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(54) **METHOD AND APPARATUS FOR THE PRODUCTION OF ALUMINIUM**

VERFAHREN UND VORRICHTUNG ZUR PRODUKTION VON ALUMINIUM

PROCEDE ET APPAREIL DE PRODUCTION D'ALUMINIUM

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**WO-A-00/37691 WO-A-2004/088000
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Description

FIELD OF THE INVENTION

[0001] The invention relates to a method for the continuous production of aluminium from alumina comprising a first step of converting alumina (Al_2O_3) into aluminiumsulphide (Al_2S_3) and a second step of separation of aluminium from aluminiumsulphide in a separating reactor. Furthermore, the invention relates to an apparatus for operating the method.

BACKGROUND OF THE INVENTION

[0002] International publication WO-00/37691, incorporated herein by reference, discloses a method wherein in a first step, also called sulphidation step, solid alumina is converted into solid aluminiumsulphide (Al_2S_3) by reacting with gaseous carbon sulphide. In a second step, also called separation step, the solid aluminiumsulphide is fed into a separating reactor such as an electrolysis cell wherein metallic aluminium is separated from the aluminiumsulphide.

[0003] This has various drawbacks. One such drawback is that it requires two separate processes: the sulphidation step and further the separation step. As a consequence the aluminiumsulphide has to be transported from the reactor in which it is formed to the reactor in which the separation step is carried out. Aluminiumsulphide has a very high affinity to oxygen. Therefore, any oxygen with which the aluminiumsulphide comes into contact, e.g. as oxygen in air or in water, converts the aluminiumsulphide back into alumina. The known process therefore puts high demands on the handling of aluminiumsulphide.

[0004] Another drawback of the disclosed method is that, in order to perform the separation step of aluminiumsulphide efficiently at a low voltage, in particular by electrolysis using inert electrodes, it is required that a large fraction, preferably all, of the alumina is converted in the sulphidation step into aluminiumsulphide before the reaction components of the sulphidation step are fed into the electrolysis cell. Alumina present in an electrolysis cell operated at a low voltage is not decomposed and settles in the cell as a sludge, which has to be removed. Removal of sludge disturbs the operation of the electrolysis cell and more importantly, brings about the risk of introducing oxygen into the electrolysis cell, which converts aluminiumsulphide back into alumina. Furthermore, the alumina that remains present in the electrolysis cell may dissolve and saturate the electrolyte, thus hindering further dissolution of aluminiumsulphide and subsequent separation of aluminium from aluminiumsulphide.

[0005] However, a nearly complete conversion of alumina into aluminiumsulphide reduces the overall efficiency of the process. In practice the conversion rate slows down as the reaction proceeds, and the efficiency of the

sulphidation reaction decreases, as the time, the reactor volume, and the amount of sulphidation agents required per unit of aluminiumsulphide increase. A further drawback is that compounds from the separation step, in particular alumina, have to be discarded.

DESCRIPTION OF THE INVENTION.

[0006] It is an object of the present invention to provide a method for the manufacture of aluminium, in particular primary aluminium, which has a higher efficiency of use of the alumina.

[0007] It is another object of the present invention to provide a method for the manufacture of aluminium, in particular primary aluminium, with which a higher conversion of alumina can be achieved.

[0008] It is yet another object of the present invention to provide a method for the manufacture of aluminium, in particular primary aluminium, which requires fewer steps, preferably a method with which, the sulphidation and separation steps are at least partly integrated.

[0009] It is a further object of the present invention to provide a method for the manufacture of primary aluminium, which avoids or at least reduces the problem associated with the handling of aluminiumsulphide.

[0010] One or more of these objects are achieved with the method according to the invention for the continuous production of aluminium, in particular primary aluminium, from alumina comprising a first step of converting alumina (Al_2O_3) into aluminiumsulphide (Al_2S_3) and a second step of separation of aluminium from aluminiumsulphide in a separating reactor, and wherein the separating apparatus is a electrolysis cell, and wherein in the first step in a conversion reactor alumina is dissolved in a molten salt to form a melt and a sulphur containing gas is fed through the melt whereby the sulphur containing gas acts as a reagent to convert at least part of the alumina into aluminiumsulphide and at least part of the melt is used in the second step, and wherein the melt with the dissolved alumina and the aluminiumsulphide is continuously recirculated between the first and the second process step.

[0011] For the purpose of this description the term "salt" also comprises a mixtures of salts, and the term "sulphur containing gas" comprises sulphides.

[0012] The method according to the invention has one or more of the following advantages. The aluminiumsulphide formed is dissolved in the molten salt and can easily be transported to the second, separation, step. So the handling problem of the prior art method is eliminated or at least reduced.

[0013] Another advantage is that the melt, even with an incomplete conversion of alumina into aluminiumsulphide, is suitable for a variety of separation processes. Any alumina remaining in the melt after separation can be fed back with the molten salt into the first, conversion, step.

[0014] Another advantage is that the process is oper-

ated in a continuous or at least semi-continuous fashion, which to a very large extent eliminates yield losses and operating difficulties that are associated with batch type processes or processes that require frequent standstills or maintenance. Examples of the latter include the present Hall-Héroult process for the reduction of alumina into metallic aluminium, which requires regular replacement of the consumable anodes. In the current invention, due to the reduced cell voltage, the carbon electrodes remain inert and can be used for a prolonged time.

