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(54) **ELECTROLYTIC CELL WITH IMPROVED FEED DEVICE**

ELEKTROLYSEZELLE MIT VERRBESSERTER ZUFUHRVORRICHTUNG

CELLULE ELECTROLYTIQUE A DISPOSITIF D'ALIMENTATION AMELIORE

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Description

Field of the Invention

[0001] The present invention relates to a cell for the electrowinning of a metal from a compound thereof dissolved in a molten electrolyte. The cell is fitted with a device for feeding particulate of the metal compound over to the molten electrolyte.

Background of the Invention

[0002] The feed device of the invention can be used in various molten salt electrolysis cells in particular for aluminium electrowinning.

[0003] The technology for the production of aluminium by the electrolysis of alumina, dissolved in molten cryolite containing salts, at temperatures around 950°C is more than one hundred years old and has not undergone any great change or improvement, in particular in the way in which alumina is fed to the molten electrolyte for its subsequent dissolution and electrolysis.

[0004] Conventional cells are usually operated with a crust of frozen electrolyte above the molten electrolyte. This crust needs to be periodically broken to form an opening for feeding alumina into the molten electrolyte situated underneath. Various systems have been provided to locally break the frozen electrolyte crust and feed alumina into the molten electrolyte, for instance as described in US Patents 3'664,946 (Schaper/Springer/Kyburz), 4,049,529 (Golla), 4,437,964 (Gerphagnon/Wolter), 5,045,168 (Dalen/Kvalavag/Nagell), 5,108,557 (Nordquist), 5,299,318 (Grant/Kristoff), 5,324,408 and 5,423,968 (both in the name of Kissane).

[0005] One drawback of feeding alumina to the molten electrolyte by initially breaking the electrolyte crust resides in the introduction of a mass of frozen electrolyte into the molten electrolyte which generates a thermal shock therein. Moreover, after the crust is broken cold alumina is added to the molten electrolyte which freezes the bath, forming dense alumina and/or electrolyte aggregates increasing the chance of sludging.

[0006] With the trend towards automated systems, the frequency of feeding alumina has been increased. Feeding may take place every 20 to 90 min., sometimes even shorter, for instance every 1 to 5 min. as described in US Patent 3,673,075 (Kibby), while smaller amounts of alumina are introduced with each feed. The advantages are in particular maintaining a more constant concentration of dissolved alumina in the electrolyte and reducing the temperature variation in the electrolyte. A typical automated break and feed system comprises a pneumatically-operated crust breaker beam and an ore bin capable of discharging a fixed amount of alumina (K. Grjotheim & B. J. Welsh, "Aluminium: Smelter Technology", 1988, 2nd Edition, Aluminium Verlag GmbH, D-4000 Düsseldorf 1, pp. 231-232).

[0007] US Patent 5,476,574 (Welsh/Stretch/Purdie)

discloses a feeder arranged to continuously feed alumina to an aluminium electrowinning cell. The feeder is associated with a point breaker which is operated to maintain a hole in a frozen electrolyte crust on the surface of the molten electrolyte.

[0008] In order to enhance dispersion, dissolution and control of the amount of fine particulate alumina fed to the electrolytic bath, various alumina feed devices have been developed involving fluidisation of alumina powder by using compressed gas such as compressed air, for instance as disclosed in US Patents 3,901,787 (Niizeki/Watanabe/Yamamoto/Takeuchi/Kubota), 4,498,818 (Gudmundur/Eggertsson) and 4,525,105 (Jaggi).

[0009] Despite substantial efforts to enhance the feeding of alumina as described above, feeding is still locally limited to one or more feeding points over the electrolytic bath between suspended carbon anode blocks using vertical point feeders. Furthermore, the above described processes still necessitate to periodically form or continuously maintain as many holes in the frozen electrolyte crust above the molten bath as there are feeding points.

[0010] WO03/006717 (Berclaz/Duruz) discloses a device for feeding alumina to a thermally insulated aluminium electrowinning cell in which metered quantities of alumina are dropped from a dosing system onto a divider that divides the metered quantities into batches and that directs these batches into a plurality of feeding tubes which guide the batches to different areas of the cell's molten electrolyte.

[0011] Dispersive spraying of alumina has been proposed for crustless aluminium production cells. WO00/63464 (de Nora/Berclaz) discloses an aluminium electrowinning cell with a thermally insulated crustless molten electrolyte and inter-alia an alumina feeding tube extending horizontally above the molten electrolyte. The feeding tube has a series of openings along its length for spraying sideways alumina fed along the tube.

[0012] Despite the improvement of the different alumina spraying systems disclosed in WO00/63464 and WO03/006717, there is still a need to simplify and enhance the spraying of a particulate feed, e.g. alumina, over the molten electrolyte of a cell for the electrowinning of a metal, such as aluminium.

Objects of the Invention

[0013] It is an object of the invention to provide a cell for the electrowinning of a metal, such as aluminium, fitted with a simple feeder of a compound of the metal, such as alumina, designed to deliver, in particular dispersing, the compound as a particulate over the cell's molten electrolyte.

[0014] A further object of the invention is to provide a cell for the electrowinning a metal, such as aluminium, fitted with a feeder of a compound of the metal, such as alumina, designed to operate with a substantially crustless molten electrolyte.

[0015] Another object of the invention is to provide a

cell for the electrowinning of a metal, such as aluminium, fitted with a feeder of a compound of the metal, such as alumina, designed to deliver the pre-heated compound to the molten electrolyte to minimise the risk of sludging and enhance dissolution of the delivered particulate.

[0016] Yet another object of the invention is to provide a cell for the electrowinning of a metal, such as aluminium, fitted with a feeder of a compound of the metal, such as alumina, designed to continuously or intermittently deliver the compound as a particulate to the molten electrolyte.

