of the vapors therein.

BACKGROUND OF THE INVENTION

Thermal reduction processes for use upon magnesium oxide materials to yield metallic magnesium have evolved along two general lines: those which use carbon as a reducing agent and those which use free metals, mainly silicon, as a reducing agent. In both types of reaction the necessary heat is usually supplied by an electric arc furnace in which an electric current is passed through the feed-stock mixture of materials and usually also through the resulting liquid or solid slag by-product. Calcined dolomite is the favored ore for such processes and usually carbon electrodes are employed because few other electrode materials can stand up to the high temperatures involved.

In carbon reduction processes, magnesium vapor is produced along with carbon oxide gases. To prevent back reaction between these products, the vapor mixture generally is shock-cooled and the magnesium is recovered as a powdered solid. Because of the further work involved in handling such a product, processes using free metals appear to be increasingly favored. Such processes generally employ as a reductant silicon in the form of ferro-silicon and operate upon MgO-bearing raw materials, e.g., with dolomite according to the equation:



This reaction takes place at a temperature usually above 1110° C., at which temperature magnesium metal is volatile or can be made volatile by operating at a reduced pressure. Since magnesium is usually produced in closed equipment, so that air may be excluded, reduced pressures usually do not require extensive modification of the equipment. The same is true, if aluminum is used as reductant, preferably in combination with silicon in form of Al-Si-Fe-Ti alloys which can be obtained by thermal reduction from bauxite and/or clays. Such alloys also contain common impurities like carbides, oxycarbides, calcium and others.

The use of metallic reductant theoretically allows the magnesium to be condensed in liquid form; however, as a practical matter, it has been found that under the reduced pressures prevailing in, for example, the system disclosed in U.S. Patent 2,971,833, the temperature of the condenser must be kept so low that the magnesium solidifies. The reason for requiring such a low temperature is the still considerable vapor pressure of magnesium, approximately 3 mm./Hg, just above its melting point, namely at 650° C. At 720° C., the vapor pressure is on the order of 0.01 atmosphere or 7.6 mm./Hg. Condensation in practical operations must consider surges of Mg vapor and, hence, upward temperature fluctuations. It is, therefore, not practical to condense magnesium to a liquid with an ambient "vacuum" of about 5–20 mm./Hg.

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It will be readily recognized that solid magnesium formed in the condenser requires periodic removal of the condenser for product recovery by remelting. This procedure involves stopping the entire reduction process and manually dismantling the condenser, while exposing the system to the air. It can be readily seen that a good deal of time and materials can be lost in this fashion.

If operations are attempted at a higher pressure, say, about 35 mm./Hg, it is possible to get liquid condensation of the magnesium, but other operating difficulties are experienced in such a system, for example, premature condensation in the conduit leading to the condenser. This conduit builds up crustations of matter entrained in the vapor, particularly slag particles, which stick to the refractory lining, forming a spongy mass which is filled with magnesium and which burns while being removed manually.

More difficult is the maintenance of proper thermal conditions during the operations themselves. Despite the rather high latent heat of vaporization, which is approximately 1.35 kcal. per gram magnesium, it has been found necessary to maintain inside the condenser conduit an electrical resistance heater. The reason is that the Mg vapors do not enter the condenser in an even stream, but in pulses of lower or higher quantities according to their charge rhythm and perhaps temperature fluctuations in the slag, if, e.g., a system is used as described in U.S. Patent 2,971,833. If too much Mg vapor comes, the inside refractory lining of the condenser pipe must absorb a lot of heat, which gradually travels to the outside shell from where it is removed. If too little Mg vapor comes, the danger of solid condensation on the inside refractory lining must be avoided by extra heat provided by the inserted resistance heater.

SUMMARY

In this invention, magnesium vapor is condensed as a liquid at a temperature below 600° C., preferably below 560° C., by absorbing the Mg vapor in a liquid heel of an aluminum-base magnesium alloy. The liquidus of the starting alloy, low in Mg, say about 75% aluminum and 25% magnesium, and of the final alloy, high in Mg, as well as the liquidus of all intermediate compositions remains below 600° C., preferably below 560° C.

DESCRIPTION

This invention is made practical by the fact that one of the largest single consumers of magnesium is the aluminum industry which applies Mg as alloying constituent in a large number of common Al-base alloys. Also, the greatest use of Mg-base alloys is for castings which contain between 3 and 6% Al. Therefore, an alloy rich in Al and Mg is useful to introduce Mg into Al-base alloys and Al into Mg-base alloys. The alloy produced using the method of this invention may contain approximately 72–85% Mg, preferably 75% Mg, the rest Al.

The liquidus temperature of an alloy 72% Mg, 28% Al is approximately 480° C.; that of the 85% Mg, 15% Al alloy approximately 560° C., both well below the 649° C. liquidus of pure magnesium. On the Al side of the binary phase diagram of Al and Mg is the eutectic containing approximately 65% Al and melting at 451° C., while an alloy of 85% Al, 15% Mg is liquid at approximately 580° C. Actually, this rich alloy is partially liquid already at approximately 480° C. because of its high content of low melting eutectic. Thus, condensation an Al-Mg heel can be done with a temperature approximately 100–200° C. lower than with pure Mg, according to the choice of final composition being enriched in magnesium.