[0015] Another advantage of the process according to the invention over the known prior art process is related to the thermal imbalance. The known sulphidation process is endothermic and requires heat input. In the separation process, on the other hand, heat is generated by ohmic losses. Integration of the two steps in accordance with the present invention enables a direct input of the heat generated by the separation process into the sulphidation reaction. Reference to the current Hall-Héroult process serves to illustrate this point, namely in modern Hall-Héroult cells, typically about 30% of the energy is dissipated as heat losses in the molten salt. As the bath temperature should remain constant, this heat must be dissipated to the surroundings. Apart from the loss of energy, the Hall-Héroult cell must be designed to dissipate heat, which obstructs more favourable compact cell designs. In the current invention, substantially all the heat that is generated by ohmic losses is absorbed in the conversion from alumina to aluminium, and the cell design can be made much more compact.

[0016] Yet another advantage connected with the continuous recycling process is that it is not necessary to convert a considerable amount of alumina into aluminiumsulphide. So the time for conversion can be selected such that an optimum can be reached between time for conversion on the one hand and flow of aluminium containing melt back from the separation step into the conversion step on the other hand.

[0017] Any alumina that is not converted but fed into the separation step as part of the melt, can be fed back into the conversion step and therefore, does not create a waste flow that may have to be discarded.

[0018] A relevant characteristic of the alumina being dissolved in the melt is that any product from the sulphidation reaction is directly available in the melt, which eliminates the need for a separation of the alumina and aluminiumsulphide containing species. Another relevant characteristic is that the sulphidation reaction proceeds by direct contact between the sulphidising gas and the melt. Thus the whole gas/liquid interface is used as a contact area for the sulphidation reaction. This is an important advantage over reactions between a gas and particles dispersed in a melt, where only a small fraction of the gas/liquid interface is occupied by gas/particle contact.

[0019] The melt as described herein comprises a mixture of various, complex ions, similar to what is known from the regular Hall-Héroult process for the reduction

of alumina. In this melt, Al_2O_3 and Al_2S_3 need not be present in their molecular form, but also may be present as ionic species that are associated in particular with the dissolution of Al_2O_3 and Al_2S_3 . For simplicity, the words "alumina" and "aluminiumsulphide" that are used throughout this description refer to and include these ionic species as well as the molecular form.

[0020] At least part of the melt may be fed to the electrolysis cell where the salt can act as the electrolyte for the electrolysis. The conditions in the electrolysis cell can be selected such that aluminiumsulphide is decomposed, thereby separating aluminium, while at the same time not decomposing alumina. The melt in the electrolysis cell is lower in aluminiumsulphide content but in practice unchanged in alumina and can be fed back into the conversion reactor.

[0021] Further, because of the lower cell voltage needed to decompose aluminiumsulphide as compared to the voltage needed to decompose alumina, inert electrodes with a long lifetime can be used.

[0022] A feature of the invention is also that at least part of the melt with dissolved aluminiumsulphide is fed to the separating reactor and at least part of the melt with dissolved reaction products from the step of separation in the separating reactor is fed into the conversion reactor. At least part of the melt from the conversion reactor is fed to the separating reactor, and at least part of the melt in the separating reactor is fed back into the conversion reactor, wherein feeding and feeding back is done in a continuous process.

[0023] An advantage is that the operating conditions in both the conversion reactor and in the separating reactor do not, or only to a small extent, vary in time. In the conversion reactor and in the separating reactor optimum conditions can be selected. Also there is no need to aim at a full conversion of alumina into aluminiumsulphide or a full separation of alumina from the aluminiumsulphide. The method according to the invention is therefore carried out as a continuous process. Conversely, the prior art process is a batch process. In the first step, all alumina should be converted into aluminiumsulphide, which is then batch-wise fed into the separating apparatus. In particular when the separation takes place in an electrolysis cell, the batch-wise addition of aluminiumsulphide disturbs the electrolysis and changes the operating condition of the cell.

[0024] An embodiment of the method of the invention is characterized in that the separating apparatus is a multi-pole electrolysis cell.

[0025] As the anode is not consumed in the electrolysis of aluminiumsulphide, a multipolar cell can be used which incorporates a series of anodes and cathodes in one single cell. An advantage is a far more compact cell design, thus reducing investment and operational costs. A second advantage is a reduction of ohmic losses, thus contributing to the energy efficiency of the process.

[0026] In a further embodiment according to the invention the electrolysis cell has a compact design and any

heat dissipation to the surroundings is minimised in order to use substantially all of the enthalpy from the ohmic losses as energy input to the sulphidation step.

[0027] A further embodiment of the method according to the invention is **characterized in that** the first step and the second step are performed or carried out in a reactor vessel operating as a single reactor.

[0028] In this embodiment the method of the invention can be carried out in a compact reactor which requires less volume and is less costly, both in construction and in operation, then separate reactors for steps one and two. Also transport problems as mentioned before are further mitigated.

[0029] A further advantage can be obtained in energy consumption. The conversion of alumina into aluminiumsulphide is an endothermic reaction. The separation of alumina from aluminiumsulphide, in particular in an electrolysis cell is connected with heat generation through energy dissipation in the electrolyte.

[0030] By supplying this generated heat to the conversion step, a high energy efficiency can be achieved. This is particularly so when at least part of the melt is made to circulate between the two steps using two reactors or a single integrated reactor.

[0031] In an embodiment the sulphur containing gas is substantially carbondisulphide (CS_2).

[0032] Another embodiment of the method of the invention is **characterized in that** the molten salt substantially comprises chloride salts, and preferably a mixture of NaCl and KCl. In particular NaCl and KCl are relatively inexpensive, its mixture, more in particular the eutectic composition, has a suitable melting point, a low vapour pressure in the proposed operational window of the process, and they are harmless under regular operating conditions.

[0033] Preferably the composition of the molten salt comprises in the range of between 30 and 70 wt.% NaCl and in the range of between 70 and 30 wt.% KCl.

