

Method and Device for Recycling a Battery

The present invention relates to a method and a mobile device for recycling a battery. The invention further relates to a package in which 1 to 30 kg of battery parts are contained.

Methods and devices for recycling batteries, in particular used batteries, are known in the prior art.

For example, CN 113 477 684 A discloses a mobile recycling device for lithium batteries. The lithium batteries are fed into the comminuting unit D shown in FIG. 1 of the document, which is filled with oxygen-free water; thus, the lithium batteries can be comminuted underwater in a non-explosive atmosphere. The comminuted battery parts are then conveyed by a screw conveyor E out of the comminuting unit D and reach a drying unit F, in which they are dried.

CN 114 583 305 A relates to a device for recycling lithium batteries. According to FIG. 1 of the document, the device has discharge containers with one sieve insert each. The discharge containers are filled with an aqueous solution of sodium chloride. The lithium batteries are soaked in the solution for discharge by being accommodated in the sieve insert. After the lithium batteries are discharged, they are pre-dried by rotating the sieve insert and then comminuted into pieces with a size of 20x30 mm in a first comminuting unit. The battery parts are then transferred to a drying unit by means of a conveyor belt and dried further there. The dried battery parts are then comminuted in a second comminuting unit into particles with a size of 16 mm and separated into their components.

EP 3 312 922 A1 describes a method and a plant for recycling used batteries. The batteries are first discharged in a discharge unit. They are then fed to a comminuting unit, where they are comminuted under inert gas. After comminution, the battery parts obtained are conveyed to a drying unit using a first gas-tight conveyor. During the drying of the battery parts, an electrolyte is separated. The dried, inactivated battery parts are then conveyed by a second conveyor to a packaging unit, where they are filled into a transport container.

There is a need for a further increase in the flexibility of methods and devices for recycling batteries. An object of the present invention is to provide such a flexible method and such a flexible device.

This object is achieved according to the invention in that the method for recycling a battery comprises the following steps:

- (a) providing an at least partially discharged battery,
- (b) comminuting the at least partially discharged battery in a process chamber in order to obtain battery parts,
- (c) drying the battery parts in a process chamber in order to obtain dried battery parts and a separated gas, and
- (d) packaging the dried battery parts into a package,

characterized in that steps (b) and (c) are carried out in the same process chamber.

By carrying out the comminution and drying in the same process chamber, the method can be simplified and made very efficient, since an adjustment of process parameters (e.g. pressure, temperature) is sufficient only for this one process chamber. Furthermore, drying may take place immediately after comminution. This has the advantage that an intermediate amount of not yet dried battery parts can be reduced, or that intermediate storage is not necessary at all. Intermediate storage of battery parts that have not yet dried is complex from a process engineering point of view, since a harmful, combustible steam may escape from such battery parts, and these battery parts must therefore be stored under controlled conditions. Drying is preferably started within 10 min after completion of comminution, more preferably within 3 min, particularly preferably within 1 min.

The battery provided in step (a) preferably has a voltage of 2.5 V per cell or below, more preferably 1 V per cell or below, most preferably 0.1 V per cell or below. To this end, the battery may be at least partially discharged prior to step (a). The measurement of the voltage may be carried out by means of a voltmeter connected in series. If the at least partial discharging has not already taken place (e.g. due to a previous intended use of the battery), the operational and process reliability of the subsequent steps of the method can be improved by the discharging integrated into the method, in particular the risk of thermal overload due to a short circuit, which could lead to the occurrence of a fire or the spontaneous ignition of an inflammable atmosphere, can be reduced.

The battery provided in step (a) may be obtained by disassembling a battery module or battery pack. A battery module is understood to be the combination of two or more batteries. A battery pack is understood to mean the combination of two or more battery modules, including a battery system (similar to a battery pack, but may have additional components, e.g. a cooling and/or management system) is to be regarded as comprised by a battery pack within the scope of this application. It is preferable for the disassembling to take place after the battery has been discharged. The battery module or the battery pack can then be in a voltage-free or at least low-voltage state, which can be advantageous from a safety point of view.

Before comminuting, a housing of the battery may be opened. As a result, the subsequent drying of the comminuted battery parts can be carried out more efficiently, as the gas can be separated more easily.

A protective atmosphere is preferably provided in the process chamber. A protective atmosphere is understood to mean an atmosphere with a controlled pressure, a controlled temperature and a controlled composition. This allows comminuting and drying to be carried out in a controlled, safe and reproducible manner. The protective atmosphere may be produced by means of a fractional vacuum process. As a result, the protective atmosphere can be built up quickly.

