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(72) Inventeurs/Inventors:
SUN, SONGTAO, CN;
FANG, YULIN, CN
(73) Propriétaire/Owner:
INNER MONGOLIA UNITED INDUSTRIAL CO., LTD.,
CN
(74) Agent: BLAKE, CASSELS & GRAYDON LLP

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(54) Title: INERT ALLOY ANODE FOR ALUMINUM ELECTROLYSIS AND PREPARING METHOD THEREOF

(57) **Abrégé/Abstract:**

An inert alloy anode used for aluminum electrolysis. The anode has Fe and Cu as the main constituents and comprises Sn. The addition of the Sn metal is conducive to the formation of a layer of oxidized film having a great antioxidant activity and structural stability on the surface of the inert alloy anode, and is conducive to an increase in the corrosion resistance of the anode. On this basis, the constituents of the inert alloy anode also comprise Ni, Al, and Y. The addition of the Al metal prevents the main metal constituents from being oxidized, the addition of the Y metal controls the alloy to provide a required polymorph in a preparation process, thus achieving the goal of anti-oxidation. The inert alloy anode having Fe and Cu as the main constituents has a low over-voltage, high electric conductivity, and reduced costs, and is applicable in the aluminum electrolysis industry



Abstract

1
2 An inert alloy anode used for aluminum electrolysis. The anode has Fe and Cu as the main
3 constituents and comprises Sn. The addition of the Sn metal is conducive to the formation of a
4 layer of oxidized film having a great antioxidant activity and structural stability on the surface of
5 the inert alloy anode, and is conducive to an increase in the corrosion resistance of the anode.
6 On this basis, the constituents of the inert alloy anode also comprise Ni, Al, and Y. The addition
7 of the Al metal prevents the main metal constituents from being oxidized, the addition of the Y
8 metal controls the alloy to provide a required polymorph in a preparation process, thus
9 achieving the goal of anti-oxidation. The inert alloy anode having Fe and Cu as the main
10 constituents has a low over-voltage, high electric conductivity, and reduced costs, and is
11 applicable in the aluminum electrolysis industry.

INERT ALLOY ANODE FOR ALUMINUM ELECTROLYSIS AND PREPARING METHOD THEREOF

Field of the Invention

The present invention relates to an inert alloy anode for aluminum electrolysis and a preparing method thereof, belonging to the field of aluminum electrolysis industry.

Background of the Invention

Aluminum electrolysis refers to acquisition of aluminum by alumina electrolysis. In the prior art, a traditional Hall-Heroult molten salt aluminum electrolysis process is typically adopted for aluminum electrolysis, this process is featured by use of a cryolite-alumina molten salt electrolysis method in which cryolite Na_3AlF_6 fluoride salt melt is taken as flux, Al_2O_3 is dissolved in the fluoride salt, a carbon body is taken as an anode, aluminum liquid is taken as a cathode, and electrolytic aluminum is obtained by performing electrochemical reaction at the anode and cathode of the electrolytic cell at a high temperature ranging from 940°C to 960°C after a strong direct current is introduced. In the traditional aluminum electrolysis process, a carbon anode is ceaselessly consumed in the electrolysis process, thus constant replacement for the carbon anode is required; moreover, carbon dioxide, carbon monoxide, toxic fluorine hydride and other waste gases are continuously generated at the anode during alumina electrolysis, emission of these gases into environment will be harmful to environment and health of human and livestock, so that the waste gases generated by aluminum electrolysis need to be purified before emission, which accordingly increases the investment cost of the alumina electrolysis production process.

Consumption of the anode material in the process of aluminum electrolysis is mainly caused by oxidization reaction, in the electrolysis process, of the carbon anode material used in the traditional Hall-Heroult process. Therefore, many domestic and foreign researchers have commenced the study on anode material in order to reduce consumption of the anode material in the process of aluminum electrolysis and simultaneously lessen waste gas emission. For example, disclosed in Chinese patent document CN102230189A is a metal ceramic inert anode material for aluminum electrolysis, which is obtained by the steps of preparing an $\text{NiO-NiFe}_2\text{O}_4$ metal ceramic matrix from raw materials including Ni_2O_3 and Fe_2O_3 and then adding metal copper powder and nano NiO , and which has an electric conductivity as high as $102\Omega^{-1}\cdot\text{cm}^{-1}$. In the above art, the anode material with metal ceramic as the matrix, though hardly reacting with electrolyte, is large in resistance and high in overvoltage, which results in large power

1 consumption of the process and high cost in the process of aluminum electrolysis; furthermore,
2 the anode material with metal ceramic as the matrix has poor thermal shock resistance and
3 consequently is liable to brittlement during use; and in addition, the processability in use of the
4 anode made from the above materials is poor just because the anode material having the metal
5 ceramic matrix is liable to brittlement, as a result, the anode in any shape cannot be obtained.

6 To solve the problem that the anode material having the metal ceramic matrix is low in electric
7 conductivity and brittle in structure, some researchers have brought forward use of alloy metals
8 as the anode material, in order to improve the electric conductivity of the anode material and
9 simultaneously improve the processability of the anode material. Disclosed in Chinese patent
10 document CN1443877A is an inert anode material applied to aluminum, magnesium, rare earth
11 and other electrolysis industries, this material is formed by binary or multi-element alloy
12 composed of chromium, nickel, ferrum, cobalt, titanium, copper, aluminum, magnesium and
13 other metals, and the preparation method thereof is a method of smelting or powder metallurgy.
14 The prepared anode material is good in electric and thermal conductivity and generates oxygen
15 in the electrolysis process, wherein in Example 1, an anode is made of the alloy material
16 composed of 37wt% of cobalt, 18wt% of copper, 19wt% of nickel, 23wt% of ferrum and 3wt% of
17 silver and is used for aluminum electrolysis, the anode has a current density of $1.0\text{A}/\text{cm}^2$ in the
18 electrolysis process at 850°C and the cell voltage is steadily maintained within a range from
19 4.1V to 4.5V in the electrolysis process, the prepared aluminum has a purity of 98.35%.

