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COMPOSITE ELECTRICAL CONDUCTOR FOR AN ELECTROLYSIS CELL USED IN MANUFACTURE OF ALUMINUM AND METHOD FOR MAKING SAME

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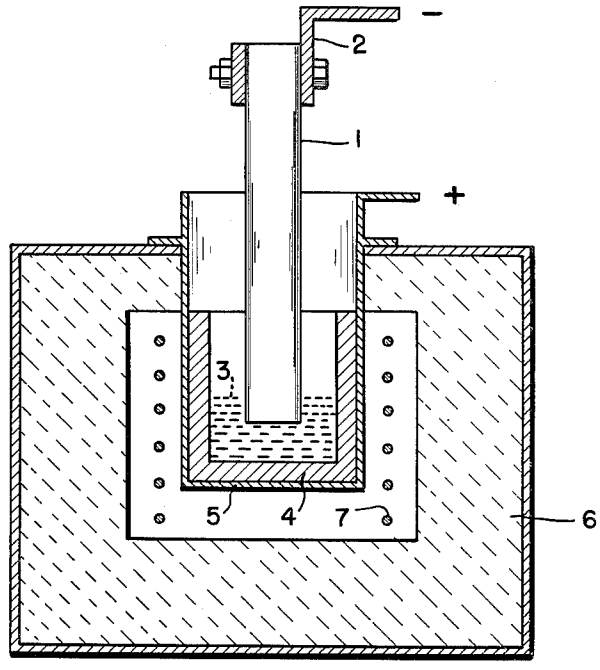



Fig. 1

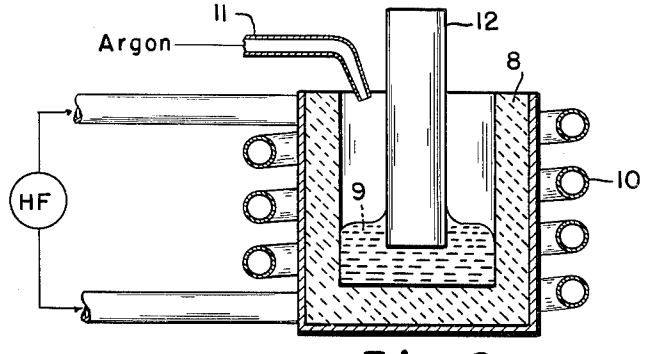



Fig. 2

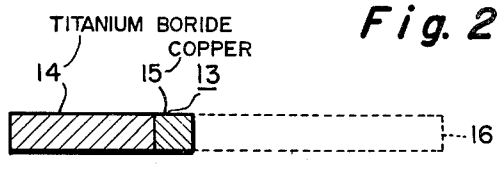



Fig. 3

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# COMPOSITE ELECTRICAL CONDUCTOR FOR AN ELECTROLYSIS CELL USED IN MANUFACTURE OF ALUMINUM AND METHOD FOR MAKING SAME

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The electrolysis bath used for aluminum production is generally constituted of a solution of alumina dissolved in molten cryolite.

Unfortunately, this bath attacks almost all known industrial refractory materials, and up to the present only those consisting mainly of carbon could be used for intenal linings of the cells, and particularly to establish the conducting bottoms of the cells which serve as current conductors for the cathodic metal layer. Yet, these materials present serious drawbacks:

(1) Their resistance is not perfect; impregnation and swelling phenomena, which appear in relation to the passage of the electric current, leading indeed to their destruction over a more or less long period.

(2) For this reason they must be applied in a relatively thick layer, which in turn results in important ohmic losses of energy.

In order to remedy these drawbacks, it was recently suggested to separate the two roles of the lining in establishing the direct current supply to the cathodic layer by means of current feeding rods composed of at least one of the compounds of the group formed by the nitrides, carbides and borides of titanium, zirconium, vanadium, tantalum, columbium or hafnium, i.e., metals of the subgroup A of the groups IV and V, and of the series IV, V and VI of the periodic table of chemical elments.

In fact, these compounds resist attack by molten aluminum and cryolite; they are wetted by the liquid aluminum and present an electric conductivity at least equal to that of graphite.

In the known device the conductors are constituted by quite long rods which transverse the lining of the cell (side walls or bottom) from one side to the other. The end of the rod situated inside the cell is immersed directly in the cathodic metal, whereas the end situated at the exterior of the cell is directly connected to current feeding bars, this connection being ensured by direct molding of aluminum around the rod.

These devices therefore require rods of relatively considerable length, which again results in several drawbacks:

(1) Taking into account the very high melting point of the compounds involved (nitrides, carbides and borides of the refractory metals), the production of these rods is limited exclusively to the field of powder metallurgy, resulting in expensive production means (molding presses, high temperature sintering furnaces with controlled atmosphere, etc.).

(2) The sintered rods so obtained, although generally offering great hardness and a relatively good mechanical resistance to tensile and compressive stresses, resist poorly bending and shear stresses.

(3) The raw materials involved are expensive.