Summary of the Invention

[0017] The invention relates to a cell for the electrowinning of a metal from a compound thereof dissolved in a molten electrolyte. The cell comprises: a thermally insulated cell trough and a thermally insulated cell cover which are arranged to contain an electrolyte and maintain it in a substantially crustless molten state; means for feeding a particulate of the metal compound to the molten electrolyte comprising at least one feeding tube extending into the cell trough and having a tubular end portion which is located between the molten electrolyte and the insulating cell cover and which has a substantially horizontal axial direction, these means being arranged to feed the particulate into the feeding tube, along the feeding tube and through an opening in the tubular end portion from where it is delivered over the molten electrolyte.

[0018] In accordance with the invention, the opening is located at an end of the tubular end portion and is arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion. The end opening may be coaxial with the tubular end portion or it may be off-axis. The feeding tube can be substantially linear or gradually curved. As explained below, feeding tubes whose shape cause the particulate to be driven around corners or other sharp angles should be avoided along the feeding tube.

[0019] The axial direction of the tubular end portion is usually horizontal or at an angle of up to $\pm 15^\circ$ to the horizontal. In average, the particulate exits the tubular end portion along its axial direction or at a small angle thereto, typically up to 15° or 20° .

[0020] The feeding means of the invention can be used to disperse the particulate of the metal compound over an entire expanse of the surface of the electrolyte, which facilitates dissolution of the particulate in the electrolyte by avoiding or reducing local saturation of the electrolyte with the metal compound.

[0021] In other words, the particulate is delivered over at least an entire portion of the surface of the electrolyte (hereinafter sometimes referred to as the "feeding area") whose size is substantially greater than that with conventional point feeders. Thus, the particulate fed with this feeder is spread over a substantially greater surface of molten electrolyte and can much easier dissolve. Typi-

cally, the expanse of this portion is of at least 0.1 m^2 , usually 0.5 or 1 or 2 m^2 to 6 or 10 m^2 or more.

[0022] According to the invention, the particulate delivered from the feeding tube over the molten electrolyte is driven along the tube and exits the tube through the end opening over the electrolyte substantially along the axial direction of the tube. This provides an improvement over the abovementioned WO00/63464's feeding device regarding the simplified tube design and the straight delivering of the particulate as it is not fed like in WO00/63464 through lateral openings in a direction orthogonal to the tube's horizontal axis, which leads to a loss of velocity of the particulate as it exits the tube and increases the risk of clogging the lateral openings.

[0023] Especially for large or industrial cells in which alumina is preferably delivered at several different locations, the feeding means may comprise a plurality of tubular end portions, each end portion having a substantially horizontal axial direction and an end opening arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion. Several tubular end portions, in particular fan-shaped end portions, can be part of the same feeding tube.

[0024] For the same reason, the feeding means can comprise a plurality of feeding tube, each having a tubular end portion with an end opening for delivering the particulate.

[0025] The feeding means usually comprise a gas flow generator to fluidise the particulate in the feeding tube and to feed the fluidised particulate through the end opening of the end portion over the molten electrolyte. Fluidising the particulate enhances its flow along the feeding tube and its dispersion when delivered over the molten electrolyte.

[0026] Advantageously, the feeding means are arranged to feed and disperse the particulate over substantially the entire molten electrolyte, if necessary using feeding means with several tubular end portions and optionally several feeding tubes.

[0027] The cell cover above the molten electrolyte is placed and spaced above the surface of the molten electrolyte, for instance as disclosed in WO99/02763 (de Nora/Sekhar), WO02/070784 and US2003/0102228 (both de Nora/Berclaz). Such cover thermally insulates the surface of the molten electrolyte and substantially prevents formation of an electrolyte crust on the molten electrolyte. The thermally insulated cavity thereby created between the molten electrolyte and the cover serves to house the feeding means.

[0028] Furthermore, there is no need to remove the feeding means from under the cell cover. Normally the means is permanently located under the cover which can remain sealed off while the particulate is fed to the molten electrolyte to avoid thermic losses. Conversely, conventional feeders are located above the crust of molten electrolyte, the crust being periodically broken to permit alumina feeding from above the crust into the molten elec-

trolyte.

[0029] The feeding tube can extend into the cell trough through a cell sidewall or through the cell cover. In the latter case, the feeding tube preferably extends through a fixed section of the cell cover, or between a movable cover section and a fixed cover section, or between movable cover sections, so that the feeding tube which extends through the cover does not require to be removed when movable cover sections are moved away to uncover the molten electrolyte, as disclosed in the abovementioned US2003/0102228.

[0030] The cell cover is normally arranged to inhibit formation of an electrolyte crust on the surface of the molten electrolyte during operation. However, the surface of the electrolyte does not need to be entirely crust free, but at least the feeding area should be free from any frozen electrolyte crust for optimal operation.

[0031] Usually, the feeding means comprise a fan or a blower for driving the particulate along the feeding tube and through the end opening with gas, in particular hot gas, e.g. air such as hot dry air.

[0032] Also, to overcome a prior art prejudice when electrolysis is carried out at high temperature which is for instance the case for aluminium electrowinning, it is preferred to supply preheated particulate to the molten electrolyte to minimise electrolyte freezing caused by contact with "cold" solid particulate and by the possibly endothermic dissolution reaction of the particulate in the molten electrolyte which for instance happens with the dissolution of alumina. Ideally, the fed particulate supplies at least part of the energy needed for its dissolution. Heat may be provided to the particulate during the feeding process by contact with hot air, by using a heater or possibly with a burner providing a flame which may also be used to drive the particulate along the feeding tube. The particulate may be preheated before feeding, for instance by heating a reservoir in which it is stored and from which it is delivered through the feeding tube to the molten electrolyte. More generally, the particulate may be heated before and/or during delivery.

[0033] Therefore, the feeding means preferably associated with a heater arranged to heat the particulate before it is delivered from the end opening over the molten electrolyte.

[0034] In one embodiment, the cell of the invention is an aluminium electrowinning cell and the molten electrolyte is a fluoride-based electrolyte. The aluminium electrowinning cell can have one or more oxygen-evolving anodes, in particular metal-based or ceramic-based anodes, or possibly consumable carbon anodes.