20 In the case that the alloy composed of a plurality of metals, including chromium, nickel, ferrum,
21 cobalt, titanium, copper, aluminum and magnesium, is used as the anode material for aluminum
22 electrolysis in the above art, this alloy anode material has higher electric conductivity than the
23 anode ceramic matrix anode material, can be processed in any shape by a smelting or powder
24 metallurgy method and is hardly consumed in the electrolysis process compared with the
25 carbon anode material. However, a large amount of expensive metal materials are used in
26 preparation of the alloy anode in the above art to result in high cost of the anode material, and
27 thus this alloy anode fails to meet the demand on industrial cost; moreover, the alloy anode
28 prepared from the above metal components is low in electric conductivity and high in
29 overvoltage, so that the power consumption of the process is increased, thus the alloy anode
30 cannot meet the needs of the aluminum electrolysis process.

31 In addition, an oxide film is generated on the surface of the prepared alloy anode in the prior art,
32 and if this oxide film is destroyed, the anode material exposed to the surface will be oxidized as

1 a new oxide film. The oxide film on the surface of the alloy anode in the above art has low
2 oxidization resistance and is further liable to oxidization reaction to generate products that are
3 likely to be corroded by electrolyte, and the oxide film with low stability is liable to fall off the
4 anode electrode in the electrolysis process; after the previous oxide film is corroded or falls off,
5 the material of the alloy anode exposed to the surface will create a new oxide film by reaction
6 with oxygen, such replacement between new and old oxide films results in continuous
7 consumption and poor corrosion resistance of the anode material as well as short service life of
8 electrodes; furthermore, the corroded or falling oxide film enters into liquid aluminum in the
9 electrolysis process of alumina to degrade the purity of the final product aluminum, as a result,
10 the manufactured aluminum product cannot meet the demand of national standards and
11 accordingly cannot be directly used as a finished product.

12 **Summary of the Invention**

13 The first technical problem to be solved by the present invention is that the alloy anode in the
14 prior art is expensive in metal materials used, high in process cost, low in electric conductivity
15 and high in overvoltage, as a result, power consumption of the process is increased; therefore,
16 provided is an inert alloy anode for aluminum electrolysis with low cost and overvoltage, and a
17 preparing method thereof.

18 Simultaneously, the second technical problem to be solved by the present invention is that, an
19 oxide film on the surface of the alloy anode in the prior art is low in oxidation resistance and
20 liable to fall off, which leads to continuous consumption of the alloy anode and poor corrosion
21 resistance, furthermore, the corroded or falling oxide film enters into liquid aluminum to degrade
22 the purity of the final product aluminum; therefore, provided is an inert alloy anode for aluminum
23 electrolysis, which is strong in oxidization resistance of the oxide film formed on the surface and
24 not liable to fall off so as to improve the corrosion resistance thereof and the purity of the
25 product aluminum, and a preparing method of the inert alloy anode.

26 To solve the aforementioned technical problems, the present invention provides an inert alloy
27 anode for aluminum electrolysis, which contains Fe and Cu as primary components, and further
28 contains Sn.

29 The mass ratio of Fe to Cu to Sn is (23-40): (36-60): (0.2-5) or (40.01-80): (0.01-35.9): (0.01-
30 0.19).

31 The inert alloy anode further contains Ni.
22653401.2

1 The mass ratio of Fe to Cu to Ni to Sn is (23-40): (36-60): (14-28): (0.2-5) or (40.01-80): (0.01-
2 35.9): (28.1-70): (0.01-0.19).

3 The inert alloy anode is composed of Fe, Cu, Ni and Sn, wherein the content of Fe is 23-40wt%,
4 the content of Cu is 36-60wt%, the content of Ni is 14-28wt% and the content of Sn is 0.2-5wt%,
5 or the content of Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is
6 28.1-59.97wt% and the content of Sn is 0.01-0.19wt%.

7 The inert alloy anode further contains Al.

8 The inert alloy anode is composed of Fe, Cu, Ni, Sn and Al, wherein the content of Fe is 23-
9 40wt%, the content of Cu is 36-60wt%, the content of Ni is 14-28wt%, the content of Al is more
10 than zero and less than or equal to 4wt% and the content of Sn is 0.2-5wt%, or the content of
11 Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt%,
12 the content of Al is more than zero and less than or equal to 4wt% and the content of Sn is 0.01-
13 0.19wt%.

14 The inert alloy anode further contains Y.

15 The inert alloy anode is composed of Fe, Cu, Ni, Sn, Al and Y, wherein the content of Fe is 23-
16 40wt%, the content of Cu is 36-60wt%, the content of Ni is 14-28wt%, the content of Al is more
17 than zero and less than or equal to 4wt%, the content of Y is more than zero and less than or
18 equal to 2wt% and the content of Sn is 0.2-5wt%, or the content of Fe is 40.01-71.88wt%, the
19 content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt%, the content of Al is more
20 than zero and less than or equal to 4wt%, the content of Y is more than zero and less than or
21 equal to 2wt% and the content of Sn is 0.01-0.19wt%.

22 A preparing method of the inert alloy anode comprises the following steps:

23 melting and uniformly mixing the metals Fe, Cu and Sn, and then rapidly casting and cooling the
24 mixture to obtain the inert alloy anode;

25 or, melting the metals Fe, Cu and Sn at first, then adding and melting the metal Al or Y, and
26 uniformly mixing, or adding and melting the metal Al at first, then adding and melting the metal
27 Y, uniformly mixing, and rapidly casting and cooling the mixture to obtain the inert alloy anode;

1 or, melting and mixing the metals Fe, Cu, Ni and Sn and then casting the mixture to obtain the
2 inert alloy anode;

3 or, melting the metals Fe, Cu, Ni and Sn at first, then adding and melting the metal Al or Y, and
4 uniformly mixing, or adding and melting the metal Al at first, then adding and melting the metal
5 Y, uniformly mixing, and casting the mixture to obtain the inert alloy anode.

