

EXHIBIT 1020

Method for reclaiming active material from a galvanic cell and active material separation installation, in particular active metal separation installation

The invention relates to a method for reclaiming active material, in particular lithium or lithium compounds, from a galvanic cell, which comprises an active material, a support for the active material, a binder for bonding the active material and the support, and optionally an electrolyte, comprising the steps of: (a) crushing the cells, in particular under inert gas, in such a way that solid cell fragments are at least additionally formed, (b) heating the solid cell fragments to a decomposition temperature selected high enough that the binder decomposes and/or evaporates, in such a way that heat-treated cell fragments are formed, and (c) classifying the heat-treated cell fragments.

A second aspect of the invention relates to an active metal separation installation, which is configured to reclaim active material, in particular lithium, from a galvanic cell, which comprises an active material, a support for the active material, a binder for bonding the active material and the support, and an electrolyte, comprising (a) a cell crushing device for crushing the cells, the cell crushing device being gastight and comprising an inert gas supply mechanism, in such a way that the cells can be crushed to cell fragments under inert gas, and (b) an oven connected at least indirectly to the cell crushing device and set up to heat the cell fragments to a decomposition temperature selected high enough that the binder decomposes.

When active material is recycled, in particular lithium from lithium accumulators or batteries, the problem arises that the chemical processes are relatively resource-intensive. This is because the active material is only partially separated from its support.

From US 2005/0241943 A1, a method is known in which the cells are first crushed and then undergo heat treatment. After this, the cells are shredded and heated to the decomposition temperature. Subsequently, the heat-treated cell fragments are separated by vibration sieving. However, this method has been found to be resource-intensive. The object of the invention is to improve the reclaiming of active material, in particular of lithium or lithium compounds, from old batteries or accumulators.

From DE 199 54 998 A1 A, a cutting mill is known in which the material cut by a cutting rotor is continually conveyed through a sieve, in particular an air jet sieve, in such a way that only particles of less than a given size can leave the device.

From DE 29 803 442 U1, an air jet sieve for analysis is known with which a high number of analyses can be carried out in a short time, and which for this purpose has a plurality of sieve surfaces separated off from one another. This air sieve is used to determine particle size distributions in the fine particle range.

From AT 386 769 B, an air jet multi-deck sieving machine is known by means of which dry, free-flowing bulk materials of small particle size can be classified into up to 25 fractions in one pass.

The invention solves the problem by way of a generic method in which the classifying comprises air jet sieving. In a second aspect, the invention solves the problem by way of an active metal separation installation having an air jet sieving device which is at least directly connected to the oven and which is set up to classify the active material and the support, in particular the support foil.

The invention is advantageous in that the active material can be obtained at a high purity. This is because with air jet sieving very small mesh sizes can be used, and so even small impurity particles are also excluded.

Advantageously, the support material can be also reclaimed at a high purity. For example, aluminium foil is frequently used as a support, and can only be recycled efficiently if it meets particular minimum purity requirements. For example, support foil having more than 0.03% impurities is only somewhat suitable for recycling. During further hydrometallurgical processing, transition metal salt solutions from an acidic lithium solution tend to agglomerate if they contain the aluminium contamination of approximately 1% by mass which is typical of conventional separation. This issue occurs because aluminium hydroxide complexes form and tightly bind the agglomerates. These solid agglomerates cannot be fully ground down in a conventional process, and this leads to material waste. Aluminium-contaminated transition metal salt solutions manufactured in this manner would then require expensive cleaning before being ground down. If the aluminium content is reduced to less than 0.1%, this effect is no longer observed. Once an Al contamination of only 0.05–0.06% by mass is achieved, the materials can therefore be recycled in an ecologically and economically beneficial manner. Because the active material is knocked off upon impact against the sieve during air jet sieving, very high purities can be obtained for the support, in particular the support foil.

The invention is based on the finding that heating the cell fragments to the decomposition temperature would theoretically have to be sufficient to destroy the binder to such an extent that the active material is released, but that the active material is still difficult to remove from the support. The effect causing the active material to adhere to the support even without a binder is as yet still unexplained.