The protective atmosphere preferably comprises at least 85 % by volume of an inert gas, more preferably at least 95 % by volume, particularly preferably at least 98 % by volume, based on the total volume of the protective atmosphere. The inert gas preferably comprises nitrogen, since this makes it easy to avoid an explosion or ignition of the battery parts.

Preferably, a water partial pressure of the protective atmosphere is 100 Pa or below, preferably 70 Pa or below, particularly preferably 50 Pa or below. As a result, the decomposition of components of the battery, in particular hexafluorophosphate, can be avoided, and with it the formation of lithium hydroxide compounds or hydrogen fluoride compounds.

Furthermore, it is preferred if an oxygen partial pressure of the protective atmosphere is 100 mbar or below, more preferably 50 mbar or below, particularly preferably 30 mbar or below. As a result, not only can the corrosion of the components of the device according to the invention be reduced, but the tendency to form molecular hydrogen, which together with oxygen could form an ignitable atmosphere, can also be reduced.

In step (b) of the method, the at least partially discharged battery is comminuted in the process chamber to obtain battery parts. As a result, the specific free surface area of the battery can be increased, which can increase the efficiency of the subsequent method steps.

The comminution may be carried out under vacuum, preferably at a pressure in the process chamber of 100 mbar or below, more preferably at 50 mbar or below, particularly preferably at a pressure in the range from 10 to 50 mbar. As a result, a pressure that can subsequently be used for drying can already be set before comminution, so that drying can be carried out efficiently.

Alternatively, the comminution may be carried out at normal pressure in the process chamber. A normal pressure is understood to mean a pressure in the range from 1 to 1.1 bar. A pressure used for drying may then be set after step (b) or even during it. In particular, this can be done when the process chamber is reduced in size after step (b), as described further below.

The comminution may be carried out at a temperature of 20 to 200 °C in the process chamber. The comminution is preferably carried out at 20 to 30 °C. As a result, the method can be carried out in a more energy-efficient manner. On the other hand, if a moist battery is provided, it may be advantageous to increase the temperature during comminuting so that water contained in the battery may evaporate. The comminution is then preferably carried out at a temperature of 40 °C or above, more preferably at 60 °C or above, even more preferably at a temperature in the range from 90 to 200 °C, particularly preferably from 90 to 150 °C.

The battery parts preferably have a diameter or a maximum extension (e.g. a maximum length) of 100 mm or less, more preferably 50 mm or less, particularly preferably 20 mm or less. Due to the large specific free surface area of the battery parts, this can not only significantly increase the efficiency of drying, but also improve the subsequent packaging of the battery parts. This may also simplify further processing of the battery parts, in particular metallurgical processing, in order to obtain raw materials.

The size of the process chamber may be reduced after step (b). For these purposes, a separating device may be arranged in the process chamber. Then, during subsequent drying, the entire process chamber no longer needs to be heated and/or operated under vacuum, and the protective atmosphere no longer needs to be maintained in the entire process chamber. Reducing the process chamber can not only be advantageous in terms of energy consumption, but drying can also be faster and more uniform because the remaining process chamber can be brought to a certain temperature and/or pressure more quickly.

In step (c) of the method, the battery parts are dried in the process chamber to obtain dried battery parts and a separated gas. The separated gas may be withdrawn via a filter, preferably via a vapor filter.

The drying in step (c) may be carried out under vacuum in the process chamber, preferably at a pressure of 100 mbar or below, more preferably at 50 mbar or below, particularly preferably at a pressure in the range from 10 to 50 mbar. As a result, a vapor pressure of the gas to be separated, in particular of the electrolyte, can be undershot.

If step (c) is carried out under vacuum, a vacuum pump may be operated in a hysteresis mode to generate the vacuum in the process chamber. As a result, the pressure in the process chamber can be quickly reduced. This may also reduce the duty cycle of the vacuum pump. A "hysteresis mode" is understood to mean an operating mode of the vacuum pump in which the power of the vacuum pump alternates between a minimum value and a maximum value. Preferably, the power of the vacuum pump alternates between 0 and 150 kW, more preferably between 0 and 100 kW, particularly preferably between 0 and 60 kW.

The drying in step (c) is preferably carried out at a temperature in the process chamber of 60 °C or above, preferably at a temperature in the range from 90 to 200 °C. As a result, drying can be carried out efficiently, and the risk of decomposition of components contained in the comminuted battery parts can be kept low.