6 Compared with the prior art, the inert alloy anode for aluminum electrolysis in the present
7 invention has the beneficial effects below:

8 (1) The inert alloy anode for aluminum electrolysis in the present invention contains Fe and Cu
9 as primary components, and further contains Sn. The inert alloy anode with the above
10 components is low in cost, low in overvoltage and small in power consumption of the aluminum
11 electrolysis process; the anode material is alloy composed of Fe, Cu and Sn, so an oxide film
12 formed on the surface of the inert alloy anode in the electrolysis process is high in oxidation
13 resistance and is hardly corroded by electrolyte, and the formed oxide film is stable and not
14 liable to fall off, therefore, the inert alloy anode is imparted with quite high oxidation resistance
15 and corrosion resistance. It is precisely because of high oxidation resistance and corrosion
16 resistance of the inert alloy anode, impurities entering into liquid aluminum, which are generated
17 by corrosion or falling off of the anode material, are avoided, so as to ensure the purity of
18 aluminum products, that is, the purity of the produced aluminum can reach 99.8%. The following
19 problems are avoided: the alloy anode in the prior art has high cost and overvoltage and large
20 power consumption of process, the oxide film on the alloy surface is low in oxidation resistance
21 and liable to fall off, which leads to continuous consumption of the alloy anode and poor
22 corrosion resistance, furthermore, the corroded or falling oxide film enters into liquid aluminum
23 to degrade the purity of the final product aluminum.

24 (2) The inert alloy anode for aluminum electrolysis in the present invention is composed of Fe,
25 Cu, Ni and Sn, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60wt%, the
26 content of Ni is 14-28wt% and the content of Sn is 0.2-5wt%, or the content of Fe is 40.01-
27 71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt% and the
28 content of Sn is 0.01-0.19wt%.

29 The alloy anode in the present invention contains Fe and Cu as primary components, their
30 content proportions are high, so the material cost of the inert alloy anode is reduced,
31 meanwhile, the inert alloy anode composed of the aforementioned metal components is high in

1 electric conductivity and has a cell voltage as low as 3.1V to 3.4V, power consumption for
2 aluminum electrolysis is small, the power consumption for per ton of aluminum is not more than
3 11000kw•h, so the production cost of electrolytic aluminum is low. The following problems are
4 avoided: a large quantity of expensive metal materials are used in the anode material in the
5 prior art, resulting in increase of the anode production cost; the prepared alloy anode is low in
6 electric conductivity, large in power consumption for aluminum electrolysis and increased in
7 cost, and cannot be applied to industrial production. The added metal Ni is capable of promoting
8 firmer combination among other types of metals, and the added metal Sn ensures that an oxide
9 film with high oxidization resistance, good corrosion resistance and high stability can be formed
10 on the surface of the inert alloy anode in the electrolysis process.

11 (3) The inert alloy anode for aluminum electrolysis in the present invention is composed of Fe,
12 Cu, Ni, Sn, Al and Y, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60wt%, the
13 content of Ni is 14-28wt%, the content of Al is more than zero and less than or equal to 4wt%,
14 the content of Y is more than zero and less than or equal to 2wt% and the content of Sn is 0.2-
15 5wt%, or the content of Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content
16 of Ni is 28.1-59.97wt%, the content of Al is more than zero and less than or equal to 4wt%, the
17 content of Y is more than zero and less than or equal to 2wt% and the content of Sn is 0.01-
18 0.19wt%. Similarly, the aforementioned inert alloy anode has the advantages of low material
19 cost and high electric conductivity, in addition, the metal Al contained in the aforementioned
20 inert alloy anode plays a role of oxidization resistance and can serve as a reducing agent for
21 metallothermic reduction reaction with a metal oxide in the inert anode alloy, thus ensure the
22 percentage of the primary components in the inert alloy anode, meanwhile, the added metal Y
23 can be used for controlling a crystal structure for anode material formation in the preparation
24 process of the inert anode, achieving the anti-oxidization purpose.

25 (4) The inert alloy anode for aluminum electrolysis in the present invention has a melting point of
26 1360-1386°C, a specific resistivity of 68-76.8 $\mu\Omega\cdot\text{cm}$ at 20°C and a density of 8.1-8.3g/cm³. The
27 prepared inert alloy anode has a quite high melting point and accordingly can meet the demand
28 of aluminum electrolysis on high temperature environment; furthermore, the aforementioned
29 inert alloy anode has a quite low overvoltage, so power consumption of the aluminum
30 electrolysis process can be reduced; the prepared inert alloy anode is even in texture and has a
31 density within a range from 8.1 g/cm³ to 8.3g/cm³, in this way, stable service property of the
32 inert alloy anode is guaranteed.

(5) The preparing method of the inert alloy anode comprises the following steps: melting and uniformly mixing the metals Fe, Cu and Sn, and then rapidly casting and cooling the mixture to obtain the inert alloy anode; or, melting the metals Fe, Cu and Sn at first, then adding and melting the metal Al or Y, and uniformly mixing, or adding and melting the metal Al at first, then adding and melting the metal Y, uniformly mixing, and rapidly casting and cooling the mixture to obtain the inert alloy anode; or, melting and mixing the metals Fe, Cu, Ni and Sn and then casting the mixture to obtain the inert alloy anode; or, melting the metals Fe, Cu, Ni and Sn at first, then adding and melting the metal Al or Y, and uniformly mixing, or adding and melting the metal Al at first, then adding and melting the metal Y, uniformly mixing, and casting the mixture to obtain the inert alloy anode. The aforementioned inert alloy anode is simple in preparation process and can be prepared in any shape according to the actual needs. During preparation of the alloy containing the metals Al and Y, Al is added at first to prevent other molten metal components from being oxidized, and then, Y is added and molten to finally obtain the alloy having a desired crystal form.