With air jet sieving, there is a heavy impact of the support, with active material still adhering on, against the sieve. This impact removes active material still adhering on, in such a way that it can be reclaimed.

Because of the impact of the support against the sieve and the resulting separation effect, air jet sieving may also be referred to as impact separation. Analogously, the air jet sieving device may also be referred to as an impact separation device, and the air jet sieve as an impact separator.

Thus, a further subject matter of the invention is an active material separation installation which has an impact separation device, connected at least indirectly to the oven and set up to classify the active material and the support, by carrying out the air jet sieving in such a way that the active material is at least also separated from the support by impact against a sieve of the impact separation device and/or against an impact plate.

Air jet sieving is known as a laboratory method for separating small particles from other small particles. However, the heat-treated cell fragments have a diameter orders of magnitude greater than that of the particles of the active material, and so the capacity of the air jet sieving to separate two types of particles which both have small diameters is irrelevant for the method according to the invention. In the method according to the invention, air jet sieving is also used as an additional separation step.

In the context of the present description, crushing the cells is understood in particular to mean cutting, shattering, hacking or compressing. This can take place at temperatures between -195.79°C and 100°C , and so requirements on the temperature conditions are low.

Heating solid cell fragments means in particular heating in a gastight container, in such a way that oxygen, for example, is prevented from entering. In particular, the heating takes place under inert gas or in a vacuum.

The active material means in particular a compound which can reversibly absorb and emit lithium ions: on the cathode side, for example, lithium nickel manganese cobalt oxide, lithium nickel aluminium oxide and lithium iron phosphate; on the anode side, for example, graphite.

The support for the active material means in particular a support foil to which the active material is applied in the form of particles. The support foil may for example be aluminium foil. The binder may for example be polyvinylidene fluoride (PVDF).

The crushing of the cells and/or the heating of the solid cell fragments preferably takes place under inert gas, for example under nitrogen. It is favourable for the cells to be crushed at ambient temperature, in particular at at most 30°, it potentially being advantageous for the crushing device with which the cells are crushed to be cooled, in such a way that the effect of heat on the cells remains negligible.

The method according to invention is preferably carried out as a continual process, as opposed to in batches.

The throughput is preferably more than 100 tonnes per year. Air jet sieving has thus far been used on a laboratory scale, where it is used for processing samples in batches. These samples are also very small. The use of air jet sieving in a mass-scale method is unknown thus far.

In a preferred embodiment, galvanic cells are used of which the active material is formed of particles, the particles having a particle diameter distribution and this particle diameter distribution having a 90% diameter, corresponding to the diameter greater than the diameter of 90% of all particles and less than the diameter of 10% of all particles, the air jet sieving taking place using a sieve of which the mesh size corresponds to at most 200 times the 90% diameter. The specified particle diameter is the one obtained by sieving.

The mesh size of the sieve is preferably a maximum of 250 μm , in particular a maximum of 100 μm . Modern lithium ion batteries have an active material composed of particles having a diameter of less than 200 μm . In traditional sieving methods, for example vibration sieving, a

much larger mesh size has to be selected so that the sieving time does not become so long that the method becomes uneconomical. However, a larger mesh size results in more dirt particles passing through the sieve, reducing the purity of the active material obtained.

The galvanic cells preferably each comprise at least one anode and at least one cathode, the anodes and cathodes being heated together and the resulting heat-treated cell fragments being classified in the same air jet sieve. The feature whereby the anodes and cathodes are heated together means that a mixture of the two is heated up in a single device. This is possible because air jet sieving leads to sufficiently accurate separation of power collector foil and coating particles.

The method preferably comprises the step whereby, before the cell fragments are heated to the decomposition temperature, the cell fragments are dried at a drying temperature, in such a way that dry cell fragments and drying vapours arise, at least part of the drying vapours being condensed. This has the advantage that the electrolyte solvent can be reclaimed. In this context, it is advantageous for the drying temperature to be below 100 °C, in particular below 80 °C.