[0035] An oxygen-evolving anode of the aluminium production cell may comprise an active anode structure having through-openings for the flow of alumina-depleted electrolyte from below to above the anode and/or through-openings for the flow of alumina-enriched electrolyte from above to below the anode.

[0036] In this case, the feeding means can be arranged to deliver and disperse alumina over an expanse which

includes at least part of the perpendicular projection onto the molten electrolyte surface of an active anode structure. The size of the expanse may be at least a tenth or a fifth of the surface area of the anode structure, in particular from a quarter to a half of the full surface area. Typically, the size of the expanse is at least 0.1 m², usually 0.5 or 1 or 2 m² to 6 or 10 m² or more.

[0037] Conveniently, the size of this expanse corresponds approximately to the perpendicular projection on the surface of the molten electrolyte of the active anode surface. For example, the expanse covers entirely or at least partly the perpendicular projection onto the molten electrolyte surface of an active anode structure. The alumina feeding area may correspond to the feeding area on the surface of the molten electrolyte of one anode or several anodes.

[0038] In one embodiment, the anode feeding area corresponds to a projection onto the surface of the electrolyte of the active anode surfaces, this projection possibly being smaller or greater than the corresponding area(s) of the active anode surfaces. This anode feeding area is usually, but not necessarily, situated directly above the active anode surfaces.

[0039] The alumina feeding area typically occupies an expanse of the molten electrolyte surface which can be about the same size as the surface area of the corresponding active anode surfaces. However, when anodes co-operate with special electrolyte circulation means, for instance as disclosed in co-pending application WO00/40782 (de Nora), the size of the feeding area may be smaller than the actual size of the active anode surfaces. In practice, powder alumina may even be supplied over substantially the entire surface of the molten electrolyte. This is particularly advantageous in configurations where at least part of the alumina-rich electrolyte flows through the open anode structures to the inter-electrode gap.

[0040] At least part of the alumina-rich electrolyte may flow down around the open anode structures into the inter-electrode gap to be electrolysed and then alumina-depleted electrolyte can rise to the feeding area through the open anode structures.

[0041] Whether or not alumina flows around the anodes, alumina dissolution is improved with such an alumina feeding device. The improvement is not bound to a specific electrolyte circulation path. Either alumina-rich electrolyte flows from the feeding area down through the anode structure, or alumina-depleted electrolyte flows through the anode structure up to the feeding area, or both flow patterns are combined.

[0042] The concept of this invention may be adapted to any aluminium electrowinning cell and is particularly suitable for cells operating with metal-based anodes at reduced temperatures, typically below 940°C, such as in the range of 730° to 910°C or 850° to 880°C, for instance cells as disclosed in WO00/40781, WO00/40782 and WO03/006716 (all in the name of de Nora) operating with metal-based oxygen-evolving grid-like anodes provided

with vertical through openings for the circulation of electrolyte and the escape of anodically produced oxygen.

[0043] Suitable materials for oxygen-evolving anodes include iron and nickel based alloys which may be heat-treated in an oxidising atmosphere as disclosed in WO00/06802, WO00/06803 (both in the name of Duruz/de Nora/Crottaz), WO00/06804 (Crottaz/Duruz), WO01/42534 (Duruz/de Nora) WO01/42535 (de Nora/Duruz) WO01/42536 (Duruz/Nguyen/de Nora), WO02/083991 and WO03/078695 (both Nguyen/de Nora). Further oxygen-evolving anode materials are disclosed in WO99/36593, WO99/36594, WO00/06801, WO00/06805, WO00/40783 (all in the name of de Nora/Duruz), WO00/06800 (Duruz/de Nora), WO99/36591, WO99/36592 (both in the name of de Nora) and WO03/087435 (Nguyen/de Nora).

[0044] The anode can comprise an applied cerium oxyfluoride-based outermost coating, for example as disclosed in WO02/070786 (Nguyen/de Nora) and WO02/083990 (de Nora/Nguyen). Such a coating may be applied before or during use and maintained during use by the presence of cerium species in the electrolyte.

[0045] Advantageously, the aluminium electrowinning cell comprises an aluminium-wettable cathode, in particular a carbon cathode covered with an aluminium-wettable coating to increase the lifetime of the cathode. The cathode may be a drained cathode whereby the anode-cathode gap and the voltage drop through the electrolyte can be reduced.

[0046] Suitable cell bottoms for aluminium production are for example disclosed in WO00/63463 (de Nora), WO01/31086 (de Nora/Duruz), WO01/31087 (Duruz/de Nora), WO01/42168 (de Nora/Duruz), WO01/42531 (Nguyen/Duruz/de Nora), WO02/096831 (Nguyen/de Nora), EP 1 146 146 (de Nora), WO02/070783, WO02/070785, WO02/097169, WO03/023091, WO02/097168 (all de Nora) and WO03/083176 (de Nora/Nguyen).

[0047] Another aspect of the invention relates to a method of electrowinning a metal from a compound thereof dissolved in a substantially crustless molten electrolyte. This method comprises: feeding particulate of the metal compound into and along a feeding tube having a substantially horizontally tubular end portion extending over the substantially crustless molten electrolyte, and delivering the particulate through an opening in the tubular end portion over the molten electrolyte where it is dissolved and then electrolysed to produce said metal.

[0048] In accordance with the invention, the particulate is delivered over the substantially crustless molten electrolyte from the feeding tube substantially along the axial direction of the tubular end portion through the opening which is located at an end of the tubular end portion. The particulate can be delivered continuously or in batches to the electrolyte.

[0049] In one embodiment, the particulate is alumina and the produced metal is aluminium.