For more easily understanding the technical solution of the present invention, further description will be made below to the technical solution of the present invention in conjunction with the embodiments.

Detailed Description of the Embodiments

Embodiment 1

23 parts by weight of Fe metal blocks, 60 parts by weight of Cu metal blocks and 0.2 parts by weight of Sn metal blocks are molten and then uniformly mixed under high-speed electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-100°C/s to obtain an inert alloy anode 1 which is homogeneous in texture. The inert alloy anode has a density of 8.3g/cm³, a specific resistivity of 62μΩ•cm and a melting point of 1400°C.

Embodiment 2

40 parts by weight of Fe metal blocks, 36 parts by weight of Cu metal blocks and 5 parts by weight of Sn metal blocks are molten and then uniformly mixed under high-speed electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-100°C/s to obtain an inert alloy anode 2 which is homogeneous in texture. The inert alloy anode has a density of 7.8g/cm³, a specific resistivity of 82μΩ•cm and a melting point of 1369°C.

1 Embodiment 3

2 30 parts by weight of Fe metal blocks, 45 parts by weight of Cu metal blocks and 3 parts by
3 weight of Sn metal blocks are molten and then uniformly mixed under high-speed
4 electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-
5 100°C/s to obtain an inert alloy anode 3 which is homogeneous in texture. The inert alloy anode
6 has a density of 7.9g/cm³, a specific resistivity of 86μΩ•cm and a melting point of 1390°C.

7 Embodiment 4

8 30 parts by weight of Fe metal blocks, 50 parts by weight of Cu metal blocks, 20 parts by weight
9 of Mo and 5 parts by weight of Sn metal blocks are molten and then cast to obtain an inert alloy
10 anode 4. The inert alloy anode has a density of 8.2g/cm³, a specific resistivity of 78μΩ•cm and a
11 melting point of 1370°C.

12 Embodiment 5

13 23 parts by weight of Fe metal blocks, 60 parts by weight of Cu metal blocks, 14 parts by weight
14 of Ni and 3 parts by weight of Sn metal blocks are molten and then cast to obtain an inert alloy
15 anode 5. The inert alloy anode has a density of 8.3g/cm³, a specific resistivity of 68μΩ•cm and a
16 melting point of 1360°C.

17 Embodiment 6

18 40 parts by weight of Fe metal blocks, 36 parts by weight of Cu metal blocks, 19 parts by weight
19 of Ni and 5 parts by weight of Sn metal blocks are molten and then cast to obtain an inert alloy
20 anode 6. The inert alloy anode has a density of 8.1g/cm³, a specific resistivity of 76.8μΩ•cm and
21 a melting point of 1386°C.

22 Embodiment 7

23 25 parts by weight of Fe metal blocks, 46.8 parts by weight of Cu metal blocks, 28 parts by
24 weight of Ni and 0.2 parts by weight of Sn metal blocks are molten and then cast to obtain an
25 inert alloy anode 7. The inert alloy anode has a density of 8.2g/cm³, a specific resistivity of
26 72μΩ•cm and a melting point of 1350°C.

27 Embodiment 8

28 23 parts by weight of Fe metal blocks, 60 parts by weight of Cu metal blocks, 14 parts by weight
29 of Ni and 3 parts by weight of Sn metal blocks are molten and then cast to obtain an inert alloy
30 anode 8. The inert alloy anode has a density of 8.1g/cm³, a specific resistivity of 70μΩ•cm and a
31 melting point of 1330°C.

1 Embodiment 9

2 40 parts by weight of Fe metal blocks, 36 parts by weight of Cu metal blocks, 19 parts by weight
3 of Ni and 5 parts by weight of Sn metal blocks are molten and then cast to obtain an inert alloy
4 anode 9. The inert alloy anode has a density of 8.2g/cm^3 , a specific resistivity of $73\mu\Omega\cdot\text{cm}$ and a
5 melting point of 1340°C .

6 Embodiment 10

7 24 parts by weight of Fe metal blocks, 47.8 parts by weight of Cu metal blocks, 28 parts by
8 weight of Ni and 0.2 parts by weight of Sn metal blocks are molten and then cast to obtain an
9 inert alloy anode 10. The inert alloy anode has a density of 8.0g/cm^3 , a specific resistivity of
10 $74\mu\Omega\cdot\text{cm}$ and a melting point of 1350°C .

11 Embodiment 11

12 30 parts by weight of Fe metal blocks, 41 parts by weight of Cu metal blocks and 5 parts by
13 weight of Sn metal blocks are molten at first, then 3 parts by weight of Al metal blocks are
14 added and sequentially molten, uniform mixing is performed under high-speed electromagnet
15 stirring, and the mixture is rapidly cast and then rapidly cooled to obtain an inert alloy anode 11.
16 The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of $68\mu\Omega\cdot\text{cm}$ and a melting
17 point of 1370°C .

18 Embodiment 12

19 23 parts by weight of Fe metal blocks, 60 parts by weight of Cu metal blocks, 14 parts by weight
20 of Ni and 0.2 parts by weight of Sn metal blocks are molten at first, then 2.8 parts by weight of
21 Al metal blocks are added and sequentially molten, and an inert alloy anode 12 is obtained by
22 casting. The inert alloy anode has a density of 8.4g/cm^3 , a specific resistivity of $69\mu\Omega\cdot\text{cm}$ and a
23 melting point of 1340°C .