The drying in step (c) is preferably carried out at a temperature in the process chamber in the range from 90 to 200 °C and a pressure of 50 mbar or below. This can ensure that the vapor pressure of the gas to be separated, in particular the electrolyte, is undershot, which enables effective and rapid separation from the comminuted battery parts.

Preferably, the provided battery contains an electrolyte that is at least partially contained in the separated gas. A boiling point or an upper end of a boiling range of the electrolyte contained in the battery is preferably 180 °C or below, more preferably 150 °C or below, particularly preferably 130 °C or below, at a pressure of 10 mbar. As a result, the electrolyte can be separated efficiently and as completely as possible during drying in step (c). As a result, the battery may be inactivated and a subsequent electrochemical reaction and the formation of an explosive gas mixture may be avoided.

Preferably, after step (c), a remaining electrolyte content in the battery parts is 0.1 % by weight

or less, preferably 0.01 % by weight or less, particularly preferably 0.002 % by weight or less, based on the total weight of the battery parts.

Preferably, the packaging in step (d) is carried out in the same process chamber as steps (b) and (c). This allows the packaging of the dried battery parts to be carried out in a controlled environment. For example, condensation of water vapor on the battery parts and/or contamination of the battery parts before packaging can be avoided.

Packaging may be carried out under normal pressure. However, if step (d) is carried out in the same process chamber as steps (b) and (c), a pressure prevailing in the process chamber during drying may also be maintained for packaging. As a result, the atmosphere in the process chamber can be kept constant.

The dried battery parts may be packaged in a plastic-containing packaging, preferably in a barrier package. As a result, the battery parts can be packaged in a gas-tight and/or water-tight manner. Preferably, the battery parts are packaged in such a way that the formation of an ignitable atmosphere is excluded for at least four weeks at a temperature of 50 °C and normal pressure.

The dried battery parts may be packaged in a vacuum package. The package may also be sealed by welding. As a result, the battery parts can be particularly well protected against environmental influences.

In step (d), the dried battery parts are preferably packaged at 1 to 30 kg each, preferably at 1 to 25 kg each, more preferably at 1 to 20 kg each. This allows the packaged battery parts to be easily carried and transported by one person, further improving the flexibility of the method.

The method may comprise a further step (e): separating an electrolyte from the separated gas. The electrolyte content in the total weight of the gas is preferably 50 % by weight or more, more preferably 70 % by weight or more, particularly preferably 90 % by weight or more.

The electrolyte may be separated from the gas by condensation. For this purpose, the separated gas is preferably cooled to a temperature of 30 °C or below, preferably to 15 °C or below, particularly preferably to 5 °C or below. The content of the separated and thus recovered electrolyte is preferably 95 % by weight or more, more preferably 99 % by weight or more, based on the total weight of the electrolyte contained in the battery provided. As a result, the method can make a significant contribution to the circular economy and sustainability.

After step (e), the separated gas may be purified. Acidic components of the gas, such as hydrogen fluoride and/or phosphorus pentafluoride, can be at least partially removed. These components may be used for other purposes.

After step (e), a nitrogen contained in the separated gas can be at least partially separated. The separated nitrogen may be used in the method for the protective atmosphere comprising an inert gas when steps (b), (c), and optionally (d), are carried out under such a protective atmosphere. Prior to recirculation to the method, the nitrogen may be purified, in particular to separate a remainder of the electrolyte therefrom.

The invention further relates to a mobile device for recycling a battery with the method according to the invention, comprising

a loading unit for loading the at least partially discharged battery,

a comminuting unit for comminuting the at least partially discharged battery,

a drying unit for drying the battery parts, and

a packaging unit for packaging the dried battery parts,

characterized in that the comminuting unit and the drying unit are arranged in the same process chamber.

In this application, a "mobile device" is understood to mean a device that can be transported by a truck, in particular a semitrailer vehicle in accordance with Council Directive 96/53/EC of 25 July 1996, and can therefore be used flexibly locally.

The mobile device may be configured to be accommodated in a container. The container used according to the invention may be a container according to the ISO 668:2020-01 standard. A standardised container can be easily transported, for example by truck, freight train or cargo ship. Preferably, the container is a 40-foot container, more preferably a 20-foot container, particularly preferably a 10-foot container. A 40-foot container is understood to be a container approximately 12.2 m long, 2.4 m wide and 2.6 m high. A 20-foot container is understood to be a container approximately 6.1 m long, 2.4 m wide and 2.6 m high. A 10-foot container is understood to be a container approximately 3 m long, 2.4 m wide and 2.6 m high.