[0050] Bayer-process alumina or other suitable grades

of alumina, may be utilised. For instance, partly dehydrated alumina particles, modified alumina, and alumina particles of different shapes and sizes may be used. To enhance dispersion of the alumina powder above the molten electrolyte surface, and to facilitate its dissolution into the molten electrolyte, the alumina powder is preferably composed of particles in the range of 20 to 200 micron, preferably from 30 to 50 micron.

[0051] As discussed above, aluminium production cells operated at reduced temperatures should have an insulating cover above the molten electrolyte, since at such temperatures, the molten electrolyte does not usually form a rigid crust but a gel-like layer.

[0052] However, in a modification of the invention in which the molten electrolyte of a metal electrowinning cell is not crustless, for instance when an aluminium production cell is operated at a conventional temperature (i.e. around 950°C), the cell cover can include or be made of an electrolyte crust formed by electrolyte freezing. The crust should be sufficiently spaced from the molten electrolyte to permit the insertion of the feeding means between the molten electrolyte and the crust. This can be achieved for example by removing part of the molten electrolyte from the cell after formation of the crust to form a cavity for the feeding means between the remaining molten electrolyte and the crust.

[0053] The invention also relates to a cell for the electrowinning of a metal, such as aluminium, from a compound thereof, e.g. alumina, dissolved in a molten electrolyte. The cell comprises means for feeding a particulate of the metal compound to the molten electrolyte. These feeding means comprise at least one feeding tube having a tubular end portion which is located above the molten electrolyte and which has a substantially horizontal axial direction. Such means are arranged to feed the particulate into the feeding tube, along the feeding tube and through an opening in the tubular end portion from where it is delivered over the molten electrolyte.

[0054] In accordance with the invention, this opening is located at an end of the tubular end portion and is arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion. The cell of the invention may incorporate any of the above described cell feature or combination of features.

Brief Description of the Drawings

[0055] The invention will be further described by way of example with reference to the accompanying schematic drawing, in which Figure 1 illustrates a drained-cathode cell having an aluminium collection reservoir in accordance with the invention.

Detailed Description

[0056] The aluminium electrowinning cell shown in Figure 1 comprises a cathodic bottom 10, thermally in-

ulated cell sidewalls 20 and a thermally insulated cell cover 30 which are arranged to contain an electrolyte 40 and maintain it in a substantially crustless molten state, and alumina feeders 50 for feeding alumina 60 to the molten electrolyte 40.

[0057] Each alumina feeder 50 has at least one feeding tube 51 extending through a sidewall 20 into the cell trough and having a horizontal tubular end portion 52 which is located between the molten electrolyte 40 and the insulating cell cover 30. The feeder 50 is arranged to feed particulate alumina 60 into the feeding tube 51, along the feeding tube 51 and through an opening 53 in the tubular end portion 52 from where it is delivered over the molten electrolyte 40.

[0058] According to the invention, the opening 53 is located at the end of the tubular end portion 52 and is arranged to deliver the particulate alumina 60 from the feeding tube 51 over the molten electrolyte 40 substantially along the axial direction of the tubular end portion 51.

[0059] The feeder 50 comprises an alumina reservoir 54 which is connected to the feeding pipe 51 through a supply pipe 56 in which a vertical Archimedes' screw 55 doses the particulate alumina 60 fed from the reservoir to the feeding pipe 51.

[0060] The feeding pipe 51 is also connected to a compressed hot gas source 57, such as a fan or blower, for driving particulate alumina 60 along the feeding tube 51 and through the opening 53 at the end of tubular end portion 52.

[0061] The cathode bottom 10 is drained with the cathodic surface coated with a slurry-applied aluminium-wettable layer 11, for instance as disclosed in the abovementioned WO01/42168, WO01/42531 and WO02/096831. The aluminium-wettable cathode layer 11 forms a drained cathode surface on the cathode bottom 10.

[0062] Furthermore, the cathode bottom has a recessed groove 12 for collecting and storing product aluminium 70 that is drained on the aluminium-wettable cathode layer 11. The collected product aluminium 70 can be periodically tapped from the recessed groove 12 by using a conventional tapping system.

[0063] The anodes 15 comprise an electrochemically active structure 16 made of oxygen-evolving material, as disclosed above. The active anode structure 16 is provided with a series of vertical through openings for the fast release of anodically produced oxygen and for the down flow of alumina-rich electrolyte into the anode-cathode gap for electrolysis, for example as described in the abovementioned WO00/40781, WO00/40782 and WO03/006716.

[0064] The thermally insulating cover 30 is fitted on the cell and maintains the surface of the electrolyte 40 at a sufficient temperature to inhibit formation of a crust thereon, for instance as disclosed in WO99/02763 (de Nora/Sekhar) and USSN2003/0102228 (de Nora/Berclaz). Cover 30 can be made of ceramic-based materials, such

as alumina, for instance as disclosed in WO02/070784 (de Nora/Berclaz).

[0065] The ceramic cell cover 30 comprises a support section 31 which extends centrally along the cell and lateral movable sections 34 which rest on the sidewalls 20 and the support section 31. The lateral cover sections 34 can be moved whenever access is needed to the molten electrolyte 40, e.g. for tapping, to the anodes 15, e.g. when they need to be replaced, or for any other reason.

The lateral cover sections 34 can be made of a plurality of side-by-side sections which are individually movable so that whenever the area below the cover must be accessed, only a small section of the cover 30 can be removed which permits a reduction of the thermal losses.

[0066] The central support section 31 is suspended from horizontal beams 33 through suspension elements 32 made of ceramic materials, e.g. alumina, resistant to electrolyte fumes present above the molten electrolyte. Each suspension element 32 has a bottom part that extends through the support section 31 and is shaped such that the support section 31 rests thereon. As shown in Figure 1, the bottom part of the suspension member 32 is upwardly tapered, e.g. generally conical or pyramidal, so that the components can be easily assembled or disassembled. The suspension members 32 can have various shapes.

[0067] The cell is covered with a steel shell 35 located above the insulating cover 30. The steel shell 35 is fitted with a gas exhaust pipe 36. The steel shell 30 collects gases, such as oxygen and electrolyte fumes, produced during electrolysis which gases are then evacuated through the exhaust pipe 36.