The lower temperature means lower vapor pressure of the Mg. In addition, the dissolution of Mg in an Al-Mg heel lowers the vapor pressure still more, according to

Raoult's law. An estimate by extrapolation results, e.g., in a vapor pressure above a 75% Mg, 25% Al alloy at 550° C. to be less than 0.4 mm./Hg. Since the concentration of 75–85% Mg, 25–15% Al would only be reached at the end of the process cycle, the vapor pressure during the cycle itself is still lower.

Therefore, at the pressure of 5–20 mm./Hg, the Mg vapor can be condensed as a liquid on an Al-Mg heel. It is to be understood that the range of 5–20 mm./Hg is not limiting. Higher pressures, e.g., up to 40 mm./Hg may be used. But it is a distinct advantage of the condensation according to this invention that lower pressure can be used which promotes the efficiency of the reaction between the MgO-bearing material and the reductant in terms of yield per unit of space, temperature and time. The enriched Al-Mg alloy can be removed by tapping without disassembling the condenser. The alloy can be cast into pig moulds, avoiding the investment, labor, fuel and oxidation losses otherwise incurred if solid condensate would have to be remelted. This saving is in addition to saving the cost of dismounting and reassembling the condenser, when the magnesium is recovered in massive solid form.

Also, it has been found that a steel or preferably cast iron condenser can be used in this process. Cast iron, especially of the Duriron type can withstand the attack of Al-Mg alloys below 600° C. for a reasonably long time and no inside refractory needs to be employed. In one embodiment, the required amount of solid aluminum is placed within the condenser, in order to make use of its latent heat of fusion, absorbing some of the latent heat of vaporization of the magnesium within the condenser. The Mg vapor impinges on the solid aluminum and transforms it first to the Al-rich eutectic forming the liquid heel which then absorbs more Mg until the composition near to the Mg-rich eutectic is reached. A condenser of steel or cast iron or Duriron is used and the heat of condensation is withdrawn by cooling its outside walls, keeping the interior at a temperature around 550° C. On a continuous basis the liquid alloy can be pumped around through a heat exchanger and Al can be added to the recycle stream or into the condenser itself to keep the desired composition. In each pumping cycle, a stream can be withdrawn through a syphon or a valved lock which safeguards against the atmospheric pressure, versus the partial vacuum inside the condenser. Thus, the condenser could be tapped continuously and the condenser would probably not need to be dismantled except perhaps after longer operations, provided that contamination from dust and slag particles can be minimized.

The invention will be better understood by reference to the following example, which should be considered illustrative only and not limiting.

EXAMPLE

An electric furnace of a type known to the art for magnesium reduction is provided with a Duriron condenser for magnesium vapors at the end of its vapor conduit. The condenser, in turn, is provided with an inlet and an outlet which are attached by suitable leads to a heat radiator and a pump for recycling of the material in the condenser. The pump is actuated by a thermostat within the radiator leads set for a temperature of about 550° C. The radiator leads are also provided with a tap for removal of alloy and an entry conduit for addition of mol-

ten aluminum. Heat is withdrawn through the condenser walls, which are cooled on their outside, keeping the temperature of the heel and the accumulated condensate about 530–550° C. The function of the radiator is to equalize and normalize the recycle temperature, particularly after makeup aluminum has been added in molten form. A heel of 75 parts Al and 25 parts Mg melting at about 525° C. is placed in the condenser by means of the entry conduit.

A charge of calcined dolomite ore is placed in the electric furnace with an amount sufficient to reduce MgO to Mg of an intermetallic waste product analyzing as 37% Al, 37% Si, 20% Fe and 8% Ti. The furnace is operated at a temperature of about 1500° C., the slag rapidly forming a liquid within which the reduction to magnesium metal takes place. Magnesium vapor is rapidly evolved in the furnace and passes to the condenser where it condenses in liquid form in and by contact on the liquid heel. When 200 parts magnesium have been condensed on the heel, the tap is opened to withdraw liquid alloy containing 200 parts (75%) of magnesium and 66.66 parts (25%) aluminum. After this withdrawal, the tap is closed and 66.66 parts molten aluminum is added to the recycling liquid.

At the temperature of of 550° C., maintained in the condenser, an alloy of 80 parts Mg and 20 parts Al would still be liquid. It would take 275 parts of condensed Mg instead of the 200 parts of the example to reach an 80/20 ratio. This means that the condenser would not freeze up with fluctuations of the Mg yield.

If desired, other alloying constitutions may be added to the recycling liquid when these are desired in the final alloy. Hardening components such as silicon, copper and/or zinc may often be desired, although larger amounts of zinc are less suitable, because of its relatively high vapor pressure.

What is claimed is:

1. A method for condensing magnesium vapors which comprises contacting said vapors with a liquid heel of an aluminum-base magnesium alloy at a temperature below about 600° C. and recovering therefrom a liquid alloy having a higher magnesium content than the heel alloy, said liquid alloy containing about 72–85% magnesium with the rest essentially aluminum.

2. A method according to claim 1 in which the heel alloy contains about 75% aluminum and 25% magnesium.

3. A method according to claim 1 in which the recovered alloy is about 75% magnesium.

4. A method according to claim 1 in which the contact is at below about 530–550° C.

5. A method according to claim 1, in which the pressure is about 5–20 mm./Hg.

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HENRY W. TARRING II, Primary Examiner