The container can be loaded in a short time, in particular within 8 hours or less, and then transported to another place of use, where it can also be brought into an operational state in a short time, in particular within 8 hours or less. Furthermore, according to the invention, no special foundation, such as an enclosure in the form of a hall, is required. The invention thus enables an uncomplicated and flexible use of the method as required in order to recycle a battery, in particular a waste battery, directly on the spot. The method may also be carried out directly in the container. The mobile device may then also be accommodated in the container during the execution of the method, which can further improve the flexibility, since loading and unloading can be eliminated.

In the process chamber, a separating device is preferably arranged, the separating device being configured to separate the loading unit and the comminuting unit from the drying unit and the packaging unit. The separating device may have a door, in particular a sliding door or a hinged door. By providing the separating device, certain process sequences may be simplified or made more efficient. For example, the separating device may be closed after the battery parts have been fed to the drying unit. Then, during drying, the entire process chamber no longer needs to be heated and/or operated under vacuum, and the protective atmosphere no longer needs to be maintained in the entire process chamber. Process parameters (e.g. pressure, temperature) may then also be set more quickly in the drying unit.

The separating device may comprise a refractory material, preferably steel and/or aluminum. If spontaneous ignition or thermal overload occurs during the method, the separating device may be closed so that damage can be spatially limited.

The mobile device preferably has a unit for feeding an inert gas into the process chamber. The inert gas may be provided in a container, wherein the container can be connected to the process chamber via a line in order to feed the inert gas into the process chamber via an inlet opening or via a plurality of inlet openings. Preferably, two inlet openings are provided in order to feed the inert gas into the process chamber, wherein the inert gas is preferably fed into the comminuting unit via a first inlet opening and into the drying unit via a second inlet opening.

A vacuum pump for building up a protective atmosphere is preferably connected to the process chamber. Since the comminuting unit and the drying unit are arranged in the same process chamber, a vacuum pump may be sufficient to generate a certain pressure. Depending on the power of the vacuum pump, two or more vacuum pumps may also be used.

The comminuting unit may comprise a rotor shear. This is well suited for comminuting bulky substances, such as batteries.

The drying unit may comprise a paddle dryer. This may be a paddle dryer. This may be arranged horizontally or vertically. This allows the battery parts to be mixed well and thus dried evenly.

The drying unit may have a filter for withdrawing the gas. The filter is preferably a vapor filter. As a result, not only can the gas be withdrawn efficiently, but dust particles can also be separated and thus removed from the process chamber. An evaporator may be connected downstream of the filter in order to separate the electrolyte from the gas by condensation.

The drying unit is preferably an autoclave. As a result, a good gas tightness can be provided.

The drying unit is preferably arranged below the comminuting unit. Then, the battery parts may fall from the comminuting unit into the drying unit due to gravity as soon as step (b) is completed. This means that there are no as yet undried battery parts that would have to be temporarily stored. The size of the process chamber may also be kept small, since no transport device (e.g. conveyor) has to be provided in order to transport the battery parts from the comminuting unit to the drying unit. The spatial arrangement ("below") refers to the intended operating state of the mobile device.

The packaging unit is preferably arranged below the drying unit. Then, the dried battery parts may fall from the drying unit into the packaging unit due to gravity as soon as step (c) is completed. The method may thus be designed even more efficiently, since no transport device (e.g. conveyor) has to be provided in order to transport the battery parts from the drying unit to the packaging unit. If the packaging unit is arranged in the same process chamber as the comminuting unit and the drying unit, the size of the process chamber can be kept small by this arrangement.

The mobile device may further comprise a discharge unit for at least partially discharging the battery, wherein the discharge unit is arranged in front of the loading unit. If the at least partial discharging has not already taken place (e.g. due to a previous intended use of the battery), the operational and process reliability of the subsequent steps of the method can be improved by the discharge unit.

The mobile device may further comprise a disassembly unit for disassembling a battery module or a battery pack, wherein the disassembly unit is arranged in front of the loading unit. If the mobile device has a discharge unit, the disassembly unit is preferably arranged downstream of the discharge unit. The battery module or the battery pack can then be in a voltage-free or at least low-voltage state, which can be advantageous from a safety point of view.

The invention also relates to a package in which 1 to 30 kg of battery parts are contained, obtainable by the method according to the invention. Preferably, 1 to 25 kg of battery parts are packaged in the package, more preferably 1 to 20 kg. The package can thus be easily carried and transported by one person.