[0068] During operation, a continuous or intermittent controlled supply of particulate alumina 60 is provided from the alumina reservoir 54 to the feeding pipe 51 by rotating Archimedes' screw 55. Alumina 60 is then fluidised and driven by compressed gases supplied by gas source 57 along feeding pipe 51 to tubular end portion 52 and through end opening 53 where it exits substantially along the horizontal axial direction of tubular end portion 52 and is dispersed while falling under the effect of gravity over the molten electrolyte 40. In a variation, a deflector can be placed at the end opening 53 to raise or lower slightly the average alumina path.

[0069] The delivered alumina 60 enters electrolyte 40 where it dissolves to enrich it. The alumina-rich electrolyte flows down the through-openings of the active anodes structures 16 to the gap between the active anode structures 16 and the cathode bottom 10 where it is electrolysed to produce oxygen on the active anode structures 16 and molten aluminium 70 on the aluminium-wettable cathode layer 11. The produced molten aluminium 70 drains into the aluminium collection groove 12. The alumina-depleted electrolyte resulting from electrolysis is driven up by anodically released oxygen from under and through the active anode structures 16 towards the surface of the molten electrolyte 40 where it is enriched with dissolving alumina 60. Such an electrolyte circula-

tion is described in greater detail in the abovementioned WO00/40781, WO00/40782 and WO03/006716.

Claims

1. A cell for the electrowinning of a metal from a compound thereof dissolved in a molten electrolyte, comprising:

- a thermally insulated cell trough and a thermally insulated cell cover which are arranged to contain an electrolyte and maintain it in a substantially crustless molten state; and
- means for feeding a particulate of the metal compound to the molten electrolyte comprising at least one feeding tube extending into the cell trough and having a tubular end portion which is located between the molten electrolyte and the insulating cell cover and which has a substantially horizontal axial direction, the feeding means being arranged to feed said particulate into the feeding tube, along the feeding tube and through an opening in the tubular end portion from where it is delivered over the molten electrolyte,

characterised in that said opening is located at an end of the tubular end portion and is arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion.

2. The cell of claim 1, wherein the end opening is co-axial with the tubular end portion.
3. The cell of claim 1, wherein the end opening is off-axis.
4. The cell of any preceding claim, wherein the feeding tube is substantially linear or gradually curved.
5. The cell of any preceding claim, wherein the feeding means comprise a plurality of tubular end portions, in particular end portions that are part of the same feeding tube, each end portion having a substantially horizontal axial direction and an end opening arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion.
6. The cell of any preceding claim, wherein the feeding means comprise a plurality of feeding tube, each having a tubular end portion with an end opening for delivering the particulate.
7. The cell of any preceding claim, wherein the feeding means are arranged to fluidise the particulate in the

feeding tube and to feed the fluidised particulate through the end opening of the end portion over the molten electrolyte.

8. The cell of any preceding claim, wherein the feeding means are arranged to feed and disperse the particulate over substantially the entire molten electrolyte.
9. The cell of any preceding claim, wherein the feeding tube extends into the cell trough through a cell side-wall or trough through the cell cover.
10. The cell of any preceding claim, wherein the feeding means comprise a fan or a blower for driving the particulate along the feeding tube and through the end opening.
11. The cell of any preceding claim, wherein the feeding means comprise a heater arranged to heat the particulate before it is delivered from the end opening over the molten electrolyte.
12. The cell of any preceding claim, which is an aluminium electrowinning cell and wherein the molten electrolyte is a fluoride-based electrolyte, said cell optionally comprising one or more oxygen-evolving anodes, in particular metal-based or ceramic-based anodes.
13. The cell of claim 12, comprising one or more oxygen evolving anodes, wherein the or each oxygen-evolving anode comprises an active anode structure having through-openings for the flow of alumina-depleted electrolyte from below to above the anode and/or through-openings for the flow of alumina-enriched electrolyte from above to below the anode, optionally the feeding means being arranged to deliver and disperse alumina over an expanse which includes at least part of the perpendicular projection onto the molten electrolyte surface of an active anode structure.
14. The cell of any one of claims 12 or 13, comprising an aluminium-wettable cathode, in particular is a drained cathode.
15. A method of electrowinning a metal from a compound thereof dissolved in a substantially crustless molten electrolyte comprising:

feeding particulate of the metal compound into and along a feeding tube having a tubular end portion with an axial direction extending substantially horizontally over the substantially crustless molten electrolyte and delivering the particulate through an opening in the tubular end portion over the molten electrolyte where it is

dissolved and then electrolysed to produce said metal,
 said method being **characterised by** delivering the particulate over the substantially crustless molten electrolyte from the feeding tube substantially along said axial direction of the tubular end portion through said opening which is located at an end of the tubular end portion.

16. The method of claim 15, comprising delivering a particulate comprising particles, the sizes of which are in the range of 20 to 200 micron, in particular 30 to 50 micron.

17. The method of claim 15 or 16, wherein said particulate is alumina and said metal is aluminium.

18. A cell for the electrowinning of a metal from a compound thereof dissolved in a molten electrolyte, comprising means for feeding a particulate of the metal compound to the molten electrolyte, the feeding means comprising at least one feeding tube having a tubular end portion which is located above the molten electrolyte and which has a substantially horizontal axial direction, said feeding means being arranged to feed said particulate into the feeding tube, along the feeding tube and through an opening in the tubular end portion from where it is delivered over the molten electrolyte,
characterised in that said opening is located at an end of the tubular end portion and is arranged to deliver the particulate from the feeding tube over the molten electrolyte substantially along the axial direction of the tubular end portion.