The heating of the cell fragments to the decomposition temperature is preferably carried out under inert gas or in a vacuum. This has the advantage that copper thus does not oxidise, and so both the anode and the cathode can be processed together. This in turn leads to a particularly simple separation process which still provides recycled products which are sorted highly accurately. Inert gas means a gas or a gas mixture which, under the present ambient conditions, reacts neither with copper nor with aluminium (power collector foils). The copper, as a valuable component, can thus be reclaimed at a high purity.

The method preferably comprises the step of treating the dry cell fragments using magnetic separators, resulting in iron-free cell fragments. It is favourable for these iron-free cell fragments to be classified, for example using a zigzag classifier. The iron-free cell fragments are subsequently heated to the decomposition temperature of the binder.

The decomposition temperature is preferably at least 350 °C and at most 800 °C. It has been found that the binder is reliably decomposed at these temperatures.

Preferably, at least the electrolyte agent is also removed when the cells are crushed under inert gas. This increases the recycling ratio.

In a preferred embodiment, the cells are crushed in such a way that the median of the longest diameters of the resulting foil fragments does not fall below 200 μm . In a preferred embodiment, the crushing of cells is carried out in such a way that at least 80% of the foil fragments have a diameter of over 200 μm , whereby the diameter is determined by sieving.

In a preferred embodiment, the air jet sieving takes place in such a way that an air throughput of at least 250 cubic meters of air per hour per square meter of sieve surface is achieved, in particular at least 500 cubic meters of air per hour per square meter of sieve surface. At least 750 cubic meters of air per hour per square meter of sieve surface is particularly favourable. This results in a high enough particle speed for the impact to bring about a high level of separation.

Preferably, a cyclone is arranged behind the air jet sieve. It is also favourable for the supporting air to be sucked away behind the air jet sieve.

For as low an energy consumption as possible, it is favourable for the sieve to be exposed to the airflow containing the particles over at least substantially the whole surface area.

The active material separation installation preferably has a pre-dryer arranged downstream from the cell crushing device and upstream from the oven in terms of the material flow. The pre-dryer is set up to heat the cell fragments to the drying temperature.

It is favourable for the active material separation installation also to comprise a magnetic separator downstream from the pre-dryer and upstream from the oven in terms of the material flow.

It is favourable for the active material separation installation to have a stirred reactor for reclaiming conducting salt, which is connected to the cell crushing device and which removes at least part of the liquid fraction from the cell crushing device.

The method for reclaiming active material from the galvanic cells may also in particular mean a method in which electrodes from electrode production are processed without the electrodes

having been installed in a galvanic cell, but could be installed in a galvanic cell. In other words, the method may also be a method for in-process recycling.

In a preferred embodiment, an impact plate is arranged downstream from the sieve in terms of the flow of air and cell fragments. Said impact plate causes the particles of active material which have only collided weakly with the sieve to be separated from the support upon impact against the impact plate, increasing the separation efficiency.

In a preferred embodiment, the cell crushing device comprises at least one impact mill. As a result of the large number of collision events in the impact mill, the bond between the active material and the support is loosened. The cell crushing device preferably also comprises at least one shredder and/or cutting device, it being particularly favourable for this to be arranged upstream from the impact mill in terms of the material flow direction.

A further subject matter of the invention is the use of an air jet sieve in a method, in particular a continuous method, for reclaiming active material, in particular lithium and/or lithium compounds, for example from used batteries and/or accumulators as well as from waste material from the production of batteries and/or accumulators.

In the following, the invention is explained in greater detail with reference to the accompanying drawings, in which:

Fig. 1 is a flow chart of an active material separation installation according to the invention for carrying out a method according to the invention, and

Fig. 2 is an exploded drawing of an embodiment of an impact separator of the active material separation installation of Fig. 1.