The packaged battery parts preferably have a diameter or a maximum extension of 100 mm or less, more preferably 50 mm or less, particularly preferably 20 mm or less. As a result, further processing, in particular metallurgical processing for the extraction of raw materials, can be simplified due to the large specific free surface area of the battery parts.

The battery parts preferably have an electrolyte content of 0.1 % by weight or less, more preferably 0.01 % by weight or less, particularly preferably 0.002 % by weight or less, based on the total weight of the battery parts. As a result, safe handling can be achieved. In particular, the formation of an ignitable atmosphere for at least four weeks at a temperature of 50 °C and normal pressure can be excluded.

The package may be a plastic-containing package, preferably a barrier package. As a result, the battery parts may be packaged in a gas-tight and/or water-tight manner.

The package may be sealed by welding and/or be a vacuum package. As a result, the battery parts can be particularly well protected against environmental influences.

The invention relates in particular to the following embodiments:

1. A method for recycling a battery, in particular a waste battery, comprising the steps
 - (a) providing an at least partially discharged battery,
 - (b) comminuting the at least partially discharged battery in a process chamber in order to obtain battery parts,
 - (c) drying the battery parts in a process chamber in order to obtain dried battery parts and a separated gas, and
 - (d) packaging the dried battery parts into a package,

wherein steps (b) and (c) are carried out in the same process chamber.

2. The method according to the preceding embodiment, wherein the battery is a lithium-ion battery.
3. The method according to any of the preceding embodiments, wherein the provided battery has a voltage of 2.5 V per cell or below, preferably 1 V per cell or below, more preferably 0.1 V per cell or below.
4. The method according to any preceding embodiment, wherein the battery is discharged prior to step (a).
5. The method according to any of the preceding embodiments, wherein the battery provided in step (a) is obtained by disassembling a battery module or battery pack.
6. The method according to any of the preceding embodiments, wherein a housing of the battery is opened prior to comminuting.
7. The method according to any of the preceding embodiments, wherein a protective atmosphere is provided in the process chamber.
8. The method according to embodiment 7, wherein the protective atmosphere is produced by a fractional vacuum process.
9. The method according to embodiment 7 or 8, wherein the protective atmosphere comprises at least 85 % by volume of an inert gas, preferably at least 95 % by volume, particularly preferably at least 98 % by volume, based on the total volume of the protective atmosphere.
10. The method according to embodiment 9, wherein the inert gas comprises nitrogen.
11. The method according to any one of embodiments 7 to 10, wherein a water partial pressure of the protective atmosphere is 100 Pa or below, preferably 70 Pa or below, more preferably 50 Pa or below.
12. The method according to any one of embodiments 7 to 11, wherein an oxygen partial pressure of the protective atmosphere is 100 mbar or below, more preferably 50 mbar or below, most preferably 30 mbar or below.
13. The method according to any of the preceding embodiments, wherein the comminution in step (b) is carried out under vacuum, preferably at a pressure in the process chamber of 100 mbar or below,

more preferably at 50 mbar or below, particularly preferably at a pressure in the range of 10 to 50 mbar.

14. The method according to any one of embodiments 1 to 12, wherein the comminution in step (b) is carried out at normal pressure in the process chamber.

15. The method according to any of the preceding embodiments, wherein the comminution in step (b) is carried out at a temperature in the process chamber of 20 to 200 °C.

16. The method according to embodiment 15, wherein the comminution in step (b) is carried out at a temperature in the process chamber of 20 to 30 °C.

17. The method according to embodiment 15, wherein the comminution in step (b) is carried out at a temperature in the process chamber of 40 °C or above, preferably at 60 °C or above, more preferably at a temperature in the range from 90 to 200 °C, particularly preferably from 90 to 150 °C.

18. The method according to any of the preceding embodiments, wherein the battery parts have a diameter or a maximum extension of 100 mm or less, preferably 50 mm or less, more preferably 20 mm or less.

19. The method according to any of the preceding embodiments, wherein drying is started within 10 minutes after completion of comminution, preferably within 3 minutes, more preferably within 1 minute, in particular wherein drying takes place immediately after comminution.

20. The method according to any of the preceding embodiments, wherein the gas in step (c) is withdrawn via a filter, preferably via a vapor filter.

21. The method according to any of the preceding embodiments, wherein the drying in step (c) is carried out under vacuum in the process chamber, preferably at a pressure of 100 mbar or below, more preferably at 50 mbar or below, particularly preferably at a pressure in the range of 10 to 50 mbar.