Revendications

1. Cellule pour l'extraction électrolytique d'un métal à partir d'un composé de celui-ci dissous dans un électrolyte fondu, comprenant :

- une cuvette de cellule thermiquement isolée et un couvercle de cellule thermiquement isolé qui sont agencés pour contenir un électrolyte et le maintenir dans un état fondu sensiblement sans croûte ; et

- des moyens pour amener un particulat du composé métallique à l'électrolyte fondu, comprenant au moins un tube d'alimentation s'étendant dans la cuvette de la cellule et ayant une partie d'extrémité tubulaire qui est située entre l'électrolyte fondu et le couvercle isolant de la cellule et qui a une direction axiale sensiblement horizontale, les moyens d'alimentation étant agencés pour amener ledit particulat dans le tube d'alimentation, le long du tube d'alimentation et à travers une ouverture dans la partie d'extré-

mité tubulaire d'où il est délivré sur l'électrolyte fondu,

caractérisée en ce que ladite ouverture est située à une extrémité de la partie d'extrémité tubulaire et est agencée pour délivrer le particulat à partir du tube d'alimentation sur l'électrolyte fondu sensiblement le long de la direction axiale de la partie d'extrémité tubulaire.

2. Cellule de la revendication 1, dans laquelle l'ouverture - d'extrémité est coaxiale à la partie d'extrémité tubulaire.

3. Cellule de la revendication 1, dans laquelle l'ouverture d'extrémité est décalée axialement.

4. Cellule d'une quelconque revendication précédente, dans laquelle le tube d'alimentation est sensiblement linéaire ou progressivement courbé.

5. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation comprennent une pluralité de parties d'extrémité tubulaires, en particulier des parties d'extrémité qui appartiennent au même tube d'alimentation, chaque partie d'extrémité ayant une direction axiale sensiblement horizontale et une ouverture d'extrémité agencée pour délivrer le particulat à partir du tube d'alimentation sur l'électrolyte fondu sensiblement le long de la direction axiale de la partie d'extrémité tubulaire.

6. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation comprennent une pluralité de tubes d'alimentation, chacun ayant une partie d'extrémité tubulaire avec une ouverture d'extrémité pour délivrer le particulat.

7. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation sont agencés pour fluidiser le particulat dans le tube d'alimentation et pour amener le particulat fluidisé à travers l'ouverture d'extrémité de la partie d'extrémité sur l'électrolyte fondu.

8. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation sont agencés pour amener et disperser le particulat sur sensiblement la totalité de l'électrolyte fondu.

9. Cellule d'une quelconque revendication précédente, dans laquelle le tube d'alimentation s'étend dans la cuvette de la cellule via une paroi latérale de la cellule ou la cuvette via le couvercle de la cellule.

10. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation comprennent un ventilateur ou une soufflante pour entraîner

le particulat le long du tube d'alimentation et à travers l'ouverture d'extrémité.

11. Cellule d'une quelconque revendication précédente, dans laquelle les moyens d'alimentation comprennent un dispositif de chauffage agencé pour chauffer le particulat avant sa délivrance à partir de l'ouverture d'extrémité sur l'électrolyte fondu.

12. Cellule d'une quelconque revendication précédente, qui est une cellule d'extraction électrolytique d'aluminium et dans laquelle l'électrolyte fondu est un électrolyte à base de fluorure, ladite cellule comprenant éventuellement une ou plusieurs anodes à dégagement d'oxygène, en particulier des anodes particulières à base de métal ou à base de céramique.

13. Cellule de la revendication 12, comprenant une ou plusieurs anodes à dégagement d'oxygène, dans laquelle l'anode ou chaque anode à dégagement d'oxygène comprend une structure anodique active ayant des ouvertures traversantes pour l'écoulement de l'électrolyte appauvri en alumine du dessous vers le dessus des ouvertures traversantes et/ou de l'anode pour l'écoulement de l'électrolyte enrichi en alumine du dessus vers le dessous de l'anode, éventuellement les moyens d'alimentation étant agencés pour délivrer et disperser de l'alumine sur une étendue qui comprend au moins une partie de la projection perpendiculaire sur la surface électrolytique fondue d'une structure anodique active.

14. Cellule d'une quelconque des revendications 12 ou 13, comprenant une cathode mouillable par l'aluminium, en particulier une cathode drainée.

15. Procédé d'extraction électrolytique d'un métal à partir d'un composé de celui-ci dissous dans un électrolyte fondu sensiblement sans croûte consistant à :

amener un particulat du composé métallique dans et le long d'un tube d'alimentation ayant une partie d'extrémité tubulaire avec une direction axiale s'étendant sensiblement horizontalement sur l'électrolyte fondu sensiblement sans croûte et délivrer le particulat à travers une ouverture dans la partie d'extrémité tubulaire sur l'électrolyte fondu où il est dissous et ensuite électrolysé pour produire ledit métal, ledit procédé étant **caractérisé en ce qu'il** consiste à délivrer le particulat sur l'électrolyte fondu sensiblement sans croûte depuis le tube d'alimentation sensiblement le long de ladite direction axiale de la partie d'extrémité tubulaire à travers ladite ouverture qui est située à une extrémité de la partie d'extrémité tubulaire.

16. Procédé de la revendication 15, consistant à délivrer

un particulat comprenant des particules, dont les dimensions sont dans la plage de 20 à 200 micromètres, en particulier 30 à 50 micromètres.

17. Procédé de la revendication 15 ou 16, dans lequel ledit particulat est de l'alumine et ledit métal est de l'aluminium.

18. Cellule pour l'extraction électrolytique d'un métal à partir d'un composé de celui-ci dissous dans un électrolyte fondu, comprenant des moyens pour amener un particulat du composé métallique à l'électrolyte fondu, les moyens d'alimentation comprenant au moins un tube d'alimentation ayant une partie d'extrémité tubulaire qui est située au-dessus de l'électrolyte fondu et qui présente une direction axiale sensiblement horizontale, lesdits moyens d'alimentation étant agencés pour amener ledit particulat dans le tube d'alimentation, le long du tube d'alimentation et à travers une ouverture dans la partie d'extrémité tubulaire d'où il est délivré sur l'électrolyte fondu, **caractérisée en ce que** ladite ouverture est située à une extrémité de la partie d'extrémité tubulaire et est agencée pour délivrer le particulat depuis le tube d'alimentation sur l'électrolyte fondu sensiblement le long de la direction axiale de la partie d'extrémité tubulaire.