24 Embodiment 13

25 40 parts by weight of Fe metal blocks, 36 parts by weight of Cu metal blocks, 15 parts by weight
26 of Ni and 5 parts by weight of Sn metal blocks are molten at first, then 4 parts by weight of Al
27 metal blocks are added and sequentially molten, and an inert alloy anode 13 is obtained by
28 casting. The inert alloy anode has a density of 8.15g/cm^3 , a specific resistivity of $69\mu\Omega\cdot\text{cm}$ and a
29 melting point of 1369°C .

1 Embodiment 14

2 36 parts by weight of Fe metal blocks, 47 parts by weight of Cu metal blocks, 14 parts by weight
3 of Ni and 2.9 parts by weight of Sn metal blocks are molten at first, then 0.1 parts by weight of
4 Al metal blocks are added and sequentially molten, and an inert alloy anode 14 is obtained by
5 casting. The inert alloy anode has a density of 8.0g/cm^3 , a specific resistivity of $67.6\mu\Omega\cdot\text{cm}$ and
6 a melting point of 1379°C .

7 Embodiment 15

8 27 parts by weight of Fe metal blocks, 50 parts by weight of Cu metal blocks and 4 parts by
9 weight of Sn metal blocks are molten at first, then 1 part by weight of Y metal blocks are added
10 and sequentially molten, uniform mixing is performed under high-speed electromagnet stirring,
11 and the mixture is rapidly cast and then rapidly cooled to obtain an inert alloy anode 15. The
12 inert alloy anode has a density of 8.4g/cm^3 , a specific resistivity of $67\mu\Omega\cdot\text{cm}$ and a melting point
13 of 1358°C .

14 Embodiment 16

15 35 parts by weight of Fe metal blocks, 45 parts by weight of Cu metal blocks, 24 parts by weight
16 of Ni and 4 parts by weight of Sn metal blocks are molten at first, then 2 parts by weight of Y
17 metal blocks are added and sequentially molten, and an inert alloy anode 16 is obtained by
18 casting. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of $70.9\mu\Omega\cdot\text{cm}$ and
19 a melting point of 1375°C .

20 Embodiment 17

21 25 parts by weight of Fe metal blocks, 50 parts by weight of Cu metal blocks and 4 parts by
22 weight of Sn metal blocks are molten at first, then 3 parts by weight of Al metal blocks are
23 added and sequentially molten, finally, 1 part by weight of Y metal blocks are added and molten,
24 uniform mixing is performed under high-speed electromagnet stirring, and the mixture is rapidly
25 cast and then rapidly cooled to obtain an inert alloy anode 17. The inert alloy anode has a
26 density of 8.3g/cm^3 , a specific resistivity of $68.9\mu\Omega\cdot\text{cm}$ and a melting point of 1381°C .

27 Embodiment 18

28 23 parts by weight of Fe metal blocks, 60 parts by weight of Cu metal blocks, 14 parts by weight
29 of Ni and 0.9 parts by weight of Sn metal blocks are molten at first, then 0.1 parts by weight of
30 Al metal blocks are added and sequentially molten, finally, 2 parts by weight of Y metal blocks
31 are added and molten, mixing is performed, and the mixture is cast to obtain an inert alloy

1 anode 18. The inert alloy anode has a density of 8.3g/cm^3 , a specific resistivity of $68\mu\Omega\cdot\text{cm}$ and
2 a melting point of 1360°C .

3 Embodiment 19

4 40 parts by weight of Fe metal blocks, 36 parts by weight of Cu metal blocks, 14.9 parts by
5 weight of Ni and 5 parts by weight of Sn metal blocks are molten at first, then 4 parts by weight
6 of Al metal blocks are added and sequentially molten, finally, 0.1 parts by weight of Y metal
7 blocks are added and molten, mixing is performed, and the mixture is cast to obtain an inert
8 alloy anode 19. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
9 $76.8\mu\Omega\cdot\text{cm}$ and a melting point of 1386°C .

10 Embodiment 20

11 29 parts by weight of Fe metal blocks, 38.3 parts by weight of Cu metal blocks, 28 parts by
12 weight of Ni and 0.2 parts by weight of Sn metal blocks are molten at first, then 3.5 parts by
13 weight of Al metal blocks are added and sequentially molten, finally, 1 part by weight of Y metal
14 blocks are added and molten, mixing is performed, and the mixture is cast to obtain an inert
15 alloy anode 20. The inert alloy anode has a density of 8.2g/cm^3 , a specific resistivity of $70\mu\Omega\cdot\text{cm}$
16 and a melting point of 1365°C .

17 Embodiment 21

18 40 parts by weight of Fe metal blocks, 36.5 parts by weight of Cu metal blocks, 18 parts by
19 weight of Ni and 3 parts by weight of Sn metal blocks are molten at first, then 1.5 parts by
20 weight of Al metal blocks are added and sequentially molten, finally, 1 part by weight of Y metal
21 blocks are added and molten, mixing is performed, and the mixture is cast to obtain an inert
22 alloy anode 21. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
23 $76.8\mu\Omega\cdot\text{cm}$ and a melting point of 1386°C .

24 Embodiment 22

25 24.3 parts by weight of Fe metal blocks, 59 parts by weight of Cu metal blocks, 14 parts by
26 weight of Ni and 0.2 parts by weight of Sn metal blocks are molten at first, then 2 parts by
27 weight of Al metal blocks are added and sequentially molten, finally, 0.5 parts by weight of Y
28 metal blocks are added and molten, mixing is performed, and the mixture is cast to obtain an
29 inert alloy anode 22. The inert alloy anode has a density of 8.22g/cm^3 , a specific resistivity of
30 $68.2\mu\Omega\cdot\text{cm}$ and a melting point of 1360°C .