[0034] A further embodiment of the method of the invention is **characterized in that** the melt of salt comprises a fluorine containing compound.

[0035] The suitable fluorine containing compound may include one or more compounds having a molecular formula $\text{Na}_a\text{AlF}_{a+3}$ and/or $\text{K}_a\text{AlF}_{a+3}$ ("a" being an integer equal to a greater than 1), such as NaAlF_4 , Na_2AlF_5 and Na_3AlF_6 , and KAlF_4 , K_2AlF_5 and K_3AlF_6 . The fluorine compound may further include one or more of: a simple mixture of NaF or AlF_3 , a simple mixture of KF or KF_3 , an eutectic mixture of NaF and AlF_3 , an eutectic mixture of KF and KF_3 , and a certain complex such as sodium-fluoraluminate or potassiumfluoraluminate. Any one of these fluxes may be selected, though two or more of them may be added in combination.

[0036] In a preferred embodiment fused sodium aluminiumfluoride, commonly called cryolite, or a mixture of cryolite and other fluorides is used.

[0037] Tests have shown that addition of fluorine containing compounds, such as cryolite, to the molten salt

has a very beneficial effect on the current density in an electrolyses cell at a given cell potential. An increase of a factor three or more as compared to a molten salt without cryolite, is achievable.

5 [0038] Although not intended to be bound to any particular mechanism, it is assumed that for, an efficient conversion of alumina into aluminiumsulphide, carbon and sulphur are required as reactants. Carbondisulphide contains both these elements and its manufacture and
10 processing is based on proven technology. Furthermore, carbondisulphide is a gas at the operational' conditions, thus facilitating the contact between the reactants. Carbondisulphide is also a compound that is substantially free of oxygen, as required for a good conversion as explained above.

15 [0039] Preferably the melt of salt is substantially free of alkaline earth metals or compounds thereof.

[0040] It has been shown that alkaline earth metals have a good affinity to sulphur and form sulphides before aluminiumsulphides can form. Therefore earth alkaline
20 metals have a detrimental effect on the efficiency of the sulphide containing gas.

[0041] Preferably the conversion reactor is a bubble column wherein the sulphide containing gas is fed into the lower portion thereof thereby forming bubbles which
25 rise in the bubble column.

[0042] Bubble columns per se are known in the process industry. They have the advantage of being based on a proven technology and they can be manufactured
30 in an embodiment suitable for the method of the invention.

[0043] An advantageous embodiment of the method according to the invention is **characterized in that** the bubbles rising in the bubble column are used to transport
35 at least part of the aluminiumsulphide containing melt to the separating apparatus.

[0044] Bubbles rising up in the bubble column lift molten salt with aluminiumsulphide dissolved therein. This lifting action can be used to transport aluminiumsulphide
40 from the bubble column to the separating reactor, thereby saving energy and reducing complexity of the total plant for the production of primary aluminium.

[0045] In a preferred embodiment the bubbles rising in the bubble column are used to provide at least part of the driving force to recirculate the melt between the
45 sulphidation and separation stages.

[0046] Yet another embodiment of the method according to the invention is **characterized in that** the conversion of alumina into aluminiumsulphide is carried out at
50 a temperature in a range of between 700°C and 1100°C, preferably in a range of between 800°C and 1000°C, more preferably in a range of between 800°C and 900°C.

[0047] Tests have shown that the conversion of alumina into aluminiumsulphide proceeds faster at higher temperature. However, it has also been found that for an efficient conversion γ -alumina is being preferred. At temperature above about 1100°C, γ -alumina transforms to α -alumina at a high rate. Therefore the temperature at

which the conversion is carried out is preferably chosen below about 1100°C, more preferably below about 1000°C and even more preferably below about 900°C.

[0048] On the other hand, to have a sufficiently high conversion rate, the temperature at which the conversion is done is preferably chosen above about 700°C, more preferably above 800°C.

[0049] Preferably the sulphidation process is carried out at a pressure above atmospheric pressure, preferably at a pressure above 2 bar, and more preferably at a pressure of 3 bar or more.

[0050] Tests have shown that the conversion rate of alumina into aluminiumsulphide increases with the partial pressure of the sulphide containing gas.

[0051] Therefore it is preferred to execute the method at above atmosphere pressure in the conversion reactor.

[0052] The invention is also embodied in an apparatus for carrying out the method according to the invention and comprising a bubble column suitable for converting alumina into aluminiumsulphide by a gaseous sulphur containing compound, feeding means for feeding the gaseous sulphur containing compound into the bottom portion of the bubble column, an electrolysis cell, a first connecting duct between the top portion of the bubble column and the electrolysis cell and a second connecting duct between the lower portion of the bubble column and the electrolysis cell.

[0053] A bubble column is a well-known reactor vessel embodying proven technology and suitable for reactions between a melt and a gaseous reactant. Advantageously, use can be made of the lifting effect of the rising bubbles to convey aluminiumsulphide to the electrolysis cell. For transport of molten salt from the bubble column to the electrolysis cell and in reverse direction, ducts are provided. It is noted that the ducts can be part of the two reactors, bubble column and the electrolysis cell, whereby these two reactors are then integrated into a single reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] The invention will now be illustrated with reference to a non-limiting embodiment according to the drawings in which:

Fig. 1 shows a basic diagram of an apparatus for the production of aluminium for alumina according to the invention;

Fig. 2 shows the decrease of the reaction rate as conversion proceeds for various temperatures according to the prior art;

Fig. 3 shows the effect of the reaction time (in minutes) on the conversion rate (in %) according to the present invention;

Fig. 4 shows the effect of the temperature (in °C) in the conversion reactor on the conversion rate (in %);

Fig. 5 shows the effect of the partial pressure (in bar) of carbonsulphide on the conversion rate (in %).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0055] In Fig. 1 reference number 1 refers to a conversion reactor, preferably in the form of a bubble column. Alumina is fed into the conversion reactor through alumina supply line 2. The conversion reactor 1 contains a bath 3 of molten salt. Through supply line 4 a sulphur and carbon containing gas, such as CS₂, is fed to the bottom portion of the conversion reactor 1. In the conversion reactor, alumina is dissolved in the molten salt and converted into aluminiumsulphide.

