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**(54) ELECTROLYTIC CELL FOR ALUMINIUM ELECTROLYSIS AND ELECTROLYSIS PROCESS  
USING THE ELECTROLYTIC CELL**

ELEKTROLYSEZELLE ZUR ELEKTROLYSE VON ALUMINIUM UND ELEKTROLYSEVERFAHREN  
MIT DIESER ELEKTROLYSEZELLE

CELLULE ÉLECTROLYTIQUE POUR L'ÉLECTROLYSE D'ALUMINIUM ET PROCÉDÉ UTILISANT  
LA CELLULE ÉLECTROLYTIQUE

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## Description

### Field of the Invention

**[0001]** The present invention relates to an electrolytic cell for aluminum electrolysis and an electrolysis process using the electrolytic cell, belonging to non-ferrous metal smelting industry.

### Background of the Invention

**[0002]** In aluminum electrolysis industry, a traditional Hall-Heroult molten salt aluminum electrolysis process is typically adopted to perform electrolysis on the molten salts of cryolite-alumina in a prebaked carbon anode electrolytic cell typically by adopting, that is, cryolite  $\text{Na}_3\text{AlF}_6$  fluoride salt melt is taken as flux,  $\text{Al}_2\text{O}_3$  is dissolved in the fluoride salt, a carbon body is taken as an anode and vertically inserted into the electrolytic cell, a carbon body with aluminum liquid covering the bottom of the electrolytic cell is taken as a cathode, electrochemical reaction is carried out on the anode and cathode of the electrolytic cell at a high temperature ranging from 940 to 960°C after a strong direct current is introduced, and the resultant aluminum liquid product covers the cathode at the bottom of the electrolytic cell. Due to high electrolysis temperature, the traditional aluminum electrolysis process has such characteristics as large volatilization amount of electrolyte, large oxidization loss of a carbon anode, large energy consumption and poor working environment.

**[0003]** In the prior art, in order to lower electrolysis temperature, a low temperature molten salt system for aluminum electrolysis is disclosed in Chinese patent document CN101671835A, the molten salt composition of the system includes  $\text{AlF}_3$ ,  $\text{Al}_2\text{O}_3$  and one or more salts selected from the group consisting of  $\text{KF}$ ,  $\text{NaF}$ ,  $\text{MgF}_2$ ,  $\text{CaF}_2$ ,  $\text{NaCl}$ ,  $\text{LiF}$ , and  $\text{BaF}_2$ , and the electrolysis temperature of the electrolyte can be lowered to be within a wide area from 680 to 900°C for the purpose of operations.

**[0004]** Addition of  $\text{NaCl}$  to the aforementioned electrolyte aims at lowering the liquidus temperature of the electrolyte, however,  $\text{NaCl}$  will lead to corrosion to metal parts like electrolytic cell accessories at the aforementioned electrolysis temperature, furthermore,  $\text{NaCl}$  is extremely liable to volatilization in the electrolysis process so as to form  $\text{HCl}$  toxic gas, so its application is difficult; in addition to addition of  $\text{NaCl}$ , decrease of the molar ratio of  $\text{NaF}$  to  $\text{AlF}_3$  can also lower the liquidus temperature of the electrolyte in light of common knowledge in this art, but in the existing industry, the molar ratio of  $\text{NaF}$  to  $\text{AlF}_3$  is generally larger than 2.2, this is because, if the molar ratio of  $\text{NaF}$  to  $\text{AlF}_3$  further decreases,  $\text{NaF}$  and  $\text{AlF}_3$  will lead to a 'crusting' phenomenon of the cathode in the process of low-temperature electrolysis while the liquidus temperature of the electrolyte is lowered, the reason for this 'crusting' phenomenon is that sodium ions and aluminum ions in the electrolyte will gather at the cathode

in the electrolysis process to generate sodium cryolite, which is seldom molten at a low temperature due to its high melting point, as a result, the surface of the cathode is covered by a layer of refractory cryolite crust to affect normal electrolysis in the electrolysis process tremendously. Due to the above problems in the prior art, industrial application of the electrolyte is significantly limited, and it is an unsolved problem in the prior art to find a way of avoiding corrosion to electrolysis devices and damage to human body and ensuring proper electric conductivity and alumina solubility as well as no cathode 'crusting' phenomenon of the prepared electrolyte while the liquidus temperature of the electrolyte is further lowered.

**[0005]** In addition to the high electrolysis temperature problem that needs to be solved, the carbon anode in the traditional electrolytic cell for aluminum electrolysis is ceaselessly consumed by oxidization in the electrolysis process, thus constant replacement for the carbon anode is required; moreover, carbon dioxide, carbon monoxide and other waste gases are continuously generated at the anode during aluminum electrolysis. Hence, to lessen the consumption of an anode material in the aluminum electrolysis process and simultaneously reduce the emission of waste gases, disclosed in the prior art is plenty of documents for research on anode material, e.g. disclosed in Chinese patent document CN1443877A is an inert anode material applied to aluminum, magnesium and rare earth electrolysis industries, this material is formed by binary or multi-element alloy composed of chromium, nickel, ferrum, cobalt, titanium, copper, aluminum, magnesium and other metals, and the preparation method thereof is a smelting or powder metallurgy method. The prepared anode material is good in electric and thermal conductivity and generates oxygen in the electrolysis process, wherein in Example 1, an anode is made of the alloy material composed of 37wt% of cobalt, 18wt% of copper, 19wt% of nickel, 23wt% of ferrum and 3wt% of silver and is used for aluminum electrolysis, the anode has a current density of 1.0A/cm<sup>2</sup> in the electrolysis process at 850°C and the cell voltage is maintained within a range from 4.1V to 4.5V in the electrolysis process, the prepared aluminum has a purity of 98.35%.

**[0006]** Compared with the carbon material, the alloy anode material in the technologies aforementioned has higher electric conductivity and lower corrosion amount in the electrolysis process and can be processed into random shapes, however, the alloy anode composed of the aforementioned components is still high in overvoltage, which results in large industrial power consumption and low product quality, besides, since a large quantity of expensive metal materials are used, the anode material is high in cost and cannot adapt to industrial needs.