1 In the aforementioned embodiment, 1 part by weight is 10g, and the inert anode alloy resulted
2 from casting can be in any shape as required.

3 Embodiment 23

4 40.01 parts by weight of Fe metal blocks, 35.9 parts by weight of Cu metal blocks and 0.19
5 parts by weight of Sn metal blocks are molten and then uniformly mixed under high-speed
6 electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-
7 100°C/s to obtain an inert alloy anode 23 which is homogeneous in texture. The inert alloy
8 anode has a density of 8.2g/cm³, a specific resistivity of 61μΩ•cm and a melting point of
9 1400°C.

10 Embodiment 24

11 80 parts by weight of Fe metal blocks, 0.01 parts by weight of Cu metal blocks and 0.01 parts by
12 weight of Sn metal blocks are molten and then uniformly mixed under high-speed
13 electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-
14 100°C/s to obtain an inert alloy anode 24 which is homogeneous in texture. The inert alloy
15 anode has a density of 7.5g/cm³, a specific resistivity of 82μΩ•cm and a melting point of
16 1369°C.

17 Embodiment 25

18 60 parts by weight of Fe metal blocks, 25 parts by weight of Cu metal blocks and 0.1 part by
19 weight of Sn metal blocks are molten and then uniformly mixed under high-speed
20 electromagnetic stirring, the mixture is rapidly cast and then rapidly cooled at a speed of 20-
21 100°C/s to obtain an inert alloy anode 25 which is homogeneous in texture. The inert alloy
22 anode has a density of 7.9g/cm³, a specific resistivity of 84μΩ•cm and a melting point of
23 1390°C.

24 Embodiment 26

25 50 parts by weight of Fe metal blocks, 30 parts by weight of Cu metal blocks, 20 parts by weight
26 of Mo and 0.05 parts by weight of Sn metal blocks are molten and then cast to obtain an inert
27 alloy anode 26. The inert alloy anode has a density of 8.4g/cm³, a specific resistivity of 78μΩ•cm
28 and a melting point of 1370°C.

29 Embodiment 27

30 40.01 parts by weight of Fe metal blocks, 35.9 parts by weight of Cu metal blocks, 70 parts by
31 weight of Ni and 0.01 parts by weight of Sn metal blocks are molten and then cast to obtain an
22653401.2

1 inert alloy anode 27. The inert alloy anode has a density of 8.5g/cm^3 , a specific resistivity of
2 $68\mu\Omega\cdot\text{cm}$ and a melting point of 1360°C .

3 Embodiment 28

4 80 parts by weight of Fe metal blocks, 0.01 parts by weight of Cu metal blocks, 28.1 parts by
5 weight of Ni and 0.19 parts by weight of Sn metal blocks are molten and then cast to obtain an
6 inert alloy anode 28. The inert alloy anode has a density of 7.7g/cm^3 , a specific resistivity of
7 $76.8\mu\Omega\cdot\text{cm}$ and a melting point of 1386°C .

8 Embodiment 29

9 71.88 parts by weight of Fe metal blocks, 0.01 parts by weight of Cu metal blocks, 28.1 parts by
10 weight of Ni and 0.01 parts by weight of Sn metal blocks are molten and then cast to obtain an
11 inert alloy anode 29. The inert alloy anode has a density of 8.2g/cm^3 , a specific resistivity of
12 $72\mu\Omega\cdot\text{cm}$ and a melting point of 1350°C .

13 Embodiment 30

14 40.01 parts by weight of Fe metal blocks, 31.88 parts by weight of Cu metal blocks, 28.1 parts
15 by weight of Ni and 0.01 parts by weight of Sn metal blocks are molten and then cast to obtain
16 an inert alloy anode 30. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
17 $70\mu\Omega\cdot\text{cm}$ and a melting point of 1330°C .

18 Embodiment 31

19 40 parts by weight of Fe metal blocks, 0.02 parts by weight of Cu metal blocks, 59.97 parts by
20 weight of Ni and 0.01 parts by weight of Sn metal blocks are molten and then cast to obtain an
21 inert alloy anode 31. The inert alloy anode has a density of 8.2g/cm^3 , a specific resistivity of
22 $73\mu\Omega\cdot\text{cm}$ and a melting point of 1340°C .

23 Embodiment 32

24 45 parts by weight of Fe metal blocks, 4.81 parts by weight of Cu metal blocks, 50 parts by
25 weight of Ni and 0.19 parts by weight of Sn metal blocks are molten and then cast to obtain an
26 inert alloy anode 32. The inert alloy anode has a density of 8.0g/cm^3 , a specific resistivity of
27 $74\mu\Omega\cdot\text{cm}$ and a melting point of 1350°C .

28 Embodiment 33

29 60 parts by weight of Fe metal blocks, 35.9 parts by weight of Cu metal blocks and 0.1 parts by
30 weight of Sn metal blocks are molten at first, then 4 parts by weight of Al metal blocks are

1 added and sequentially molten, uniformly mixing is performed under high-speed
2 electromagnetic stirring, and the mixture is rapidly cast and then rapidly cooled to obtain an inert
3 alloy anode 33. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of $68\mu\Omega\cdot\text{cm}$
4 and a melting point of 1370°C .

5 Embodiment 34

6 40.01 parts by weight of Fe metal blocks, 27.7 parts by weight of Cu metal blocks, 28.1 parts by
7 weight of Ni and 0.19 parts by weight of Sn metal blocks are molten at first, then 4 parts by
8 weight of Al metal blocks are added and sequentially molten, and an inert alloy anode 34 is
9 obtained by casting. The inert alloy anode has a density of 8.4g/cm^3 , a specific resistivity of
10 $69\mu\Omega\cdot\text{cm}$ and a melting point of 1340°C .