[0056] A two phase flow of bubbles, containing gaseous reagents and reaction products, dispersed in a liquid containing the molten salt, aluminiumsulphide and unconverted alumina, rises in the conversion reactor 1 and lifts the liquid to the first transfer duct 5 through which the components are conveyed to the separating reactor 6, here in the form of a multi-pole electrolysis cell. In the multi-pole electrolysis cell, aluminiumsulphide is decomposed into molten aluminium and gaseous sulphur. A bath of molten aluminium 7 is formed, which can be tapped off through tapping line 8. As the liquid is transported to the first transfer duct 5 by the gas lift in the bubble column, a similar amount of liquid is entrained from the second transfer duct 9. Thus the gas lift in the bubble column provides a driving force for the recirculation of the melt between the sulphidation and the separation reactor. Thus no external agents like pumps may be required.

[0057] Components present in the separating reactor 6 are fed back into the conversion reactor 1 through the second transfer duct 9. The components fed back into the conversion reactor may still contain alumina and not yet decomposed aluminiumsulphide.

[0058] Conversion reactor 1, first transfer duct 5, separating reactor 6 and second transfer duct 9 form a closed loop system in which molten salt, alumina and aluminiumsulphide circulate. First transfer duct 5 and second transfer duct 9 may be constructed such that they form part of one or both of the reactors leading to a single reactor in which both steps, conversion and separating, take place.

[0059] Gaseous sulphur from the separation step is fed back through sulphur return line 10 to the carbondisulphide plant 11. To this carbondisulphide plant 11 also reaction products or unreacted reactants from the conversion process, such as COS, CS₂ and S₂ are fed back through feed back line 12.

[0060] Make-up sulphur is fed to the carbondisulphide plant 11 through sulphur supply line 13; a carbon containing reactant, such as natural gas is fed to the carbondisulphide plant 11 through carbon supply line 14.

[0061] Through the energy, dissipated in the electrolysis cell, the components therein rise in temperature, such that the flow of components through the second transfer duct 9 have a higher temperature than the components conveyed through first transfer duct 5. As a typ-

ical value, a temperature rise from 790°C to 800°C can be mentioned.

[0062] This extra sensible heat can be used for the endothermic conversion of alumina into aluminium sulphide.

[0063] The components flowing through the first transfer duct 5 are high in aluminiumsulphide, the components flowing through the second transfer duct 9 are low in aluminiumsulphide.

EXAMPLES

[0064] Fig. 2 shows the effect of reaction time of the conversion rate for the sulphidation process according to the prior art disclosed in WO-00/37691. It is observed that the reaction rate slows down as conversion proceeds. Thus, the known process becomes less efficient for a high conversion ratio, while at the same time, a full conversion is desired for the subsequent separation process.

[0065] Fig. 3 shows the effect of the reaction time on the conversion ratio in a method according to the invention.

[0066] In this experiment gamma alumina was added to a salt mixture containing a eutectic composition of NaCl and KCl, and to which 10 wt.% of cryolite was added. The salt mixture was preheated to 850°C under argon atmosphere, and at t=0 a mixture of argon and CS₂ was supplied through a tube injected into the salt mixture from the top. The experiment was carried out at atmospheric pressure, the CS₂ partial pressure being about 0.70 bar. As can be seen, increase of reaction time has a positive effect on the conversion ratio. However, the conversion rate (amount of alumina converted per unit of time) remains substantially constant. This facilitates the tuning of the process towards its most efficient operational window, and reduces possible transient effects that may occur, for instance, during start up or as a consequence of changes in the alumina content of the melt.

[0067] Fig. 4 shows the measured effect of the temperature on the conversion ratio after 100 minutes. Apart from the temperature, all experimental conditions were identical to those described with figure 2. These measurements show that the temperature in the conversion reactor preferably lies in the range between about 800°C and about 1000°C.

[0068] Fig. 5 shows the effect of the partial pressure of carbondisulphide in the conversion reactor on the conversion rates after 100 minutes. Apart from the CS₂ partial pressure, all experimental conditions were identical to those described with Fig 2. This graph shows that considerable advantages can be achieved by operating the conversion reactor at a pressure above atmospheric pressure.

[0069] Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made without departing from the scope of the invention as set out in the ap-

pended claims.