30 Patentansprüche

1. Zelle für die elektrolytische Gewinnung eines Metalls aus einer Metallverbindung, die in einem geschmolzenen Elektrolyten gelöst ist, mit:

einer thermisch isolierten Zellenwanne und einem thermisch isolierten Deckel, die dazu ausgestaltet sind, um den Elektrolyten aufzunehmen und ihn in einem im Wesentlichen krustenfreien, geschmolzenen Zustand zu erhalten, und

Mitteln zur Zufuhr der Metallverbindung in Teilchenform zu dem geschmolzenen Elektrolyten mit wenigstens einem Zufuhrrohr, das in die Zellenwanne hinein verläuft und einen röhrenförmigen Endbereich aufweist, der zwischen dem geschmolzenen Elektrolyten und dem isolierenden Zellendeckel angeordnet ist und der eine im Wesentlichen horizontale axiale Richtung hat, wobei die Zufuhrmittel dazu ausgestaltet sind, das teilchenförmige Material in das Zufuhrrohr, entlang des Rohres und durch eine Öffnung in dem röhrenförmigen Endbereich zu fördern, von wo es über den geschmolzenen Elektrolyten verteilt wird,

dadurch gekennzeichnet, dass die Öffnung an einem Ende des röhrenförmigen Endbereichs liegt

- und dazu ausgestaltet ist, um das teilchenförmige Material aus dem Zufuhrrohr über den geschmolzenen Elektrolyten im Wesentlichen entlang der axialen Richtung des röhrenförmigen Endbereichs auszugeben.
2. Zelle nach Anspruch 1, wobei die Endöffnung koaxial mit dem röhrenförmigen Endbereich ist.
 3. Zelle nach Anspruch 1, wobei die Endöffnung gegen die Achse versetzt ist.
 4. Zelle nach einem der vorhergehenden Ansprüche, wobei das Zufuhrrohr im Wesentlichen gerade oder stetig gekrümmt ist.
 5. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel eine Mehrzahl von röhrenförmigen Endbereichen aufweisen, insbesondere Endbereiche, die Teile des selben Zufuhrrohres sind, wobei jeder Endbereich eine im Wesentlichen horizontale axiale Richtung und eine Endöffnung hat, die dazu ausgestaltet ist, um das teilchenförmige Material aus dem Zufuhrrohr über den geschmolzenen Elektrolyten im Wesentlichen entlang der axialen Richtung des röhrenförmigen Endbereichs auszugeben.
 6. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel eine Mehrzahl von Zufuhrrohren aufweisen, von denen jedes einen röhrenförmigen Endbereich mit einer Endöffnung zur Ausgabe des teilchenförmigen Materials hat.
 7. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel dazu ausgestaltet sind, das teilchenförmige Material in dem Zufuhrrohr zu fluidisieren und das fluidisierte teilchenförmige Material durch die Endöffnung des Endbereichs über den geschmolzenen Elektrolyten zu fördern.
 8. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel so ausgestaltet sind, das teilchenförmige Material zu fördern und im Wesentlichen über den ganzen geschmolzenen Elektrolyten zu verteilen.
 9. Zelle nach einem der vorhergehenden Ansprüche, wobei das Zufuhrrohr durch eine Zellenseitenwand oder durch den Zellendeckel in die Zellenwanne hinein verläuft.
 10. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel einen Ventilator oder ein Gebläse zum Fördern des teilchenförmigen Materials entlang des Zufuhrrohres und durch die Endöffnung aufweisen.
 11. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zufuhrmittel eine Heizeinrichtung aufweisen, die dazu ausgestaltet ist, um das teilchenförmige Material vor seiner Abgabe aus der Öffnung über den geschmolzenen Elektrolyten zu erhitzen.
 12. Zelle nach einem der vorhergehenden Ansprüche, wobei die Zelle eine Zelle zur elektrolytischen Gewinnung von Aluminium ist und wobei der geschmolzene Elektrolyt ein Elektrolyt auf Fluoridbasis ist, wobei die Zelle eine oder mehrere Sauerstoff entwickelnde Anoden aufweist, insbesondere Anoden auf Metallbasis oder Keramikbasis.
 13. Zelle nach Anspruch 12, mit einer oder mehreren Sauerstoff entwickelnden Anoden, wobei die oder jede Sauerstoff entwickelnde Anode eine aktive Anodenstruktur mit hindurchgehenden Öffnungen für den Durchfluss von an Aluminiumoxid verarmtem Elektrolyten von der Unterseiten zur Oberseite der Anode und/oder mit hindurchgehenden Öffnungen für den Durchfluss von mit Aluminiumoxid angereichertem Elektrolyten von der Oberseite zur Unterseite der Anode aufweist, wobei die Zufuhrmittel optional dazu ausgestaltet sind, das Aluminiumoxid über eine Fläche zuzuführen und zu verteilen, die wenigstens einen Teil der senkrechten Projektion einer aktiven Anodenstruktur auf die geschmolzene Elektrolytoberfläche umfasst.
 14. Zelle nach einem der Ansprüche 12 oder 13, mit einer aluminiumbenetzbaren Kathode, insbesondere mit einer Abflusskathode.
 15. Verfahren zur elektrolytischen Gewinnung eines Metalls aus einer Metallverbindung, die in einem im Wesentlichen krustenfreien, geschmolzenen Elektrolyten gelöst ist, bei dem:

die Metallverbindung in Teilchenform in und entlang eines Zufuhrrohres transportiert wird, das einen röhrenförmigen Endbereich mit einer axialen Richtung hat, der sich im Wesentlichen horizontal über den im Wesentlichen krustenfreien, geschmolzenen Elektrolyten erstreckt und der das teilchenförmige Material durch eine Öffnung in dem röhrenförmigen Endbereich über den geschmolzenen Elektrolyten ausgibt, wo es gelöst und dann elektrolysiert wird, um das Metall zu erzeugen,

wobei das Verfahren **dadurch gekennzeichnet ist, dass** das teilchenförmige Material über den im Wesentlichen krustenfreien, geschmolzenen Elektrolyten aus dem Zufuhrrohr im Wesentlichen entlang der axialen Richtung des röhrenförmigen Endbereichs durch die Öffnung ausgegeben wird, die an einem

Ende des röhrenförmigen Endbereichs angeordnet ist.