11 Embodiment 35

12 71.88 parts by weight of Fe metal blocks, 0.005 parts by weight of Cu metal blocks, 28.1 parts
13 by weight of Ni and 0.01 parts by weight of Sn metal blocks are molten at first, then 0.005 parts
14 by weight of Al metal blocks are added and sequentially molten, and an inert alloy anode 35 is
15 obtained by casting. The inert alloy anode has a density of 8.15g/cm^3 , a specific resistivity of
16 $69\mu\Omega\cdot\text{cm}$ and a melting point of 1369°C .

17 Embodiment 36

18 40.01 parts by weight of Fe metal blocks, 31.88 parts by weight of Cu metal blocks, 25.01 parts
19 by weight of Ni and 0.1 parts by weight of Sn metal blocks are molten at first, then 3 parts by
20 weight of Al metal blocks are added and sequentially molten, and an inert alloy anode 36 is
21 obtained by casting. The inert alloy anode has a density of 8.0g/cm^3 , a specific resistivity of
22 $67.6\mu\Omega\cdot\text{cm}$ and a melting point of 1379°C .

23 Embodiment 37

24 66 parts by weight of Fe metal blocks, 31.88 parts by weight of Cu metal blocks and 0.01 parts
25 by weight of Sn metal blocks are molten at first, then 2 parts by weight of Y metal blocks are
26 added and sequentially molten, uniformly mixing is performed under high-speed
27 electromagnetic stirring, and the mixture is rapidly cast and then rapidly cooled to obtain an inert
28 alloy anode 37. The inert alloy anode has a density of 8.4g/cm^3 , a specific resistivity of $67\mu\Omega\cdot\text{cm}$
29 and a melting point of 1358°C .

1 Embodiment 38

2 40 parts by weight of Fe metal blocks, 0.01 parts by weight of Cu metal blocks, 59.97 parts by
3 weight of Ni and 0.01 parts by weight of Sn metal blocks are molten at first, then 0.01 parts by
4 weight of Y metal blocks are added and sequentially molten, and an inert alloy anode 38 is
5 obtained by casting. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
6 $70.9\mu\Omega\cdot\text{cm}$ and a melting point of 1375°C .

7 Embodiment 39

8 62 parts by weight of Fe metal blocks, 31.88 parts by weight of Cu metal blocks and 0.19 parts
9 by weight of Sn metal blocks are molten at first, then, 4 parts by weight of Al metal blocks are
10 added and sequentially molten, finally, 2 parts by weight of Y metal blocks are added and
11 molten, uniform mixing is performed under high-speed electromagnet stirring, and the mixture is
12 rapidly cast and then rapidly cooled to obtain an inert alloy anode 39. The inert alloy anode has
13 a density of 8.3g/cm^3 , a specific resistivity of $68.9\mu\Omega\cdot\text{cm}$ and a melting point of 1381°C .

14 Embodiment 40

15 40 parts by weight of Fe metal blocks, 25.7 parts by weight of Cu metal blocks, 28.1 parts by
16 weight of Ni and 0.19 parts by weight of Sn metal blocks are molten at first, then 4 parts by
17 weight of Al metal blocks are added and sequentially molten, finally, 2 parts by weight of Y
18 metal blocks are added and molten, mixing is performed, and the mixture is cast to obtain an
19 inert alloy anode 40. The inert alloy anode has a density of 8.3g/cm^3 , a specific resistivity of
20 $68\mu\Omega\cdot\text{cm}$ and a melting point of 1360°C .

21 Embodiment 41

22 71.88 parts by weight of Fe metal blocks, 0.005 parts by weight of Cu metal blocks, 28.1 parts
23 by weight of Ni and 0.01 parts by weight of Sn metal blocks are molten at first, then, 0.002 parts
24 by weight of Al metal blocks are added and sequentially molten, finally, 0.003 parts by weight of
25 Y metal blocks are added and molten, mixing is performed, and the mixture is cast to obtain an
26 inert alloy anode 41. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
27 $76.8\mu\Omega\cdot\text{cm}$ and a melting point of 1386°C .

28 Embodiment 42

29 36.92 parts by weight of Fe metal blocks, 31.88 parts by weight of Cu metal blocks, 28.1 parts
30 by weight of Ni and 0.1 parts by weight of Sn metal blocks are molten at first, then 1 part by
31 weight of Al metal blocks are added and sequentially molten, finally, 2 parts by weight of Y

1 metal blocks are added and molten, mixing is performed, and the mixture is cast to obtain an
2 inert alloy anode 42. The inert alloy anode has a density of 8.2g/cm^3 , a specific resistivity of
3 $70\mu\Omega\cdot\text{cm}$ and a melting point of 1365°C .

4 Embodiment 43

5 39.81 parts by weight of Fe metal blocks, 0.01 parts by weight of Cu metal blocks, 59.97 parts
6 by weight of Ni and 0.01 parts by weight of Sn metal blocks are molten at first, then 0.1 parts by
7 weight of Al metal blocks are added and sequentially molten, finally, 0.1 parts by weight of Y
8 metal blocks are added and molten, mixing is performed, and the mixture is cast to obtain an
9 inert alloy anode 43. The inert alloy anode has a density of 8.1g/cm^3 , a specific resistivity of
10 $76.8\mu\Omega\cdot\text{cm}$ and a melting point of 1386°C .

11 Embodiment 44

12 45 parts by weight of Fe metal blocks, 24.4 parts by weight of Cu metal blocks, 29 parts by
13 weight of Ni and 0.1 parts by weight of Sn metal blocks are molten at first, then 1 part by weight
14 of Al metal blocks are added and sequentially molten, finally, 0.5 parts by weight of Y metal
15 blocks are added and molten, mixing is performed, and the mixture is cast to obtain an inert
16 alloy anode 44. The inert alloy anode has a density of 8.22g/cm^3 , a specific resistivity of
17 $68.2\mu\Omega\cdot\text{cm}$ and a melting point of 1360°C .