Claims

1. Method for the continuous production of aluminium from alumina, the method comprising a first step of converting alumina (Al₂O₃) into aluminiumsulphide (Al₂S₃) and a second step of separation of aluminium from aluminiumsulphide in a separating reactor, and wherein in the first step in a conversion reactor alumina is dissolved in a molten salt to form a melt and a sulphur containing gas is fed through the melt whereby the sulphur containing gas acts as a reagent to convert at least part of the alumina into aluminiumsulphide and at least part of the melt is used in the second step, and wherein the separating apparatus is a electrolysis cell, and whereby the melt with the dissolved alumina and the aluminiumsulphide is continuously recirculated between the first and the second process step.
2. Method according to claim 1, wherein the separating apparatus is a multi-pole electrolysis cell.
3. Method according to any one of the preceding claims, wherein the first step and the second step are performed in a reactor vessel operating as a single reactor.
4. Method according to any one of the preceding claims, wherein the sulphur containing gas is substantially carbondisulphide.
5. Method according to any one of the preceding claims, wherein the molten salt substantially comprises chloride salts, preferably a mixture of NaCl and KCl.
6. Method according to any of the preceding claims, wherein the melt of salt comprises a fluorine containing compound, and preferably cryolite.
7. Method according to any one of the preceding claims, wherein the melt of salt is substantially free of alkaline earth metals or compounds thereof.
8. Method according to any one of the preceding claims, wherein the conversion reactor is a bubble column wherein the sulphide containing gas is fed into the lower portion thereof thereby forming bubbles which rise in the bubble column.
9. Method according to claim 8, wherein the bubbles rising in the bubble column are used to transport at least part of the aluminiumsulphide containing melt to the separating apparatus.

10. Method according to claim 9, wherein the bubbles rising in the bubble column are used to provide at least part of the driving force to recirculate the melt between the sulphidation and separation stages.
11. Method according to any one of the preceding claims, wherein the conversion of alumina into aluminiumsulphide is carried out at a temperature in a range of between 700°C and 1100°C, preferably in a range of between 800°C and 1000°C, more preferably in a range of between 800°C and 900°C.
12. Method according to any one of the preceding claims, wherein the sulphidation process is carried out at a pressure above atmospheric pressure, and preferably at a pressure of 3 bar or more.
13. Apparatus for the use with a method according to any one of the preceding claims comprising:
- a bubble column suitable for converting alumina into aluminiumsulphide by a gaseous sulphur containing compound,
 - a feeder for feeding the gaseous sulphur containing compound into the bottom portion of the bubble column,
 - an electrolysis cell,
 - a first connecting duct between the top portion of the bubble column and the electrolysis cell,
 - and a second connecting duct between the lower portion of the bubble column and the electrolysis cell.

Patentansprüche

1. Verfahren zur kontinuierlichen Produktion von Aluminium aus Aluminiumoxid, wobei das Verfahren einen ersten Schritt eines Umwandelns von Aluminiumoxid (Al_2O_3) in Aluminiumsulfid (Al_2S_3) und einen zweiten Schritt einer Trennung von Aluminium von Aluminiumsulfid in einem Trennreaktor umfaßt, und wobei in dem ersten Schritt in einem Umwandlungsreaktor Aluminiumoxid in einem geschmolzenen Salz gelöst wird, um eine Schmelze auszubilden, und schwefelhaltiges Gas durch die Schmelze geleitet wird, wodurch das schwefelhaltige Gas als ein Reagenz wirkt, um wenigstens einen Teil des Aluminiumoxids in Aluminiumsulfid umzuwandeln, und wenigstens ein Teil der Schmelze in dem zweiten Schritt verwendet wird, und wobei die Trennvorrichtung eine Elektrolysezelle ist, und wobei die Schmelze mit dem gelösten Aluminiumoxid und dem Aluminiumsulfid kontinuierlich zwischen dem ersten und dem zweiten Verfahrensschritt recirkuliert wird.
2. Verfahren nach Anspruch 1, wobei die Trennvorrichtung eine Mehrpol-Elektrolysezelle ist.

3. Verfahren nach einem der vorhergehenden Ansprüche, wobei der erste Schritt und der zweite Schritt in einem Reaktorkessel durchgeführt werden, welcher als ein Einzelreaktor arbeitet.
4. Verfahren nach einem der vorhergehenden Ansprüche, wobei das schwefelhaltige Gas im wesentlichen Schwefeldisulfid ist.
5. Verfahren nach einem der vorhergehenden Ansprüche, wobei das geschmolzene Salz im wesentlichen Chloridsalze, vorzugsweise eine Mischung aus NaCl und KCl umfaßt.
6. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Salzschnmelze eine fluorhaltige Verbindung, und vorzugsweise Cryolit enthält.
7. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Salzschnmelze im wesentlichen frei von Erdalkalimetallen oder Verbindungen derselben ist.
8. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Umwandlungsreaktor ein Blasenturm ist, wobei das schwefelhaltige Gas in den unteren Abschnitt desselben zugeführt wird, wodurch Blasen gebildet werden, welche in dem Blasenturm bzw. der Blasensäule ansteigen.
9. Verfahren nach Anspruch 8, wobei die Blasen, die in dem Blasenturm aufsteigen, verwendet werden, um wenigstens einen Teil der aluminiumsulfidhaltigen Schmelze zu der Trennvorrichtung zu transportieren.
10. Verfahren nach Anspruch 9, wobei die Blasen, die in dem Blasenturm ansteigen, verwendet werden, um wenigstens einen Teil der Antriebskraft zum Rezirkulieren der Schmelze zwischen der Sulfidierungs- und der Trennstufe zur Verfügung zu stellen.
11. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Umwandlung von Aluminiumoxid in Aluminiumsulfid bei einer Temperatur in einem Bereich zwischen 700 °C und 1100 °C, vorzugsweise in einem Bereich zwischen 800 °C und 1000 °C, noch bevorzugter in einem Bereich zwischen 800 °C und 900 °C ausgeführt wird.
12. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Sulfidierungsverfahren bei einem Druck über Atmosphärendruck, und vorzugsweise bei einem Druck von 3 bar oder mehr ausgeführt wird.
13. Vorrichtung zur Verwendung mit einem Verfahren gemäß einem der vorhergehenden Ansprüche, um-

fassend:

einen Blasenturm, der für ein Umwandeln von Aluminiumoxid in Aluminiumsulfid durch eine gasförmige schwefelhaltige Verbindung geeignet ist,
eine Zufuhreinrichtung zum Zuführen der gasförmigen schwefelhaltigen Verbindung in den Bodenabschnitt des Blasenturms,
eine Elektrolysezelle,
eine erste Verbindungsleitung zwischen dem oberen Abschnitt des Blasenturms und der Elektrolysezelle,
und eine zweite Verbindungsleitung zwischen dem unteren Abschnitt des Blasenturms und der Elektrolysezelle.