Studies carried out by the applicant permit remedying these drawbacks by applying far shorter rods, therefore very much less fragile, and at the same time permitting considerable economy of raw material and production means.



In the accompanying drawings which illustrate preferred embodiments of this invention,

FIGURES 1 and 2 illustrate devices useful in carrying out the method; and

FIGURE 3 is a longitudinal section through a current conductor.

Although it is already known that under certain conditions, liquid aluminum wets the sintered refractory products involved, it is not the case with the other metals, and the problem of connecting those sintered refractory products to metals or alloys, other than aluminum, does not seem to have been solved. However, aluminum, because of its low melting point, absolutely does not correspond to the application which we shall describe.

The object of this invention is an improvement on the electric feeders or conductors for electrolysis cells for aluminum production, which consists essentially in inserting between the external metallic bars for electric feeding and the sintered refractory rods which are in contact with the aluminum bath, a metal or an alloy with a high melting point, and to this effect:

(a) to coat with liquid aluminum the ends of the sintered refractory rods to be connected with the external metallic bars for electric feeding;

(b) to bring this end in contact with an intermediate joining metal or alloy having a melting point higher than about 950° C.;

(c) to produce a mechanical and electrical connection, analogous to one produced by welding or soldering, between the sintered rods already covered by said joining metal or alloy and the external metallic bars for electric feeding.

The strictly useful part of the rods is hence reduced to the portion which is to be directly in contact with the electrolysis bath or with the liquid aluminum during electrolysis, which represents at the most, half of their total length in the case of lateral electric supply and from 2 to 5 cm. in the case of electric supply through the bottom of the electrolysis cell.

The metal or alloy with a high meltig point to be used in step (b) of the above mentioned process in accordance with the invention, must be able to form an alloy with aluminum. One preferably uses those metals or alloys which form a solid solution, such as silver, copper and even iron, nickel and their alloys.

The invention may be carried out in an operation consisting of three consecutive steps:

(1) Wetting with liquid aluminum, the sintered refractory rod end which is to be connected to the high melting point joining metal or alloy.

(2) Bringing in contact this end, previously coated with aluminum, with a bath of liquid joining metal or alloy, such as pointed out above. Under these conditions, the thin aluminum coating deposited on the rod surface rapidly diffuses into the liquid joining metal or alloy, which results in a perfect wetting of the rod by the latter, this wetting remaining effective after cooling down and solidification, thus allowing to establish a metallic head of high melting point metal or alloy in perfect mechanical and electrical connection with the sintered refractory rod.

(3) Connecting by autogenous welding or by hard soldering the thus produced head to a metallic bar, the nature and the dimensions of which must be appropriate to the further use envisaged.

In practice, wetting with the liquid aluminum is carried out by electrolytic deposition in a small cell. A suitable device is shown in FIGURE 1 of the attached drawing.

The sintered refractory rod 1 is connected to the negative terminal of a direct current generator by means of a conducting clamp 2 and the free end of the sintered rod dips into a molten cryolite bath 3, containing ten

percent of alumina for example, contained in a graphite crucible 4, protected by a refractory steel shell 5 and by means of this shell connected to the positive terminal of the generator. The crucible 4 as well as its contents may be brought to a suitable temperature by means of a furnace 6 provided with silicon carbide rods 7. The necessary continuous current voltage is in the range of 3 to 5 volts and the cathode current density may vary within very large limits (0.5 to 20 A./cm.$^2$). According to the current density chosen, an aluminum layer of 0.1 to 0.5 mm. thickness is largely sufficient. The total duration of the electrolysis operation may vary from half an hour to a few seconds.

If silver, copper or alloys fusing at a temperature less than 1100° C. are used as joining metal, the next operation can be carried out in the same apparatus, immediately after wetting with the aluminum. After cutting off the continuous current supply, the joining metal is put in solid form into the graphite crucible and the whole is quickly brought to a temperature which is higher than the melting point of the joining metal. After elimination of a part of the electrolysis bath, if need be, the end of the sintered rod covered with aluminum is lowered so as to be in contact with the liquid joining metal. The aluminum is practically immediately replaced by the joining metal and it is sufficient to allow the whole to cool down, but in order to avoid the formation of an internal cavity, the cooling is to be controlled by directing a compressed air stream on the rod, for example. Unmolding is easily carried out after cooling down, if the precaution was previously taken to provide the graphite crucible wall with a slight taper.

If a metal with a melting point higher than 1100° C. is used as a joining metal, such as iron or nickel alloys for example, the operation of diffusion in a liquid state may no longer be performed in the same device as the wetting operation with the aluminum, but it can then be carried out by means of the device represented in FIGURE 2 of the attached drawing.

Inside a refractory crucible 8 the joining metal 9 is brought into a liquid state by high frequency induction heating by means of the inductor 10 and its surface is protected against oxidation by an argon jet 11. The end of the rod 12, previously coated with aluminum is then lowered (slowly, to avoid thermal shock) until it is immersed in the joining metal or alloy. Then the whole is cooled down, taking the same precautions to avoid the formation of a pipe, as in the above mentioned case.