**[0007]** In addition, a layer of oxide film is generated on the surface of the prepared alloy anode in the prior art, and if this oxide film is destroyed, the anode material exposed to the surface will be oxidized as a new oxide film. The oxide film on the surface of the alloy anode in the prior art has low oxidization resistance and is further

liable to oxidization reaction to generate products that are likely to be corroded by the electrolyte, and the oxide film with low stability is liable to fall off the anode electrode in the electrolysis process; after the previous oxide film is corroded or falls off, the material of the alloy anode exposed to the surface will create a new oxide film by reaction, such replacement between new and old oxide films results in continuous consumption and poor corrosion resistance of the anode material; furthermore, the corroded or falling oxide film enters into liquid aluminum in the electrolysis process of alumina to degrade the purity of the final product aluminum, as a result, the manufactured aluminum product cannot meet the demand of national standards and accordingly cannot be directly used as a finished product.

### Summary of the Invention

**[0008]** One technical problem to be solved by the process of the present invention is that, the prior art is incapable of avoiding corrosion to electrolysis devices and damage to human body and ensuring proper electric conductivity and alumina solubility as well as no 'crusting' phenomenon in the prepared electrolyte while the liquidus temperature of the electrolyte is further lowered. Thus the present invention provides a process using an electrolytic cell, containing an electrolyte for aluminum electrolysis which is low in liquidus temperature, free from metal corrosion, not liable to volatilization, proper in electric conductivity and alumina solubility and free from cathode 'crusting' phenomenon.

**[0009]** The technical problem to be solved by the present invention is that, an alloy anode composed of metal components in the prior art is high in overvoltage, power consumption in the aluminum electrolysis process is large and the metal components employed are high in price, resulting in cost increment of the alloy anode; in addition, an oxide film on the surface of the alloy anode in the prior art is low in oxidation resistance and liable to fall off, which leads to continuous consumption of the alloy anode and poor corrosion resistance, furthermore, the corroded or falling oxide film enters into liquid aluminum to degrade the purity of the final product aluminum; and therefore, provided is an electrolytic cell for aluminum electrolysis, which is low in overvoltage of the used inert anode material, low in price, strong in oxidation resistance and stability of the oxide film formed on the surface thereof and resistant to electrolyte corrosion.

**[0010]** To solve the latter technical problem, the present invention provides an electrolytic cell for aluminum electrolysis, comprising a cell body, wherein an anode and a cathode are arranged inside the cell body, the cell body is further filled with an electrolyte; the anode is arranged above the cell body, and at least a part of the anode is immersed in the electrolyte; the cathode is arranged at the bottom of the electrolytic cell and covered by a certain amount of aluminum liquid; the electrolyte is located between the anode and the cathode; the anode

contains the components including Fe, Cu, Ni and Sn, wherein Fe and Cu serve as primary components, as defined in claim 1; in use, the electrolyte is composed of 30-38wt% of NaF, 49-60wt% of  $\text{AlF}_3$ , 1-5wt% of LiF, 1-6wt% of KF and 3-6wt% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to  $\text{AlF}_3$  is 1.0-1.52.

**[0011]** The bottom surface of the anode is kept parallel to the cell body, and an insulating layer is arranged on the inner sidewall of the cell body and is used for isolating oxygen or the electrolyte from a carbon block.

**[0012]** A cell cover is arranged at the upper end of the cell body and is provided with a vent and a feeding hole; a cathode bar is arranged inside the cathode, one end of the anode penetrates through the cell cover and is connectedly provided with a binding post for connection with a power supply.

**[0013]** The mass ratio of Fe to Cu to Sn is (23-40): (36-60): (0.2-5).

**[0014]** The components of the anode further include Ni.

**[0015]** The anode is composed of Fe, Cu, Ni and Sn, wherein the content of Fe is 23-40wt%, the content of Cu is 36-60%, the content of Ni is 14-28wt% and the content of Sn is 0.2-5wt%.

**[0016]** The components of the anode further include Al and Y.

**[0017]** The anode is 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%.

**[0018]** The molar ratio of NaF to  $\text{AlF}_3$  is 1.12-1.52.

**[0019]** The liquidus temperature of the electrolyte is 620-670°C.

**[0020]** An electrolysis process using the electrolytic cell comprises the steps of:

- (1) adding specified amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  to a melting furnace for mixing and melting to form a melt; or adding specified amounts of NaF,  $\text{AlF}_3$ , LiF and KF to a melting furnace for mixing and melting, and then adding  $\text{Al}_2\text{O}_3$  to obtain a melt; and
- (2) raising the temperature of the melt prepared in step (1) to above 720-760°C, and then, pouring the melt into the electrolytic cell and carrying out electrolysis while the temperature is maintained at 720-760°C.

**[0021]** The electrolysis temperature is 730-750°C.

**[0022]**  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0023]** The electrolysis process using the electrolytic cell comprises the steps of:

- (1) adding specified amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  to a melting furnace for mixing and melting to form a melt; or adding specified amounts of NaF,  $\text{AlF}_3$ , LiF and KF to a melting furnace for mixing and

melting, and then adding  $\text{Al}_2\text{O}_3$  to obtain a melt; and (2) raising the temperature of the melt prepared in step (1) to above 720-760°C, and then, pouring the melt into the electrolytic cell and carrying out electrolysis while the temperature is maintained at 720-760°C.

**[0024]** The electrolysis temperature is 730-750°C.

**[0025]**  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0026]** The electrolytic cell and the electrolysis process using the electrolytic cell in the present invention have the advantages below:

(1) The electrolytic cell for aluminum electrolysis in the present invention comprises a cell body, wherein an anode and a cathode are arranged inside the cell body, and the cell body is further filled with an electrolyte; the anode is arranged above the cell body, and at least a part of the anode is immersed in the electrolyte; the cathode is arranged at the bottom of the electrolytic cell and covered by a certain amount of aluminum liquid; the electrolyte is located between the anode and the cathode; the anode contains the components including Fe, Cu, Ni and Sn, wherein Fe and Cu serve as primary components; the electrolyte is composed of 30-38wt% of NaF, 49-60wt% of  $\text{AlF}_3$ , 1-5wt% of LiF, 1-6wt% of KF and 3-6wt% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to  $\text{AlF}_3$  is 1.0-1.52.

