LITHIUM-ION BATTERY SCRAP PROCESSING METHOD

TECHNICAL FIELD

This invention relates generally to a method and a system for processing and recycling materials from lithium-ion battery scraps.

Background

Lithium-Ion battery (LIB) waste is growing at more than 20% per annum. This is fueled by skyrocketing demand for rechargeable electronic equipment and the push towards electric battery-powered vehicles. Typically, batteries are valuable and recyclable. However, due to technical, economic and other factors, less than 5% are being recycled. Specifically, LIBs contain several toxic and/or flammable materials. The presence of spent Lithium-Ion battery (LIB) in the municipal solid waste management system poses significant safety risks considering that these spent LIBs can easily catch fire or may even explode. Moreover, the disposal of spent LIBs in landfills could lead to soil and groundwater contamination. This negatively impact the environmental ecosystem because the LIBs contain toxic and heavy metals. LIBs contain transition metal oxides or phosphates, aluminum, copper, graphite, organic electrolytes with harmful lithium salts, polymer separator and plastic or metallic cases.

Most of the batteries that do get recycled undergo few processes like pyrometallurgical processing, dry mechanical processing and hydrometallurgical process which implements high-temperature melting and extraction or smelting, not unlike processes used in the mining industry. These processes, which are carried out in large commercial facilities in, for example Asia, Europe and Canada, are energy intensive. Plants for such processes are also costly to build and operate and require sophisticated equipment to treat harmful emissions generated by the smelting process. Despite the high costs, these plants are not able to recover all valuable battery materials.

For dry mechanical processing, dust control is of paramount importance to handle the carcinogenic dusts. Thermal runaway is an uncontainable but common exothermic reaction that can occur inside an LIB during shredding of the LIBs. This poses potential fire hazards because of LIBs' high energy content, flammable hydrocarbon electrolyte solvent, and potential thermal instability. Further LIBs may cause thermal runaway, which is a self-sustaining uncontrolled increase in temperature within the battery. Thermal runaways often result in fire caused by the ignition of the flammable gases vented from the battery. In addition, any unburnt vented battery gases can be toxic and could accumulate to create an explosion. The smell of the VOC is also another issue especially when the temperature raise up to 60 degrees. The created organic solvent smell can be unbearable and toxic.

Therefore, there exists a solution for addressing the foregoing issues arising from processing LIBs and the like battery scraps.

Summary

In accordance with a first aspect of the invention, there is disclosed a battery scrap processing method comprising fragmentizing battery scraps in a wet condition into scrap fragments, the scraps comprising lithium-ion battery scraps, pre-processing the scrap fragments by an extractor system to extract at least one of cellulosic material and plastic material therefrom to thereby obtain pre-processed mass, and sifting the pre-processed mass by a first sifter to extract metal fractions therefrom to thereby obtain a processed mass. The metal fractions comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass comprising at least one of lithium and a lithium derivative.

In accordance with a second aspect of the invention, there is disclosed a battery scrap processing system comprising a fragmentation assembly for fragmentizing battery scraps in a wet condition into scrap fragments, the scraps comprising lithium-ion battery scraps, an extractor system for pre-processing the scrap fragments to extract at least one of cellulosic material and plastic material therefrom to thereby obtain pre-processed mass, and a first sifter for sifting the pre-processed mass to extract metal fractions therefrom to thereby obtain a

processed mass. The metal fractions comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass comprising at least one of lithium and a lithium derivative.

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Brief Description of the Drawings

FIG. 1 shows an exemplary process flow diagram of a battery scrap processing method in accordance with an aspect of the invention; and

FIG. 2 shows an exemplary system diagram of a battery scrap processing system cooling system in accordance with another aspect of the invention for applying the battery scrap processing method of FIG. 1.

Detailed Description

An exemplary embodiment of the present invention, a battery scrap processing method 100, also known as the lithium-ion battery scrap processing method 100, is described hereinafter with reference to FIG. 1 to FIG. 2. The battery scrap processing method 100 may utilize a battery scrap processing system 20, also known as the lithium-ion battery scrap processing system 20, as herein described.

Although the battery scrap processing system 20 and the battery scrap processing method 100 may be utilized to process various types of battery scraps, the exemplary application described hereinafter in most parts of this disclosure is directed at processing of Li Ion Batteries (LIBs). LIBs contain hidden cobalt, copper and aluminum metals and have to undergo through size reduction to less than 1mm in order to be processed through Hydrometallurgical Process for recovery of Cobalt. Hydrometallurgical process is considered to be the most suitable method for the recycling of spent LIBs. The LIBs (also referred to here as spent LIBs, LIB scraps, scraps or battery scraps) have to undergo mechanical shredding to reduce the size of LIB scraps such as electric vehicle (EV) batteries, lap top batteries, mobile phone batteries and the like, to less than 1mm in size. Using a combination of two or more of a series of shredding and crushing machines, separation equipment and wet pulverisers under wet condition, a high yield recovery of cobalt salt can be achieved with the battery scrap processing system.