16. Verfahren nach Anspruch 15, bei dem teilchenförmiges Material mit Teilchen ausgegeben wird, deren Größen im Bereich von 20 bis 200 Mikrometer, insbesondere 30 bis 50 Mikrometer liegen. 5
17. Verfahren nach Anspruch 15 oder 16, wobei das teilchenförmige Material Aluminiumoxid ist und das Metall Aluminium ist. 10
18. Zelle für die elektrolytische Gewinnung eines Metalls aus einer Metallverbindung, die in einem geschmolzenen Elektrolyten gelöst ist, mit Mitteln zur Zufuhr der Metallverbindung in Teilchenform zu dem geschmolzenen Elektrolyten, wobei die Zufuhrmittel wenigstens ein Zufuhrrohr aufweisen, das einen röhrenförmigen Endbereich hat, der über dem geschmolzenen Elektrolyten liegt und eine im Wesentlichen horizontale axiale Richtung hat, wobei die Zufuhrmittel dazu ausgestaltet sind, um das teilchenförmige Material in das Zufuhrrohr, entlang des Zufuhrrohres und durch eine Öffnung in dem röhrenförmigen Endbereich zu fördern, von wo es über den geschmolzenen Elektrolyten ausgegeben wird, **dadurch gekennzeichnet, dass** die Öffnung an einem Ende des röhrenförmigen Endbereichs liegt und dazu ausgestaltet ist, um das teilchenförmige Material aus dem Zufuhrrohr über den geschmolzenen Elektrolyten im Wesentlichen entlang der axialen Richtung des röhrenförmigen Endbereichs auszugeben. 15
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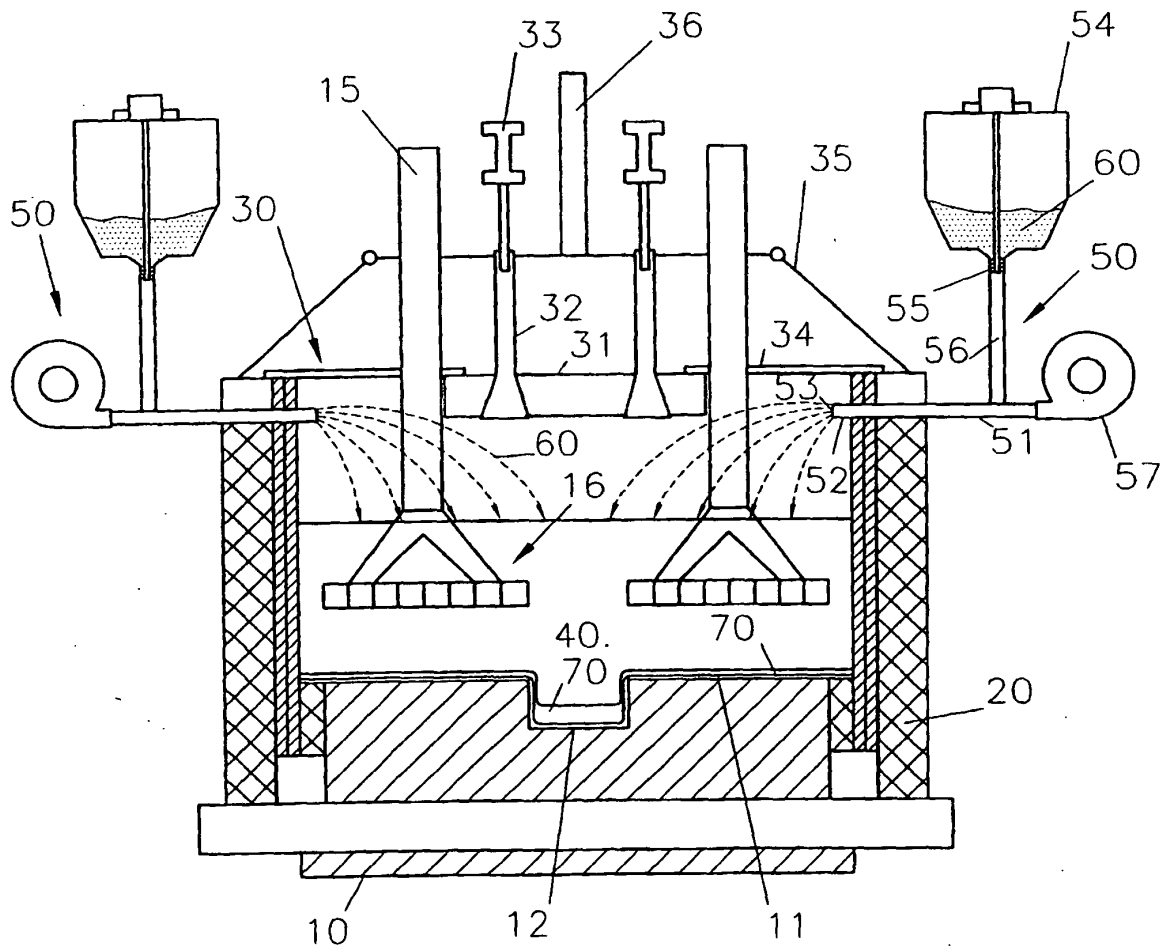


FIGURE 1