**[0027]** The anode containing metal Sn and composed of the aforementioned metal components is high in electric conductivity and low in overvoltage, the cell voltage in the electrolysis process of the electrolytic cell is about 3.1-3.4V, power consumption in the aluminum electrolysis process is small, the power consumption for per ton of aluminum is not more than 11000kw·h, so the process cost is low; the anode material is alloy composed of Fe, Cu and Sn, so an oxide film formed on the surface of the anode in the electrolysis process is high in oxidation resistance and is hardly corroded by the electrolyte, and the formed oxide film is stable and not liable to fall off, therefore, the anode is imparted with quite high oxidation resistance and strong corrosion resistance so as to ensure the purity of aluminum products, that is, the purity of the produced aluminum can reach 99.8%. The following problems in the prior art are avoided: the alloy anode has high overvoltage, the oxide film on the alloy surface is low in oxidation resistance and liable to fall off, which leads to continuous consumption of the alloy anode and poor corrosion resistance, furthermore, the corroded or falling oxide film enters into liquid aluminum to degrade the purity of the final product aluminum. In addition, Fe and Cu serve as primary components of the alloy anode and their content proportions are quite high, and accordingly, the manufacturing cost of the anode material is lowered.

**[0028]** The used electrolyte employs a pure fluoride system, substance composition in the electrolyte is defined, the contents of these substances are further defined and the molar ratio of NaF to  $\text{AlF}_3$  is 1.0-1.52, so that the liquidus temperature of the electrolyte is lowered to 640-670°C, as a result, electrolysis can be carried out at 720-760°C according to the electrolysis process, which reduces volatilization loss of fluoride salt, avoids corrosion to electrolysis devices and damage to human body, improves working environment, greatly reduces energy consumption in the electrolysis process and achieves the aim of energy saving and emission reduction; meanwhile, in the present invention, proper amounts of LiF and KF are added and can be combined with sodium ions and aluminum ions in the electrolyte to form lithium cryolite and potassium cryolite with low melting points, thus the crusting phenomenon is avoided in the electrolysis process; compared with the existing industry, the electrolyte for aluminum electrolysis in the present invention has no  $\text{CaF}_2$  and  $\text{MgF}_2$  added therein, instead, KF in an appropriate proportion, which has the function of increasing alumina solubility and dissolution velocity, is added to a system in which the molar ratio of NaF to  $\text{AlF}_3$  is 1.0-1.52, therefore, the shortcoming of low alumina solubility in the low-molar-ratio electrolyte is improved; in general, the electric conductivity of the electrolyte decreases as the temperature decreases, so typically, the electric conductivity at a low electrolysis temperature hardly meets the demand in a normal electrolysis process; the electrolysis temperature is lowered by lowering the liquidus temperature of the electrolyte in the present invention, however, the electric conductivity of the electrolyte at a low temperature can still meet the demand in the electrolysis process because LiF with a larger electric conductivity is added and component proportions in the electrolyte are optimized, thus enhancing the current efficiency in the electrolysis process. According to the invention, the content of LiF is defined as 1-5%, this is because too low content of LiF fails to improve electric conductivity and to prevent crusting, and too high content of LiF results in decrease of the alumina solubility, and the above two situations are effectively avoided by defining the content of LiF as 1-5% in the present invention; and there is no corrosion to a metal device when the electrolyte with the above proportions in the present invention is used, in this way, the service life of the electrolysis device is prolonged.

(2) In the electrolytic cell for aluminum electrolysis in the present invention, the anode is 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 less than or equal to 4wt%, the content of Y is less than or equal to 2wt%, and the content of Sn is 0.2-5wt%. Similarly, the aforementioned inert alloy anode has the advantages of low material cost and high electric conductivity, in addition, the metal Al contained in

the aforementioned inert alloy anode plays a role of oxidization resistance and can serve as a reducing agent for metallothermic reduction reaction with metal oxides in the inert anode alloy, thus preventing the metals in the inert alloy anode, i.e. primary components, from being oxidized, and causing reduction of the electric conductivity of the alloy anode; meanwhile, the metal Y added can be used for controlling a crystal structure for anode material formation in the preparation process of the inert anode, achieving the anti-oxidization purpose.

(3) In the electrolytic cell for aluminum electrolysis in the present invention, specified amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  are mixed, the resultant mixture is heated to form a melt; or specified amounts of NaF,  $\text{AlF}_3$ , LiF and KF are mixed, the resultant mixture is heated until the mixture is molten, and then  $\text{Al}_2\text{O}_3$  is added to obtain a melt; afterwards, the melt prepared is electrolyzed at 720-760°C. Electrolysis temperature is directly associated with volatilization of the electrolyte, cathode crusting phenomenon, energy consumption of the process, electric conductivity and alumina solubility, and the inventor of the present invention, by long search, set the electrolysis temperature within a range from 720-760°C in a matching way based on the components and content characteristics of the electrolyte in the present invention, thus the cathode crusting phenomenon is prevented and volatilization of the electrolyte and energy consumption of the electrolysis process are remarkably reduced while both the electric conductivity and the alumina solubility are increased, and the economic efficiency of the process is improved. Preferably, the electrolysis temperature is further set within a range from 730-750°C in the present invention.

### Brief Description of the Drawings

[0029] For more easily understanding the contents of the present invention, further description will be made below to the technical solution of the present invention in conjunction with the drawing and the embodiments.

[0030] Fig.1 is a structure diagram of the electrolytic cell for aluminum electrolysis in the present invention;

[0031] In this drawing, reference signs are as follows: 1 refers to cell body, 2 refers to anode, 3 refers to cathode, 4 refers to electrolyte, 5 refers to insulating layer, 6 refers to cell cover, 7 refers to vent, 8 refers to feeding hole, 9 refers to binding post, 10 refers to cathode bar and 11 refers to aluminum liquid.