Fig. 1 is a flow chart of an active material separation installation 10 according to the invention, which has a cell crushing device 12, to which galvanic cells 14.1, 14.2... are supplied. The cell crushing device 12 is gastight and comprises a gas washing column 16, a circulation pump 18 and a condenser 20, by means of which an inert gas, for example nitrogen, is circulated and purified. The cell crushing device additionally comprises an inert gas tank 22 for setting an inert gas pressure in the cell crushing device 12. The condenser 20 has an electrolyte outlet 24 via which condensed electrolyte can be removed.

A stirred reactor 26, arranged to remove the liquid fraction from the cell crushing device 12 and to stir it in such a way that conducting salt from the galvanic cells 14 (references without a numerical suffix denote the type of object) can be reclaimed, may be arranged downstream from the cell crushing device 12 in terms of the material flow direction.

A pre-dryer 28 is arranged downstream from the cell crushing device 12 in terms of the material flow direction, and is connected to the cell crushing device 12 via a pipe 30. Cell fragments arising when the galvanic cells 14 are crushed arrive in the pre-dryer 28 via the pipe 30. There is a drying temperature T_t of preferably $T_t = 80\text{ }^{\circ}\text{C}$ therein. The pre-dryer 28 comprises a circulation pump 32 and a condenser 34 for condensing electrolyte, which can be removed via a pipe 36. The pre-dryer 28 is formed gastight and is flushed with inert gas by the circulation pump 32.

A separator 38 is arranged downstream from the pre-dryer 28 in terms of the material flow direction, and comprises a magnetic separator and optionally also an eddy flow separator. The magnetic material is removed via a discharge pipe 40. The non-magnetic material arrives in a classifier 42, for example a zigzag classifier. The classifier 42 is optional, like the separator 38, and is particularly advantageous if, as in the present case, only the cathode of the galvanic cells is to be re-used. The anodes are removed along with any pouch foils which may be present.

An oven 44, in which there is a decomposition temperature T_z of 400 to 600 $^{\circ}\text{C}$, is arranged downstream from the classifier 42 in terms of the material flow direction. The binder, for example polyvinylidene fluoride (PVDF), thus decomposes. The decomposition product is removed via a discharge pipe 46 and passed to the gas washing column 48.

An air jet sieve 50 is arranged downstream from the oven 44 in terms of the material flow direction. The air jet sieve 50 comprises a sieve element 52. The heat-treated cell fragments coming from the oven 44 are delivered onto an air jet sieve. This is distinguished in that an airflow is supplied above or below the fine-mesh sieve element (20–200 μm). This airflow is removed below the sieve. As a result of the airflow, the electrode fragments are whirled up and then placed under mechanical stress. This stress assists in separating the support foil and the coating. The active material particles are thus drawn through the meshes in the airflow and subsequently separated out from the airflow by a cyclone. The foil fraction (aluminium and

copper) is held back by the sieve element and can be obtained as a metal fraction and re-used.

Fig. 2 is an exploded view of an impact separator or air jet sieve. The heat-treated cell fragments to be separated are fed onto one side of the sieve, and a moving airflow is blown towards the sieve from the other side, for example by way of a moving nozzle bar. The cell fragments are thus thrown against the impact plate in the form of the impact cover, where they are separated into the support and the coating.

On the side of the sieve from which the air jet is blown onto the sieve, there is an intake nozzle, by means of which the blown-in air is removed together with the coating. The impact plate is kept apart from the sieve by spacer rings.