Revendications

1. Procédé pour la production continue d'aluminium à partir d'alumine, procédé comprenant une première étape de conversion de l'alumine (Al_2O_3) en sulfure d'aluminium (Al_2S_3) et une seconde étape de séparation de l'aluminium vis-à-vis du sulfure d'aluminium dans un réacteur de séparation, et cependant, dans la première étape et dans un réacteur de conversion l'alumine est dissoute dans un sel fondu pour former une masse en fusion et un gaz contenant du soufre est alimenté à travers la masse en fusion, grâce à quoi le gaz contenant du soufre fait office de réactif pour convertir au moins une partie de l'alumine en sulfure d'aluminium, et au moins une partie de la masse en fusion est utilisée dans la seconde étape, et dans lequel l'appareil de séparation est une cellule d'électrolyse, et cependant la masse en fusion avec l'alumine dissoute et le sulfure d'aluminium est mise continuellement en recirculation entre la première et la seconde étape du procédé.
2. Procédé selon la revendication 1, dans lequel appareil de séparation est une cellule d'électrolyse multipolaire.
3. Procédé selon l'une quelconque des revendications précédentes, dans lequel la première étape et la seconde étape sont exécutées dans un récipient réacteur fonctionnant comme un réacteur unique.
4. Procédé selon l'une quelconque des revendications précédentes, dans lequel le gaz contenant du soufre est sensiblement du disulfure de carbone.
5. Procédé selon l'une quelconque des revendications précédentes, dans lequel le sel en fusion comprend sensiblement des sels de chlorure, de préférence un mélange de NaCl et KCl.
6. Procédé selon l'une quelconque des revendications précédentes, dans lequel le sel en fusion comprend un composé contenant du fluor, et de préférence de la cryolite.
7. Procédé selon l'une quelconque des revendications précédentes, dans lequel le sel en fusion est sensiblement dépourvu de métaux alcalino-terreux ou de composés de ceux-ci.
8. Procédé selon l'une quelconque des revendications précédentes, dans lequel le réacteur de conversion est une colonne à bulles dans laquelle le gaz contenant du soufre est alimenté dans la portion inférieure de la colonne, en formant ainsi des bulles qui montent dans la colonne à bulles.
9. Procédé selon la revendication 8, dans lequel les bulles qui montent dans la colonne à bulles sont utilisées pour transporter au moins une partie de la masse en fusion contenant du sulfure d'aluminium vers l'appareil de séparation.
10. Procédé selon la revendication 9, dans lequel les bulles qui montent dans la colonne à bulles sont utilisées pour fournir au moins une partie de la force d'entraînement pour mettre en recirculation la masse en fusion entre l'étage de sulfuration et l'étage de séparation.
11. Procédé selon l'une quelconque des revendications précédentes, dans lequel la conversion d'alumine en sulfure d'aluminium est effectuée à une température dans une plage entre 700°C et 1100°C, de préférence dans une plage entre 800°C et 1000°C, de façon plus préférée dans une plage entre 800°C et 900°C.
12. Procédé selon l'une des revendications précédentes, dans lequel le processus de sulfuration est effectué à une pression au-dessus de la pression atmosphérique, et de préférence à une pression de 3 bar ou plus.
13. Appareil destiné à être utilisé avec un procédé selon l'une quelconque des revendications précédentes, comprenant :
une colonne à bulles appropriée pour convertir de l'alumine en sulfure d'aluminium par un composé gazeux contenant du soufre,
un moyen d'alimentation pour alimenter le composé gazeux contenant du soufre dans la portion inférieure de la colonne à bulles,
une cellule d'électrolyse,
un premier conduit de liaison entre la portion supérieure de la colonne à bulles et la cellule d'électrolyse,

et un second conduit de liaison entre la portion inférieure de la colonne à bulles et la cellule d'électrolyse.