### Detailed Description of the Embodiments

[0032] The electrolytic cell for aluminum electrolysis in the present invention is as shown in Fig.1 and comprises a cell body 1, wherein an anode 2 and a cathode 3 are arranged inside the cell body 1, the anode 2 and the

cathode 3 can be arranged in random ways in accordance with the actual need, in this embodiment, the anode 2 is arranged above the cell body 1, the bottom surface of the anode 2 is kept parallel to the cell body 1, the cathode 3 is arranged at the bottom of the electrolytic cell and covered by a certain amount of aluminum liquid 11; the cell body 1 is further filled with an electrolyte 4, immersion of the anode 2 and the cathode 3 in the electrolyte 4 depends on the selected electrolytic cell structure, in this embodiment, at least a part of the anode 2 is immersed in the electrolyte 4; the cathode 3 is arranged at the bottom of the electrolytic cell and covered by a certain amount of aluminum liquid 11; the electrolyte 4 is located between the anode 2 and the cathode 3 and covers the aluminum liquid 11; the anode 2 contains the components including Fe, Cu, Ni and Sn, wherein Fe and Cu serve as primary components, and the molar ratio of Fe to Cu to Sn is (23-40): (36-60): (0.2-5); the electrolyte 4 is composed of 30-38wt% of NaF, 49-60wt% of  $\text{AlF}_3$ , 1-5wt% of LiF, 1-6wt% of KF and 3-6wt% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to  $\text{AlF}_3$  is 1.0-1.52, preferably 1.12-1.52, and the liquidus temperature of the electrolyte 4 is 620-670°C, preferably 640-670°C.

[0033] As a variable embodiment on this basis, in order to isolate the inner sidewall of the cell body 1 from the electrolyte 4 and oxygen to prevent transfer of electrons between the sidewall of the cell body 1 and the electrolyte 4 and corrosion of the electrolyte 4 to the sidewall of the cell body 1, an insulating layer 5 is arranged on the inner sidewall of the cell body 1 and is made of any commercially available insulating material that is resistant to high temperature and corrosion of the electrolyte 4, e.g. corundum, aluminate spinel refractory and the like. In this embodiment, a carbon block is arranged between the inner sidewall of the cell body 1 and the insulating layer 5, and the carbon block and the cathode 3 are integrally formed. Undoubtedly, the carbon block and the cathode 3 can also be arranged in a separated manner.

[0034] On this basis, in order to isolate the electrolysis environment for the electrolytic cell from outside without impediment to exhaust and feeding, a cell cover 6 is arranged at the upper end of the cell body 1 and is provided with a vent 7 and a feeding hole 8 thereon, the sizes and positions of the vent 7 and the feeding hole can be randomly determined in accordance with the actual need, and in this embodiment, the vent 7 is arranged next to the anode 2.

[0035] Further, in order to facilitate connection of the anode 2 and the cathode 3 with a power supply, a cathode bar 10 is arranged on the cathode 3 at the bottom of the electrolytic cell and is used for connection with the power supply of the cathode 3; one end of the anode 2 penetrates through the cell cover 6 and is connected and provided with a binding post 9 for connection with the power supply of the anode 2; and the cathode 10 and the binding post 9 can be made of any material with good electric conductivity, including steel, iron and alloy materials, etc.

[0036] On this basis, in order to improve the combina-

tion firmness among metals Fe, Cu and Sn, the components of the anode 2 further include Ni, preferably the anode 2 is composed of Fe, Cu, Ni and Sn, wherein the content 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%.

**[0037]** The anode 2 may be preferably composed of Fe, Cu, Ni, Sn, Al and Y, the added Al can prevent other primary metal components of the anode 2 from oxidation and improve the oxidization resistance, the component Y can be used for regulating and controlling the structure of the prepared alloy crystal in order to achieve the anti-oxidization purpose, 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 less than or equal to 4wt%, the content of Y is less than or equal to 2wt%, and the content of Sn is 0.2-5wt%.

**[0038]** The electrolysis temperature is 720-760°C when the aforementioned electrolytic cell is used for aluminum electrolysis, preferably 730-750°C. Description is made below in conjunction with the embodiments.

#### Embodiment 1

**[0039]** Fe, Cu, Ni and Sn metal blocks are mixed based on 23wt% of Fe, 60wt% of Cu, 14wt% of Ni and 3wt% of Sn, the mixture is molten by heating at high temperature and then subjected to casting to obtain an anode 1. The anode 1 has a density of 8.3/cm<sup>3</sup>, a specific resistivity of 68μΩ·cm and a melting point of 1360°C.

**[0040]** The components of the electrolyte in this embodiment are as follows: 32% of NaF, 57% of AlF<sub>3</sub>, 3% of LiF, 4% of KF and 4% of Al<sub>2</sub>O<sub>3</sub>, wherein the molar ratio of NaF to aluminum fluoride AlF<sub>3</sub> is 1.12. The liquidus temperature of the electrolyte in this embodiment is 640°C according to measurement. The electrolyte has an electric conductivity of about 1.7Ω<sup>-1</sup>·cm<sup>-1</sup>, a density of about 2.03g/cm<sup>3</sup> and an alumina saturation concentration of 5%.

**[0041]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

- (1) by means of the anode 1 and the carbon body cathode, melting the aforementioned amounts of NaF, AlF<sub>3</sub>, LiF, KF and Al<sub>2</sub>O<sub>3</sub> in a melting furnace so as to form a melt; and
- (2) raising the temperature of the melt prepared in step (1) to above 720°C in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at 720°C, wherein Al<sub>2</sub>O<sub>3</sub> is quantitatively supplied in the electrolysis process.

**[0042]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.1V, the power consumption for per ton of aluminum is 10040kw·h in the electrolysis process, and

the prepared aluminum has a purity of 99.85%.

#### Embodiment 2

**[0043]** Fe, Cu, Ni and Sn metal blocks are mixed based on 40wt% of Fe, 36wt% of Cu, 19wt% of Ni and 5wt% of Sn, the mixture is molten by heating at high temperature and then subjected to casting to obtain an anode 2. The anode has a density of 8.1/cm<sup>3</sup>, a specific resistivity of 76.8μΩ·cm and a melting point of 1386°C.