List of reference numbers

10	Active material separation installation
12	Cell crushing device
14	Galvanic cell
16	Gas washing column
18	Circulation pump
20	Condenser
22	Inert gas tank
24	Electrolyte outlet
26	Stirred reactor
28	Pre-dryer
30	Pipe
32	Circulation pump
34	Condenser
36	Pipe
38	Separator
40	Discharge pipe
42	Classifier
44	Oven
46	Discharge pipe
48	Gas washing column
50	Air jet sieve
52	Sieve element
54	Particle
56	Discharge pipe
58	Cyclone
T_t	Drying temperature
T_z	Decomposition temperature

Claims:

1. Method for reclaiming active material from a galvanic cell, which comprises an active material, a support for the active material, and a binder for bonding the active material and the support, comprising the steps of:
 - (a) crushing the cells, in particular under inert gas or in a vacuum, in such a way that solid cell fragments are at least additionally formed,
 - (b) heating the solid cell fragments to a decomposition temperature (T_z) selected high enough that the binder decomposes and/or evaporates, preferably under inert gas or in a vacuum, in such a way that heat-treated cell fragments are formed, and
 - (c) classifying the heat-treated cell fragments, characterised in that
 - (d) the classifying comprises air jet sieving,
 - (e) the air jet sieving being carried out in such a way that active material is separated from the support.

2. Method according to claim 1, characterised in that
 - galvanic cells (14) are used of which the active material is formed of particles,
 - the particles have a particle diameter distribution, the particle diameter distribution having a 90% diameter, corresponding to the diameter greater than the diameter of 90% of all particles and less than the diameter of 10% of all particles, and
 - the air jet sieving takes place using a sieve of which the mesh size corresponds to at most 200 times the 90% diameter.

3. Method according to either of the proceeding claims, characterised in that the mesh size of the sieve is at most 200 μm .

4. Method according to any of the preceding claims, characterised in that the galvanic cells (14) each comprise at least one anode and at least one cathode, and the anodes and cathodes are heated together and the resulting heat-treated cell fragments are classified in the same air jet sieve (50).

5. Method according to any of the preceding claims, characterised by the step of:

- (a2) before the cell fragments are heated to the decomposition temperature (T_z)
 - drying the cell fragments at a drying temperature (T_i), in such a way that dry cell fragments and drying vapours arise, and
 - condensing at least part of the drying vapours for the purpose of reclaiming the electrolyte solvents.

- 6. Method according to any of the preceding claims, characterised in that the heating of the cell fragments to the decomposition temperature (T_z) is carried out under inert gas or in a vacuum.

- 7. Method according to any of the preceding claims, characterised by the steps of:
 - (a3) treating the dry cell fragments using magnetic separation, resulting in iron-free cell fragments, and
 - (a4) classifying the iron-free cell fragments.

- 8. Method according to any of the preceding claims, characterised in that the galvanic cells (14) have an electrolyte and/or the electrolyte is also removed when the cells are crushed under inert gas.

- 9. Method according to any of the preceding claims, characterised in that the cells are crushed in such a way that the median of the longest diameters of the resulting foil fragments does not fall below 200 μm .

- 10. Active material separation installation, in particular an active metal separation installation (10), which is configured to reclaim active material, in particular lithium, from a galvanic cell (14), which comprises an active material, a support for the active material, a binder for bonding the active material and the support, and an electrolyte, comprising
 - (a) a cell crushing device (12) for crushing the cells, the cell crushing device being gastight and comprising an inert gas supply mechanism, in such a way that the cells can be crushed to cell fragments under inert gas, and
 - (b) an oven (44) connected at least indirectly to the cell crushing device (12) and set up to heat the cell fragments to a decomposition temperature (T_z) selected high enough that the binder decomposes,
 characterised by

- (c) an air jet sieving device, connected at least indirectly to the oven (44) and set up to classify the active material and the support, by carrying out the air jet sieving in such a way that the active material is separated from the support.
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- 11. Active material separation installation according to claim 10, characterised in that the air jet sieving device has a sieve, an impact plate and a nozzle bar, the sieve being arranged between the nozzle bar and the impact plate in terms of an airflow through the air jet sieving device.
 - 12. Active material separation installation according to claim 11, characterised in that the impact plate is at a distance of at least 30 millimetres, in particular at least 40 millimetres, from the sieve.
 - 13. Active material separation installation according to either claim 11 or claim 12, characterised in that the impact plate is at a distance of at most 250 millimetres, in particular at least 200 millimetres, from the sieve.