In both cases, the so obtained metallic head of joining metal may be connected without any difficulty to any external metallic bar by any means already known.

*Example*

A rod of sintered titanium diboride of the dimensions 50 x 50 x 200 mm. was wetted with aluminum in a device similar to that of FIGURE 1.

The graphite crucible used had an interior diameter of 95 mm. In this crucible 700 grams of cryolite-alumina mixture containing 10% of alumina was melted at 1000° C. The rod was then slowly lowered into the bath until it was immersed to a depth of 2 cm.

The electrolysis was performed at a voltage of 5 volts and a current of 50 amperes for half an hour. The aluminum layer deposited under these conditions had a thickness of 0.5 mm.

After cutting out the electrolysis current, the titanium boride rod was withdrawn from the bath and the furnace temperature was quickly raised to 1100° C. 3 kg. of solid copper were then progressively introduced into the crucible. As soon as the copper was melted, the aluminum coated boride rod was again progressively lowered into the crucible until its end dipped a few millimeters into the molten copper. After a few minutes the furnace heating current was cut off. In order to avoid the formation off a pipe in the copper, a compressed air jet was



directed on that portion of the boride rod projecting out of the bath. As soon as the copper became solid, the crucible and its contents were taken out of the furnace and the titanium boride rod and head of joining metal were recovered from the crucible.

The copper head thus obtained was then machined on a shaping machine to the section dimensions of the sintered rod. It formed a head of the dimensions 50 x 50 x 50 mm. which could without any difficulty be welded onto a copper bar of the same section and of appropriate length.

Referring to FIGURE 3, the current carrying conductor 13, made according to the example, consists of a sintered titanium boride rod 14 having connected thereto at one end, a head 15 of copper. A bar 16 of copper or other metal or alloy may be brazed or soldered to the head 15.

The voltage drop at the copper-titanium boride contact is less than one millivolt for an intensity of 2,000 amperes.

As used herein, the term "joining metal" means metal or alloy.

I claim:

1. An electrical conductor for conducting current from an external current lead to liquid aluminum in an electrolysis cell for the manufacture of aluminum, said conductor comprising a rod of sintered refractory electrically conducting material having united to a portion thereof a head of joining metal which has a melting point higher than about 950° C. and is capable of alloying with aluminum, said sintered material and said head of joining metal being united together through a mechanical and electrical connection by at least one of an alloying of said joined metal with aluminum and a diffusing of aluminum into said joining metal, said rod having prior to effecting said uniting together a coating of aluminum on that part to which said joining metal is united to said rod.

2. An electrical conductor according to claim 1, wherein said rod of sintered refractory electrically conducting material is selected from the class consisting of nitrides, carbides and borides of metals of the class consisting of titanium, zirconium, vanadium, tantalum, columbium and hafnium.

3. An electrical conductor according to claim 1, wherein said joining metal is selected from the class consisting of copper, silver, iron, nickel and their alloys.

4. An electrical conductor according to claim 1, wherein said rod of sintered refractory electrically conducting material is selected from the class consisting of nitrides, carbides and borides of metals of the class consisting of titanium, zirconium, vanadium, tantalum, columbium and hafnium, and wherein said joining metal is selected from the class consisting of copper, silver, iron, nickel and their alloys.

5. An electrical conductor according to claim 1, wherein said rod of sintered refractory electrically conducting material is made of titanium diboride and wherein said joining metal is copper.

6. A method of making an electrical conductor of a refractory electrically conducting material and a joining metal selected from the group, consisting of copper, silver, iron, nickel and their alloys, said conductor conducting current to liquid aluminum cathode of a cell for production of aluminum electrolytically, said method comprising electrodepositing from a molten bath of cryolite containing alumina, a thin layer of liquid aluminum on an end of said refractory material, pouring liquid joining metal into the molten bath, allowing aluminum to at least one of diffuse into and alloy with said joining metal and allowing said joining metal to solidify.

7. The method of making an electrical conductor according to claim 6, wherein said refractory electrically conducting material is selected from the class consisting of nitrides, carbides, and borides of metals of the class consisting of titanium, zirconium, vanadium, tantalum, columbium and hafnium.

8. A method of making an electrical conductor of a refractory electrically conducting material and a joining metal selected from the group consisting of copper, silver, iron, nickel and their alloys, said conductor conducting current to liquid aluminum cathode of a cell for production of aluminum electrolytically, said method comprising electrodepositing from a molten bath of cryolite containing alumina, a thin layer of aluminum on an end of said refractory material, immersing said aluminum coated end of said refractory material into a liquid bath of said joining metal, allowing aluminum to at least one of diffuse into and alloy with said joining metal and allowing said joining metal to solidify.

9. The method of claim 8 wherein said refractory electrically conducting material is selected from the group consisting of nitrides, carbides, and borides of metals of the class consisting of titanium, zirconium, vanadium, tantalum, columbium and hafnium.



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