**[0044]** The components of the electrolyte in this embodiment are as follows: 38% of NaF, 50% of AlF<sub>3</sub>, 2% of LiF, 5% of KF and 5% of Al<sub>2</sub>O<sub>3</sub>, wherein the molar ratio of NaF to aluminum fluoride AlF<sub>3</sub> is 1.52.

**[0045]** The performances of the electrolyte in this embodiment are measured and the measurement result is that the liquidus temperature of the electrolyte in this embodiment is 670°C. The electrolyte has an electric conductivity of about 1.8Ω<sup>-1</sup>·cm<sup>-1</sup>, a density of about 2.05g/cm<sup>3</sup> and an alumina saturation concentration of 6%.

**[0046]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

- (1) by means of the anode 2 and the carbon body cathode, melting the aforementioned amounts of NaF, AlF<sub>3</sub>, LiF and KF in a melting furnace, and then adding the aforementioned amount of Al<sub>2</sub>O<sub>3</sub> to obtain a melt by melting; and
- (2) raising the temperature of the melt prepared in step (1) to above 760°C in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at 760°C.

**[0047]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.39V, the power consumption for per ton of aluminum is 10979kw·h in the electrolysis process, and the prepared aluminum has a purity of 99.82%.

#### Embodiment 3

**[0048]** Fe, Cu, Ni and Sn metal blocks are mixed based on 25wt% of Fe, 46.8wt% of Cu, 28wt% of Ni and 0.2wt% of Sn, the mixture is molten by heating at high temperature and then subjected to casting to obtain an anode 3. The anode has a density of 8.2/cm<sup>3</sup>, a specific resistivity of 72μΩ·cm and a melting point of 1350°C.

**[0049]** The components of the electrolyte in this embodiment are as follows: 32% of NaF, 57% of AlF<sub>3</sub>, 3% of LiF, 4% of KF and 4% of Al<sub>2</sub>O<sub>3</sub>, wherein the molar ratio of NaF to aluminum fluoride AlF<sub>3</sub> is 1.12.

**[0050]** The performances of the electrolyte in this embodiment are measured and the measurement result is that the liquidus temperature of the electrolyte in this embodiment is 640°C. The electrolyte has an electric con-

ductivity of about  $1.6\Omega^{-1}\cdot\text{cm}^{-1}$ , a density of about  $2.03\text{g}/\text{cm}^3$  and an alumina saturation concentration of 5%.

**[0051]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

(1) by means of the anode 3 and the carbon body cathode, melting the aforementioned amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  in a melting furnace so as to form a melt; and

(2) raising the temperature of the melt prepared in step (1) to above  $730^\circ\text{C}$  in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at  $730^\circ\text{C}$ , wherein  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0052]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.15V, the power consumption for per ton of aluminum is  $10202\text{kw}\cdot\text{h}$  in the electrolysis process, and the prepared aluminum has a purity of 99.85%.

#### Embodiment 4

**[0053]** Fe, Cu, Ni and Sn metal blocks are mixed based on 24.2wt% of Fe, 60wt% of Cu, 14wt% of Ni and 0.2wt% of Sn, the mixture is molten by heating at high temperature, 1.8wt% of Al metal block is then added for continuous melting and mixing, and finally, 0.8wt% of Y metal block is added for melting and mixing and an anode 4 is obtained by casting of the mixture. The anode has a density of  $8.3/\text{cm}^3$ , a specific resistivity of  $68\mu\Omega\cdot\text{cm}$  and a melting point of  $1360^\circ\text{C}$ .

**[0054]** The components of the electrolyte in this embodiment are as follows: 32% of NaF, 57% of  $\text{AlF}_3$ , 3% of LiF, 4% of KF and 4% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to aluminum fluoride  $\text{AlF}_3$  is 1.12.

**[0055]** The performances of the electrolyte in this embodiment are measured and the measurement result is that the liquidus temperature of the electrolyte in this embodiment is  $640^\circ\text{C}$ . The electrolyte has an electric conductivity of about  $1.8\Omega^{-1}\cdot\text{cm}^{-1}$ , a density of about  $2.04\text{g}/\text{cm}^3$  and an alumina saturation concentration of 6%.

**[0056]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

(1) by means of the anode 4 and the carbon body cathode, melting the aforementioned amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  in a melting furnace so as to form a melt; and

(2) raising the temperature of the melt prepared in step (1) to above  $750^\circ\text{C}$  in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the

temperature is maintained at  $750^\circ\text{C}$ , wherein  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0057]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.12V, the power consumption for per ton of aluminum is  $10105\text{kw}\cdot\text{h}$  in the electrolysis process, and the prepared aluminum has a purity of 99.8%.

#### Embodiment 5

**[0058]** Fe, Cu, Ni and Sn metal blocks are mixed based on 40wt% of Fe, 36wt% of Cu, 14.9wt% of Ni and 5wt% of Sn, the mixture is molten by heating at high temperature, 0.1wt% of Al metal block is then added for continuous melting and mixing, and finally, 0.1wt% of Y metal block is added for melting and mixing and an anode 5 is obtained by casting of the mixture. The anode has a density of  $8.1/\text{cm}^3$ , a specific resistivity of  $76.8\mu\Omega\cdot\text{cm}$  and a melting point of  $1386^\circ\text{C}$ .

**[0059]** The components of the electrolyte in this embodiment are as follows: 30% of NaF, 60% of  $\text{AlF}_3$ , 1% of LiF, 6% of KF and 3% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to aluminum fluoride  $\text{AlF}_3$  is 1.0.

**[0060]** The performances of the electrolyte in this embodiment are measured and the measurement result is that the liquidus temperature of the electrolyte in this embodiment is  $620^\circ\text{C}$ . The electrolyte has an electric conductivity of about  $1.6\Omega^{-1}\cdot\text{cm}^{-1}$ , a density of about  $2.03\text{g}/\text{cm}^3$  and an alumina saturation concentration of 5%.

**[0061]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

(1) by means of the anode 5 and the carbon body cathode, melting the aforementioned amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  in a melting furnace so as to form a melt; and

(2) raising the temperature of the melt prepared in step (1) to above  $720^\circ\text{C}$  in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at  $720^\circ\text{C}$ , wherein  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0062]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.27V, the power consumption for per ton of aluminum is  $10591\text{kw}\cdot\text{h}$  in the electrolysis process, and the prepared aluminum has a purity of 99.81%.