22. The method according to embodiment 21, wherein during drying in step (c), a vacuum pump is operated in a hysteresis mode to generate a vacuum in the process chamber, wherein the power of the vacuum pump preferably alternates between 0 and 150 kW, more preferably between 0 and 100 kW, most preferably between 0 and 60 kW.

23. The method according to any of the preceding embodiments, wherein the drying in step (c) is carried out at a temperature in the process chamber of 60 °C or above, preferably at a temperature in the range of 90 to 200 °C.
24. The method according to any of the preceding embodiments, wherein the process chamber is reduced after step (b).
25. The method according to any of the preceding embodiments, wherein the provided battery contains an electrolyte at least partially contained in the separated gas.
26. The method according to embodiment 25, wherein at a pressure of 10 mbar, a boiling point or an upper end of a boiling range of the electrolyte is at a temperature of 180 °C or below, more preferably at 150 °C or below, particularly preferably at 130 °C or below.
27. The method according to embodiment 25 or 26, wherein after step (c), a remaining electrolyte content in the battery parts is 0.1 % by weight or less, preferably 0.01 % by weight or less, more preferably 0.002 % by weight or less, based on the total weight of the battery parts.
28. The method according to any of the preceding embodiments, wherein the packaging in step (d) is carried out in the same process chamber as steps (b) and (c).
29. The method according to any of the preceding embodiments, wherein the packaging in step (d) is carried out under normal pressure.
30. The method according to any of the preceding embodiments, wherein the dried battery parts in step (d) are packaged in a plastic-containing package, preferably in a barrier package.
31. The method according to any of the preceding embodiments, wherein the dried battery parts are packaged in a vacuum package in step (d).
32. The method according to any of the preceding embodiments, wherein the package is sealed by welding.
33. The method according to any of the preceding embodiments, wherein the dried battery parts in step (d) are packaged at 1 to 30 kg each, preferably at 1 to 25 kg each, more preferably at 1 to 20 kg each.
34. The method according to any of the preceding embodiments, further comprising step (e): separating an electrolyte from the separated gas.

35. The method according to embodiment 34, wherein the electrolyte content in the total weight of the gas is 50 % by weight or more, more preferably 70 % by weight or more, particularly preferably 90 % by weight or more.
36. The method according to embodiment 34 or 35, wherein the electrolyte is separated from the gas by condensation in step (e).
37. The method according to embodiment 36, wherein in step (e), the gas is cooled to a temperature of 30 °C or below, preferably to 15 °C or below, more preferably to 5 °C or below, to separate the electrolyte.
38. The method according to any one of embodiments 34 to 37, wherein the electrolyte content separated is 95 % by weight or more, more preferably 99 % by weight or more, based on the total weight of electrolyte contained in the battery provided.
39. The method according to any one of embodiments 34 to 38, wherein the separated gas is purified after step (e).
40. The method according to embodiment 39, wherein a nitrogen contained in the separated gas is at least partially separated.
41. The method according to any of the preceding embodiments, wherein the method is carried out in a container.
42. A mobile device for recycling a battery, in particular a waste battery, with the method according to any one of embodiments 1 to 41, comprising
- a loading unit for loading the battery,
 - a comminuting unit for comminuting the at least partially discharged battery,
 - a drying unit for drying the battery parts, and
 - a packaging unit for packaging the dried battery parts,
- wherein the comminuting unit and the drying unit are arranged in the same process chamber.
43. The mobile device according to embodiment 42, wherein the mobile device is configured to be accommodated in a container.
44. The mobile device according to embodiment 43, wherein the container is an ISO 668:2020-01 standard container.

45. The mobile device according to embodiment 43 or 44, wherein the container is a 40-foot container, preferably a 20-foot container, more preferably a 10-foot container.

46. The mobile device according to any one of embodiments 42 to 45, wherein a separating device is arranged in the process chamber, the separating device being configured to separate the loading unit and the comminuting unit from the drying unit and the packaging unit.

47. The mobile device according to embodiment 46, wherein the separating device comprises a door, in particular a sliding door or a hinged door.

48. The mobile device according to embodiment 46 or 47, wherein the separating device comprises a refractory material, preferably steel and/or aluminum.

49. The mobile device according to any one of embodiments 42 to 48, wherein a vacuum pump for building up the protective atmosphere is connected to the process chamber.

50. The mobile device according to any one of embodiments 42 to 49, wherein the comminuting unit comprises a rotor shear.