18 In the aforementioned embodiments 23-44, 1 part by weight is 100g, and the inert anode alloy
19 resulted from casting can be in any shape as required.

20 **Comparative Example**

21 The alloy powders containing 37wt% of Co, 18wt% of Cu, 19wt% of Ni, 23wt% of Fe and 3wt%
22 of Ag are subjected to powder metallurgic process to obtain an anode, and before use, an oxide
23 film is formed on the surface of the metal anode by pre-oxidization at 1000°C to obtain an inert
24 alloy anode A.

25 **Test Example**

26 The inert alloy anodes 1-44 and A are each taken as an anode, graphite is taken as a cathode,
27 the anode and the cathode are vertically inserted into an electrolytic cell provided with a
28 corundum liner, and the distance between the anode and the cathode is 3cm. The anode has a
29 current density of 1.0A/cm^2 at 760°C , and is electrolyzed for up to 40 hours in an electrolyte
30 having the components including 32wt% of sodium fluoride, 57wt% of aluminum fluoride, 3wt%

- 1 of lithium fluoride, 4wt% of potassium fluoride and 4wt% of alumina, and the test results are
2 shown in the Table below:

Inert Alloy Anode	Cell Voltage (V)	Direct Current Consumption for Per Ton of Aluminum (kw•h)	Purity of Product Aluminum (%)
1	3.10	10040	99.80
2	3.14	10170	99.81
3	3.22	10429	99.85
4	3.16	10235	99.80
5	3.10	10040	99.85
6	3.39	10979	99.82
7	3.15	10202	99.85
8	3.27	10591	99.85
9	3.18	10299	99.83
10	3.36	10882	99.81
11	3.28	10623	99.80
12	3.40	11000	99.82
13	3.32	10753	99.84
14	3.25	10526	99.82
15	3.12	10105	99.80
16	3.27	10591	99.81
17	3.35	10850	99.83
18	3.38	10947	99.80
19	3.16	10234	99.82
20	3.32	10753	99.83
21	3.10	10040	99.81
22	3.12	10105	99.82
23	3.11	10040	99.80
24	3.13	10159	99.81
25	3.21	10429	99.85

26	3.15	10236	99.80
27	3.11	10041	99.90
28	3.38	10979	99.82
29	3.14	10202	99.85
30	3.26	10591	99.91
31	3.17	10299	99.83
32	3.35	10879	99.81
33	3.27	10623	99.80
34	3.39	11000	99.82
35	3.33	10753	99.84
36	3.25	10526	99.82
37	3.12	10105	99.80
38	3.27	10591	99.81
39	3.35	10850	99.83
40	3.38	10945	99.80
41	3.16	10234	99.82
42	3.32	10753	99.83
43	3.10	10040	99.81
44	3.12	10110	99.82
A	4.48	14510	98.35

1

2 It can be seen from the test results of the aforementioned embodiments and the comparative
3 example that in the process of aluminum electrolysis, the inert alloy anode in the present
4 invention has a cell voltage much lower than that of the alloy anode in the comparative example,
5 consequently, using the inert alloy anode in the present invention can reduce the power
6 consumption in an aluminum electrolysis process remarkably, which further reduces energy
7 waste and lower cost. Meanwhile, the inert alloy anode in the present invention can be used for
8 producing aluminum products which meet the high-purity standard, i.e. the purity of these
9 aluminum products can be over 99.8, which meets the national primary aluminum standard.

10 Detailed description has been made to the specific contents of the present invention in the
11 aforementioned embodiments, and it should be understood by those skilled in this art that

- 1 modifications and detail variations in any form based upon the present invention pertain to the
- 2 scope that the present invention seeks to protect.

Claims

1. An inert alloy anode for aluminum electrolysis,
being composed of Fe, Cu, Ni and Sn, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60wt%, the content of Ni is 14-28wt% and the content of Sn is 0.2-5wt%, or the content of Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt% and the content of Sn is 0.01-0.19wt%.
2. The inert alloy anode according to claim 1,
being composed of Fe, Cu, Ni, Sn and Al, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60wt%, the content of Ni is 14-28wt%, the content of Al is more than zero and less than or equal to 4wt% and the content of Sn is 0.2-5wt%, or the content of Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt%, the content of Al is more than zero and less than or equal to 4wt% and the content of Sn is 0.01-0.19wt%.
3. The inert alloy anode according to claim 2,
being composed of Fe, Cu, Ni, Sn, Al and Y, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60wt%, the content of Ni is 14-28wt%, the content of Al is more than zero and less than or equal to 4wt%, the content of Y is more than zero and less than or equal to 2wt% and the content of Sn is 0.2-5wt%, or the content of Fe is 40.01-71.88wt%, the content of Cu is 0.01-31.88wt%, the content of Ni is 28.1-59.97wt%, the content of Al is more than zero and less than or equal to 4wt%, the content of Y is more than zero and less than or equal to 2wt% and the content of Sn is 0.01-0.19wt%.
4. A preparing method of the inert alloy anode according to claim 1, comprising the following steps:
melting and mixing the metals Fe, Cu, Ni and Sn and then casting the mixture to obtain the inert alloy anode.
5. A preparing method of the inert alloy anode according to claim 2 or 3, comprising the following steps:
melting the metals Fe, Cu, Ni and Sn at a ratio according to claim 2 or 3 at first, then

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adding and melting the metal Al or Y at a ratio according to claim 2 or 3, and uniformly mixing,

or adding and melting the metal Al at a ratio according to claim 3 at first, then adding and melting the metal Y at a ratio according to claim 3, uniformly mixing, and casting the mixture to obtain the inert alloy anode.