#### Embodiment 6

**[0063]** Fe, Cu, Ni and Sn metal blocks are mixed based on 25wt% of Fe, 38wt% of Cu, 28wt% of Ni and 4wt% of Sn, the mixture is molten by heating at high temperature, 4wt% of Al metal block is then added for continuous melt-

ing and mixing, and finally, 1wt% of Y metal block is added for melting and mixing and an anode 6 is obtained by casting of the mixture. The anode has a density of  $8.2/\text{cm}^3$ , a specific resistivity of  $70\mu\Omega\cdot\text{cm}$  and a melting point of  $1365^\circ\text{C}$ .

**[0064]** The components of the electrolyte in this embodiment are as follows: 38% of NaF, 54% of  $\text{AlF}_3$ , 4% of LiF, 1% of KF and 3% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to aluminum fluoride  $\text{AlF}_3$  is 1.4.

**[0065]** The performances of the electrolyte in this embodiment are measured and the measurement result is that: the liquidus temperature of the electrolyte in this embodiment is  $670^\circ\text{C}$ . The electrolyte has an electric conductivity of about  $1.8\Omega^{-1}\cdot\text{cm}^{-1}$ , a density of about  $2.05\text{g}/\text{cm}^3$  and an alumina saturation concentration of 6%.

**[0066]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

(1) by means of the anode 6 and the carbon body cathode, melting the aforementioned amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  in a melting furnace so as to form a melt; and

(2) raising the temperature of the melt prepared in step (1) to above  $760^\circ\text{C}$  in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at  $760^\circ\text{C}$ , wherein  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0067]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.35V, the power consumption for per ton of aluminum is  $10850\text{kw}\cdot\text{h}$  in the electrolysis process, and the prepared aluminum has a purity of 99.83%.

#### Embodiment 7

**[0068]** Fe, Cu, Ni and Sn metal blocks are mixed based on 40wt% of Fe, 36.5wt% of Cu, 18wt% of Ni and 3wt% of Sn, the mixture is molten by heating at high temperature, 1.5wt% of Al metal block is then added for continuous melting and mixing, and finally, 1wt% of Y metal block is added for melting and mixing and an anode 7 is obtained by casting of the mixture. The anode has a density of  $8.1/\text{cm}^3$ , a specific resistivity of  $76.8\mu\Omega\cdot\text{cm}$  and a melting point of  $1386^\circ\text{C}$ .

**[0069]** The components of the electrolyte in this embodiment are as follows: 34% of NaF, 49% of  $\text{AlF}_3$ , 5% of LiF, 6% of KF and 6% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF to aluminum fluoride  $\text{AlF}_3$  is 1.39.

**[0070]** The performances of the electrolyte in this embodiment are measured and the measurement result is that the liquidus temperature of the electrolyte in this embodiment is  $660^\circ\text{C}$ . The electrolyte has an electric conductivity of about  $1.8\Omega^{-1}\cdot\text{cm}^{-1}$ , a density of about  $2.05\text{g}/\text{cm}^3$  and an alumina saturation concentration of

6%.

**[0071]** The process using the electrolyte in the present invention for aluminum electrolysis is as follows:

(1) by means of the anode 7 and the carbon body cathode, melting the aforementioned amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  in a melting furnace so as to form a melt; and

(2) raising the temperature of the melt prepared in step (1) to above  $760^\circ\text{C}$  in the melting furnace, then pouring the melt into the electrolytic cell, switching on the power supplies of the anode and the cathode, and carrying out electrolysis for 40 hours while the temperature is maintained at  $760^\circ\text{C}$ , wherein  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

**[0072]** There is no crust at the bottom of the cell body in the electrolysis process, the cell voltage of the electrolytic cell is 3.38V, the power consumption for per ton of aluminum is  $10947\text{kw}\cdot\text{h}$  in the electrolysis process, and the prepared aluminum has a purity of 99.8%.

**[0073]** The electrolytic cell in the aforementioned embodiments is any of the electrolytic cells in the present invention.

**[0074]** Detailed description has been made to the specific contents of the present invention in the aforementioned embodiments, and it should be understood by those skilled in this art that modifications and detail variations in any form based upon the present invention pertain to the contents that the present invention seeks to protect, as long as they are covered by the scope of the appended claims.

#### Claims

1. An electrolytic cell for aluminum electrolysis, comprising:

a cell body (1) adapted to be filled with an electrolyte (4), an anode (2) and a cathode (3) being arranged inside the cell body (1); the anode (2) being arranged above the cell body (1), and at least a part of the anode (2) being immersed in the electrolyte (4); the cathode (3) being arranged at the bottom of the electrolytic cell and covered by a certain amount of aluminum liquid (11); the electrolyte (4) being located between the anode (2) and the cathode (3);

#### characterized in that

the anode (2) is 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%.

2. The electrolytic cell according to claim 1, **characterized in that** the bottom surface of the anode (2) is

kept parallel to the cell body (1), and an insulating layer (5) is arranged on the inner sidewall of the cell body (1) and is used for isolating oxygen or the electrolyte (4) from a carbon block.