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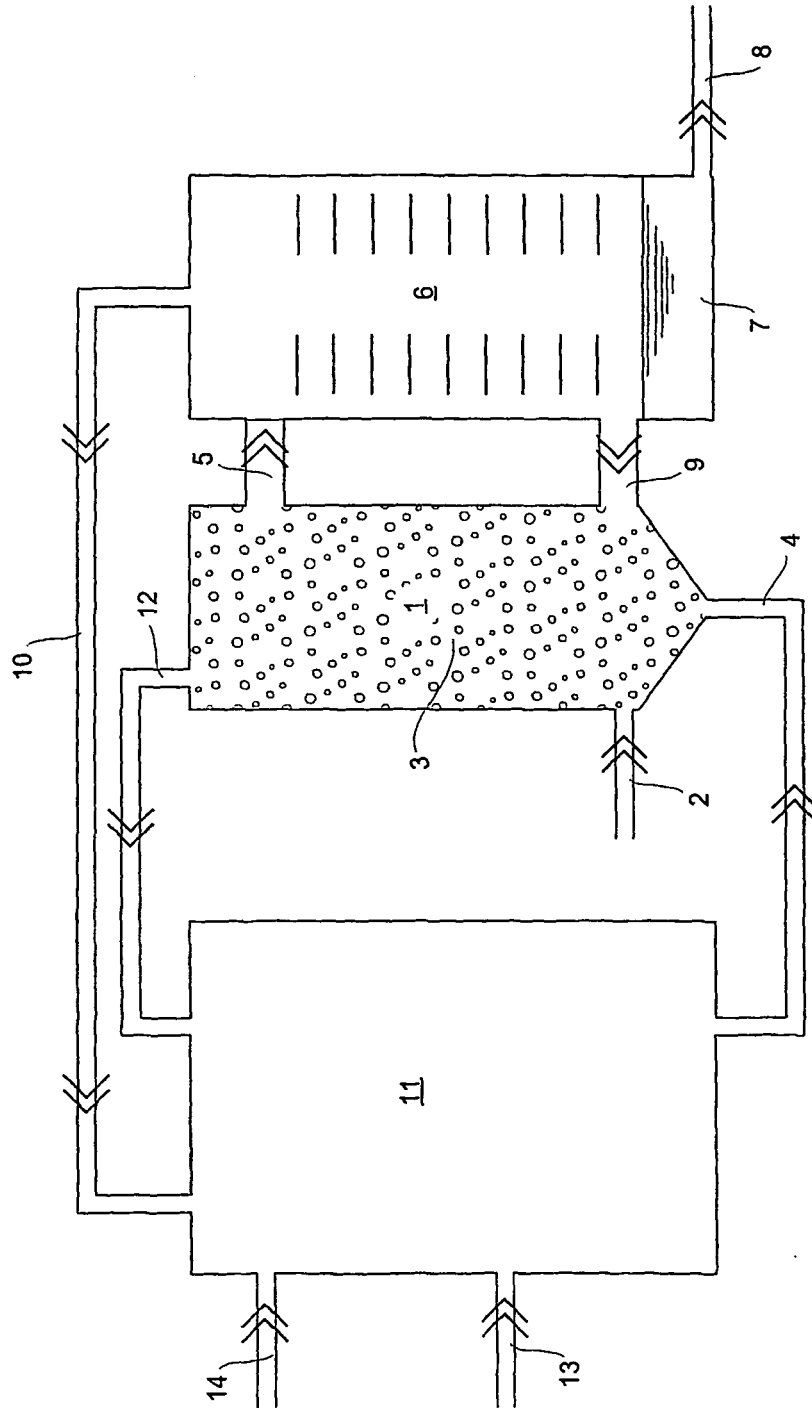