51. The mobile device according to any one of embodiments 42 to 50, wherein the drying unit comprises a paddle dryer.

52. The mobile device according to any one of embodiments 42 to 51, wherein the drying unit comprises a filter for withdrawing the gas, preferably a vapor filter.

53. The mobile device according to embodiment 52, wherein an evaporator is connected downstream of the filter.

54. The mobile device according to any one of embodiments 42 to 53, wherein the drying unit is an autoclave.

55. The mobile device according to any one of embodiments 42 to 54, wherein, in an operating state of the mobile device, the drying unit is arranged below the comminuting unit, and/or wherein, in an operating state of the mobile device, the packaging unit is arranged below the drying unit.

56. The mobile device according to any one of embodiments 42 to 55, further comprising a discharge unit for at least partially discharging the battery, wherein the discharge unit is arranged upstream of the loading unit.

57. The mobile device according to any one of embodiments 42 to 56, further comprising a disassembly unit for disassembling a battery module or battery pack.
58. The mobile device according to embodiment 57, wherein the disassembly unit is arranged in front of the loading unit, and wherein, if the mobile device has a discharge unit, the disassembly unit is preferably arranged downstream of the discharge unit.
59. A container comprising the mobile device according to any one of embodiments 42 to 58.
60. The container according to embodiment 59, wherein the container is an ISO 668:2020-01 standard container.
61. The container according to embodiment 59 or 60, wherein the container is a 40-foot container, preferably a 20-foot container, more preferably a 10-foot container.
62. A package containing 1 to 30 kg of battery parts, obtainable by a method according to any one of embodiments 1 to 41.
63. The package according to embodiment 62, wherein 1 to 25 kg of battery parts are packaged in the package, preferably 1 to 20 kg.
64. The package according to embodiment 62 or 63, wherein the battery parts have a diameter or a maximum extension of 100 mm or less, preferably 50 mm or less, more preferably 20 mm or less.
65. The package according to any one of embodiments 62 to 64, wherein the battery parts have an electrolyte content of 0.1 % by weight or less, preferably 0.01 % by weight or less, more preferably 0.002 % by weight or less, based on the total weight of the battery parts.
66. The package according to any one of embodiments 62 to 65, wherein the package is a plastic-containing package, preferably a barrier package.
67. The package according to any one of embodiments 62 to 66, wherein the package is sealed by welding.
68. The package according to any one of embodiments 62 to 67, wherein the package is a vacuum package.

In this application, the term "battery" includes both a non-rechargeable battery and a rechargeable battery (also referred to as an accumulator). Preferably, the battery is a lithium-ion battery, in particular a lithium-ion accumulator.

In this application, a "process chamber" is understood to mean, in particular, a chamber that can be treated as a uniform chamber (with a uniform atmosphere) in an operating mode (from a procedural point of view). Preferably, this chamber (in this operating mode) may be heated with a single heater and/or evacuated with a single vacuum pump.

The invention is explained in more detail below with reference to a description of the figures.

FIG. 1 shows the schematic structure of a mobile device.

FIG. 2 shows a longitudinal section of a detail of the mobile device of FIG. 1.

The mobile device 1 shown in FIG. 1 has a loading unit 2, a comminuting unit 3, a drying unit 4 and a packaging unit 5, which are arranged in the same process chamber 11 (shown in FIG. 2). Furthermore, a separating device 6 is arranged in the process chamber 11, with which the loading unit 2 and the comminuting unit 3 can be separated from the drying unit 4 and the packaging unit 5. The separating device 6 comprises steel as a refractory material and has a hinged door (not shown). To carry out the method, a protective atmosphere is produced in the process chamber 11 by means of a fractional vacuum method using a vacuum pump 7. The protective atmosphere comprises at least 98 % by volume of nitrogen, based on the total volume of the protective atmosphere. The nitrogen is fed from the container 8 via a first inlet opening into the comminuting unit 3 and via a second inlet opening into the drying unit 4. A water partial pressure of the protective atmosphere is below 50 Pa and an oxygen partial pressure is below 30 mbar. A partially discharged battery is added to the loading unit 2 and then comminuted in the comminuting unit 3 by means of a rotor shear at 40 mbar. During the comminution, the drying unit 4 is already heated, so that, due to the waste heat from the drying unit 4, the comminution also takes place at an elevated temperature of 40 °C or above.