3. The electrolytic cell according to claim 1 or 2, **characterized in that** a cell cover (6) is arranged at the upper end of the cell body (1) and is provided with a vent (7) and a feeding hole (8); a cathode bar (10) is arranged inside the cathode (3), one end of the anode (2) penetrates through the cell cover (6) and is connected and provided with a binding post (9) for connection with a power supply.
4. The electrolytic cell according to any of claims 1-3, **characterized in that** the components of the anode (2) further include Al and Y.
5. The electrolytic cell according to claim 4, **characterized in that** the anode (2) is 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%.
6. An electrolysis process using the electrolytic cell according to any of claims 1-5, comprising the electrolyte (4) which is composed of 30-38 wt% of NaF, 49-60 wt% of  $\text{AlF}_3$ , 1-5 wt% of LiF, 1-6 wt% of KF and 3-6 wt% of  $\text{Al}_2\text{O}_3$ , wherein the molar ratio of NaF and  $\text{AlF}_3$  is 1.0-1.52, the process comprising the steps of:
  - (1) adding specified amounts of NaF,  $\text{AlF}_3$ , LiF, KF and  $\text{Al}_2\text{O}_3$  to a melting furnace for mixing and melting to form a melt; or adding specified amounts of NaF,  $\text{AlF}_3$ , LiF and KF to a melting furnace for mixing and melting, and then adding  $\text{Al}_2\text{O}_3$  to obtain a melt; and
  - (2) raising the temperature of the melt prepared in step (1) to above 720-760°C, and then, pouring the melt into the electrolytic cell and carrying out electrolysis while the temperature is maintained at 720-760°C.
7. The electrolysis process according to claim 6, **characterized in that** the electrolysis temperature is 730-750°C.
8. The electrolysis process according to claim 6 or 7, **characterized in that**  $\text{Al}_2\text{O}_3$  is quantitatively supplied in the electrolysis process.

## Patentansprüche

1. Elektrolysezelle zur Aluminiumelektrolyse, umfassend:
 

einen Zellkörper (1), der eingerichtet ist, um mit einem Elektrolyt (4) befüllt zu werden, wobei eine Anode (2) und eine Kathode (3) im Inneren des Zellkörpers (1) angeordnet sind; wobei die Anode (2) oberhalb des Zellkörpers (1) angeordnet ist und mindestens ein Teil der Anode (2) im Elektrolyt (4) eingetaucht ist; wobei die Kathode (3) an der Unterseite der Elektrolysezelle angeordnet ist und von einer bestimmten Menge Aluminiumflüssigkeit (11) bedeckt ist; wobei der Elektrolyt (4) zwischen der Anode (2) und der Kathode (3) angeordnet ist; **dadurch gekennzeichnet, dass** die Anode (2) aus Fe, Cu, Ni und Sn besteht, wobei der Gehalt an Fe 23-40 Gew.-% beträgt, der Gehalt an Cu 36-60 Gew.-% beträgt, der Gehalt an Ni 14-28 Gew.-% beträgt, und der Gehalt an Sn 0,2-5 Gew.-% beträgt.
2. Elektrolysezelle nach Anspruch 1, **dadurch gekennzeichnet, dass** die unterseitige Fläche der Anode (2) parallel zum Zellkörper (1) gehalten ist, und eine Isolierschicht (5) an der inneren Seitenwand des Zellkörpers (1) angeordnet ist und dazu dient, Sauerstoff oder den Elektrolyt (4) von einem Kohlenstoffblock zu isolieren.
3. Elektrolysezelle nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** eine Zellabdeckung (6) am oberen Ende des Zellkörpers (1) angeordnet ist und mit einer Entlüftung (7) und einer Beschickungsöffnung (8) versehen ist; ein Kathodenstab (10) im Inneren der Kathode (3) angeordnet ist, ein Ende der Anode (2) die Zellabdeckung (6) durchdringt und mit einem Anschlussbolzen (9) für den Anschluss an eine Stromversorgung verbunden und versehen ist.
4. Elektrolysezelle nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** die Bestandteile der Anode (2) ferner Al und Y umfassen.
5. Elektrolysezelle nach Anspruch 4, **dadurch gekennzeichnet, dass** die Anode (2) aus Fe, Cu, Ni, Sn, Al und Y besteht, wobei der Gehalt an Fe 23-40 Gew.-% beträgt, der Gehalt an Cu 36-60 Gew.-% beträgt, der Gehalt an Ni 14-28 Gew.-% beträgt, der Gehalt an Al größer als null und kleiner als oder gleich 4 Gew.-% ist, der Gehalt an Y größer als null und kleiner als oder gleich 2 Gew.-% ist, und der Gehalt an Sn 0,2-5 Gew.-% beträgt.
6. Elektrolyseverfahren unter Verwendung der Elektro-

lysezelle nach einem der Ansprüche 1 bis 5, umfassend den Elektrolyt (4) bestehend aus 30-38 Gew.-% NaF, 49-60 Gew.-%  $\text{AlF}_3$ , 1-5 Gew.-% LiF, 1-6 Gew.-% KF, und 3-6 Gew.-%  $\text{Al}_2\text{O}_3$ , wobei das Molverhältnis von NaF und  $\text{AlF}_3$  1,0-1,52 beträgt, wobei das Verfahren die Schritte umfasst:

(1) Zugabe vorgegebener Mengen von NaF,  $\text{AlF}_3$ , LiF, KF und  $\text{Al}_2\text{O}_3$  in einen Schmelzofen zum Mischen und Schmelzen, um eine Schmelze auszubilden; oder Zugabe vorgegebener Mengen von NaF,  $\text{AlF}_3$ , LiF und KF in einen Schmelzofen zum Mischen und Schmelzen und dann Zugabe von  $\text{Al}_2\text{O}_3$ , um eine Schmelze zu erhalten; und

(2) Erhöhen der Temperatur der in Schritt (1) erzeugten Schmelze auf über 720-760 °C und dann Gießen der Schmelze in die Elektrolysezelle und Ausführen einer Elektrolyse, während die Temperatur auf 720-760 °C gehalten wird.

7. Elektrolyseverfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** die Elektrolysetemperatur 730-750 °C beträgt.
8. Elektrolyseverfahren nach Anspruch 6 oder 7, **dadurch gekennzeichnet, dass**  $\text{Al}_2\text{O}_3$  im Elektrolyseverfahren quantitativ zugeführt wird.

#### Revendications

1. Cellule électrolytique pour électrolyse d'aluminium comprenant :

un corps de cellule (1) adapté pour être rempli avec un électrolyte (4), une anode (2) et une cathode (3) étant agencées à l'intérieur du corps de cellule (1) ;  
l'anode (2) étant agencée au-dessus du corps de cellule (1), et au moins une partie de l'anode (2) étant immergée dans l'électrolyte (4) ;  
la cathode (3) étant agencée au fond de la cellule électrolytique et recouverte d'une certaine quantité d'aluminium liquide (11) ;  
l'électrolyte (4) étant situé entre l'anode (2) et la cathode (3) ;

#### **caractérisé en ce que**

l'anode (2) est composée de Fe, Cu, Ni et Sn, la teneur en Fe étant de 23 à 40 % en poids, la teneur en Cu étant de 36 à 60 % en poids, la teneur en Ni étant de 14 à 28 % en poids et la teneur en Sn étant de 0,2 à 5 % en poids.