Fig. 1

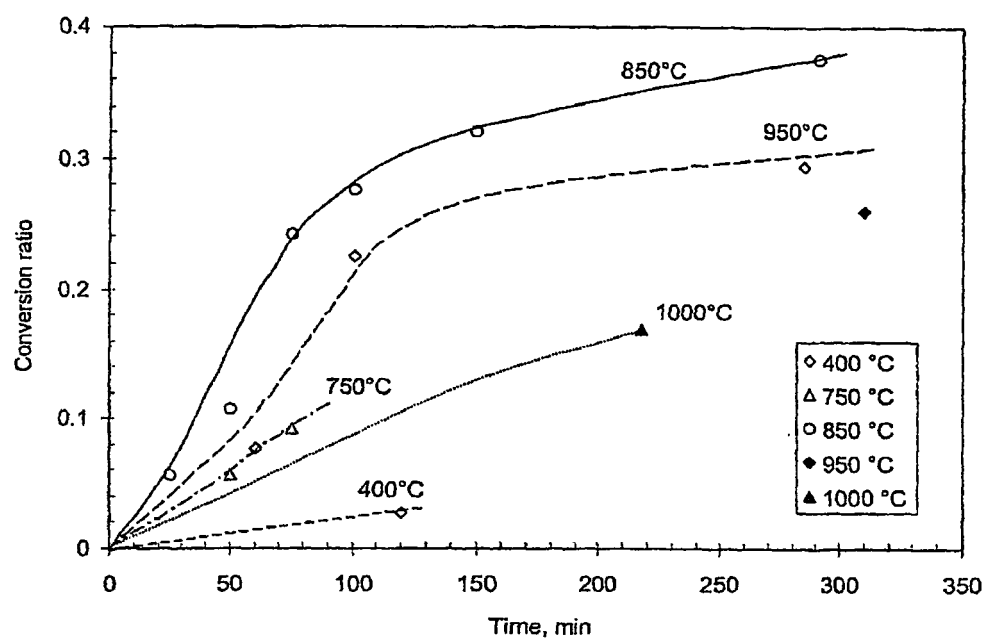


Fig. 2

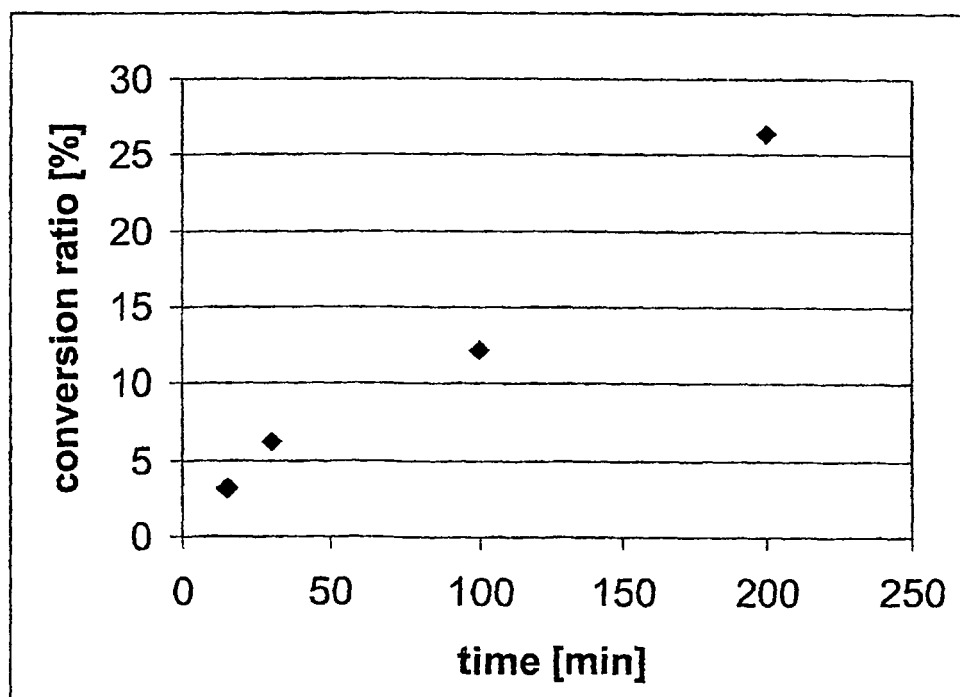


Fig. 3

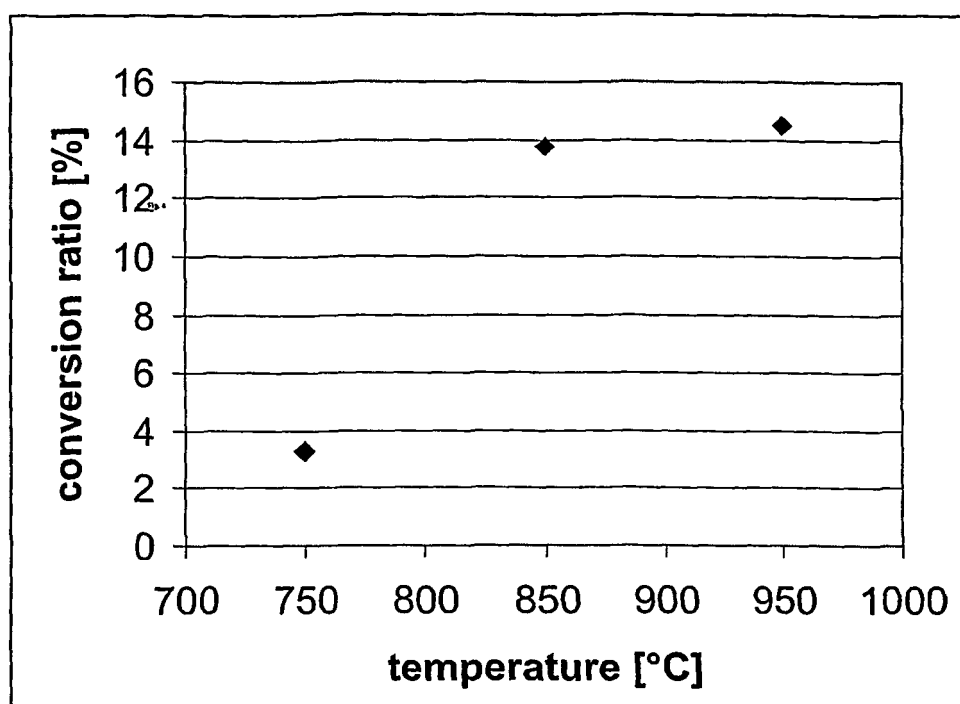


Fig. 4

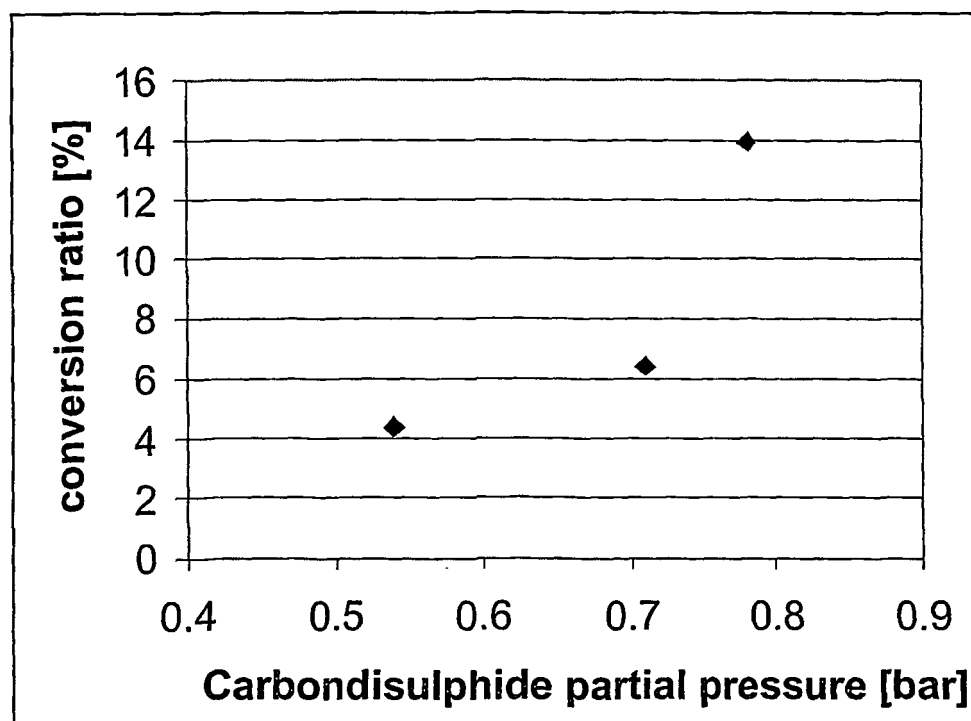


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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