As can be seen in FIG. 1, the drying unit 4 is arranged below the comminuting unit 3, so that the battery parts obtained can fall from the comminuting unit 3 into the drying unit 4 due to gravity. Thereafter, the process chamber 11 may be reduced in size by closing the hinged door of the separating device 6, so that only that part of the process chamber 11 in which the drying unit 4 and the packaging unit 5 are arranged has to be operated under vacuum and elevated temperature and the protective atmosphere has to be maintained. The battery parts are dried in the drying unit 4 at 40 mbar and 150 °C, a gas comprising an electrolyte being separated off and withdrawn from the process chamber 11 via a vapor filter 9. After drying, the battery parts have a remaining electrolyte content of less than 0.002 % by weight, based on the total weight of the battery parts. The dried battery parts are finally packaged in the packaging unit 5, each weighing 25 kg, in a barrier package. During packaging, the

pressure and the protective atmosphere in the process chamber 11 remain unchanged, but are no longer heated.

FIG. 1 further shows that the gas withdrawn via the vapor filter 9 is subsequently fed to an evaporator 10 in order to separate the electrolyte from the gas. The gas is cooled to below 30 °C. As a result, more than 99 % by weight of the electrolyte contained in the provided battery can be recovered.

A detail of the mobile device 1 of FIG. 1 is shown in longitudinal section in FIG. 2. It can be seen from this that the loading unit 2, the comminuting unit 3, the drying unit 4 and the packaging unit 5 are arranged in the same process chamber 11 (indicated by a dashed line). As a result, the method is designed to be very efficient, since setting process parameters (e.g. pressure, temperature) is sufficient only for this one process chamber. A protective atmosphere with a controlled pressure, a controlled temperature and a controlled composition may be provided throughout the process chamber 11, so that the method can be carried out reproducibly and safely.

Claims

1. A method of recycling a battery comprising the steps of
 - (a) providing an at least partially discharged battery,
 - (b) comminuting the at least partially discharged battery in a process chamber (11) in order to obtain battery parts,
 - (c) drying the battery parts in a process chamber (11) in order to obtain dried battery parts and a separated gas, and
 - (d) packaging the dried battery parts into a package,characterized in that steps (b) and (c) are carried out in the same process chamber (11).
2. The method according to claim 1, characterized in that a protective atmosphere is provided in the process chamber (11).
3. The method according to claim 1 or 2, characterized in that the drying in step (c) is carried out at a pressure in the process chamber (11) in the range from 10 to 50 mbar.
4. The method according to any one of claims 1 to 3, characterized in that during drying in step (c), a vacuum pump (7) is operated in a hysteresis mode in order to generate a vacuum in the process chamber (11).
5. The method according to claim 4, characterized in that the power of the vacuum pump (7) alternates between 0 and 60 kW in the hysteresis mode.
6. The method according to any one of claims 1 to 5, characterized in that the drying in step (c) is carried out at a temperature in the range of 90 to 200 °C.
7. The method according to any one of claims 1 to 6, characterized in that the provided battery contains an electrolyte that is at least partially contained in the separated gas, and wherein after step (c), a remaining electrolyte content in the battery parts is 0.002 % by weight or less, based on the total weight of the battery parts.
8. The method according to any one of claims 1 to 7, characterized in that the dried battery parts in step (d) are packaged at 1 to 30 kg each.
9. The method of any one of claims 1 to 8, further comprising step (e): separating an electrolyte from the separated gas.

10. A mobile device (1) for recycling a battery with the method according to any one of claims 1 to 9, comprising
 - a loading unit (2) for loading the at least partially discharged battery,
 - a comminuting unit (3) for comminuting the at least partially discharged battery,
 - a drying unit (4) for drying the battery parts, and
 - a packaging unit (5) for packaging the dried battery parts,characterized in that the comminuting unit (3) and the drying unit (4) are arranged in the same process chamber (11).
11. The mobile device (1) according to claim 10, characterized in that the mobile device (1) is configured to be accommodated in a container.
12. The mobile device (1) according to claim 10 or 11, characterized in that a separating device (6) is arranged in the process chamber (11), the separating device (6) being configured to separate the loading unit (2) and the comminuting unit (3) from the drying unit (4) and the packaging unit (5).
13. The mobile device (1) according to any one of claims 10 to 12, characterized in that, in an operating state of the mobile device (1), the drying unit (4) is arranged below the comminuting unit (3).
14. The mobile device (1) according to any one of claims 10 to 13, characterized in that, in an operating state of the mobile device (1), the packaging unit (5) is arranged below the drying unit (4).
15. A package containing 1 to 30 kg of battery parts, obtainable by a method according to any one of claims 1 to 9.