2. Cellule électrolytique selon la revendication 1, **caractérisée en ce que** la surface inférieure de l'anode (2) est maintenue parallèle au corps de cellule (1) et une couche isolante (5) est agencée sur la paroi la-

terale interne du corps de cellule (1) et est utilisée pour isoler l'oxygène ou l'électrolyte (4) d'un bloc de carbone.

3. Cellule électrolytique selon la revendication 1 ou 2, **caractérisée en ce qu'un** couvercle de cellule (6) est agencé à l'extrémité supérieure du corps de cellule (1) et est pourvu d'un évent (7) et d'un trou d'alimentation (8) ; une barre de cathode (10) est agencée à l'intérieur de la cathode (3), une extrémité de l'anode (2) pénètre à travers le couvercle de cellule (6) et est connectée et pourvue d'une borne de connexion (9) pour connexion à une alimentation électrique.
4. Cellule électrolytique selon l'une quelconque des revendications 1 à 3, **caractérisée en ce que** les composants de l'anode (2) comprennent en outre Al et Y.
5. Cellule électrolytique selon la revendication 4, **caractérisée en ce que** l'anode (2) est composée de Fe, Cu, Ni, Sn, Al et Y, la teneur en Fe étant de 23 à 40 % en poids, la teneur en Cu étant de 36 à 60 % en poids, la teneur en Ni étant de 14 à 28 % en poids, la teneur en Al étant supérieure à zéro et inférieure ou égale à 4 % en poids, la teneur en Y étant supérieure à zéro et inférieure ou égale à 2 % en poids et la teneur en Sn étant de 0,2 à 5 % en poids.

6. Procédé d'électrolyse utilisant la cellule électrolytique selon l'une quelconque des revendications 1 à 5, comprenant l'électrolyte (4) qui est composé de 30 à 38 % en poids de NaF, 49 à 60 % en poids de  $\text{AlF}_3$ , 1 à 5 % en poids de LiF, 1 à 6 % en poids de KF et 3 à 6 % en poids de  $\text{Al}_2\text{O}_3$ , le rapport molaire de NaF et  $\text{AlF}_3$  étant de 1,0 à 1,52, le procédé comprenant les étapes de :

(1) ajout de quantités spécifiées de NaF,  $\text{AlF}_3$ , LiF, KF et  $\text{Al}_2\text{O}_3$  dans un four de fusion pour les mélanger et les fondre afin de former une masse fondue ; ou ajout de quantités spécifiées de NaF,  $\text{AlF}_3$ , LiF et KF dans un four de fusion pour les mélanger et les fondre, puis ajout de  $\text{Al}_2\text{O}_3$  pour obtenir une masse fondue ; et  
(2) augmentation de la température de la masse fondue préparée dans l'étape (1) au-dessus de 720 à 760 °C, puis versement de la masse fondue dans la cellule électrolytique et conduite d'une électrolyse pendant que la température est maintenue à 720 à 760 °C.

7. Procédé d'électrolyse selon la revendication 6, **caractérisé en ce que** la température d'électrolyse est de 730 à 750 °C.
8. Procédé d'électrolyse selon la revendication 6 ou 7, **caractérisé en ce que**  $\text{Al}_2\text{O}_3$  est ajouté de façon

quantitative dans le procédé d'électrolyse.

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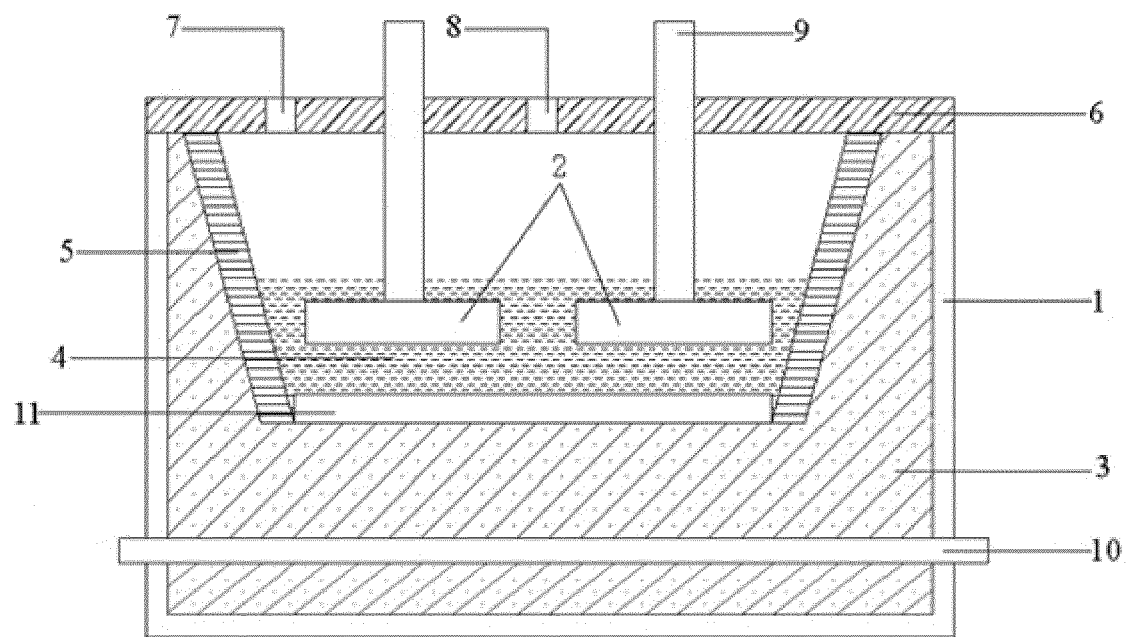


Figure 1

**REFERENCES CITED IN THE DESCRIPTION**

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