The battery scrap processing system 20 comprises a fragmentation assembly 22 for fragmentizing battery scraps 60 in a wet condition into scrap fragments 62. Preferably, the battery scraps 60 comprise lithium-ion battery scraps 60. The battery scrap processing system 20 further comprises an extractor system 24 for pre-processing the scrap fragments 62 to extract at least one of cellulosic material and plastic material therefrom to thereby obtain pre-processed mass 64, and a first sifter 26 for sifting the pre-processed mass 64 to extract metal fractions 66 therefrom to thereby obtain a processed mass 68. Preferably, the processed mass 68 contains particles that are dimensionally less than 0.02mm. Any particles

in the pre-processed mass 64 that are dimensionally from 0.02mm to 0.12mm in size will sifted and discharged by the first sifter 26 as black mass 69. The at least one of cellulosic material and plastic material may be further processed by an ultrasonic cleaner 67 for removal of any remaining non-cellulosic and non-plastic materials therefrom.

The metal fractions 66 comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass 68 comprising at least one of lithium and a lithium derivative. The lithium derivative is a compound derived or processed from lithium, for example, lithium salts. The processed mass 68 can further comprise at least one of carbon and cobalt oxide. Further, the metal fractions 66 can also further comprise cobalt or a derivative thereof, for example, a cobalt salt. Preferably, each of the pre-processed mass 64, the metal fractions 66 and the processed mass is wet.

Preferably, the battery scrap processing system 20 further comprises a separator assembly 28 28 for separating and extracting water from the processed mass 68 to obtain black mass residue 70. Preferably, each of the black mass 69 and the black mass residue may contain active material powder from the cathode or anode of the lithium-ion battery scarps 60 which may be, if intended or required, be further processed for extraction and recycling.

Preferably, the separator assembly 28 comprises a settling thickening tank 30 for settling sludge from water in the processed mass 68 through sedimentation, and a dewatering system 32 for dewatering the sludge to obtain the black mass residue 70. Preferably, water drained from dewatering the sludge is filtered prior to being provided to a chiller system 36.

The battery scrap processing system 20 further comprises a dispenser assembly 34 for dousing the battery scraps 60 with an aqueous solution prior to fragmentising thereof, and a chiller system 36 for chilling the aqueous solution prior to dousing of the battery scraps 60. Preferably, the aqueous solution is an electrolyte, for example, a salt solution. The dispenser assembly 34 can comprise a series or nozzle or a discharge valve for dispensing water or submerging of the battery scraps when being processed and/or when being conveyed, for

example by conveyor belts, for one point to another within the battery scrap processing system 20.

In the fragmentation assembly 22, the battery scraps 60 will undergo a pre-crushing process to reduce the battery scraps 60 into a medium size, for example to a size of less than 10mm. This is to protect and minimize overloading of subsequent shredding processes, and to prolong the life span of cutting blades used in the subsequent shredding processes before further reduction in size by means of a wet pulveriser.

Hence, the fragmentation assembly 22 comprises one of a crusher 38 and a primary shredder 40 for one of crushing and shredding the battery scraps 60 into first fragments of preferably less than 10mm in size, and a secondary shredder 42 for shredding the first fragments into second fragments to thereby obtain the scrap fragments 62. The second scrap fragments 62 is substantially dimensionally smaller than the first scrap fragments 62.

Also, the battery scrap processing system 20 further comprises a wet pulveriser 44 for pulverising the metal fractions 66. Preferably, the metal fractions 66 provided by the first sifter 26 to the wet pulveriser 44 contains particles that are greater than 0.12mm in size. The battery scrap processing system 20 further comprises a second sifter 46 for sifting the pulverised metal fractions 66 into a plurality of metal fraction groups 77. The metal fractions 66 are reduced into a powder when pulverised by the wet pulveriser 44, with the plurality of metal fraction groups 77 obtained from the second sifter 46 categorizing the powder according to sizes or required/predefined size ranges. Preferably, the plurality of metal fraction groups 77 contains metal fractions 66 with a particle size of less than 1mm. The second sifter 46 sifts out and redirects any metal fractions 66 with a particle size of 1mm or more back to the wet pulveriser 44 to be pulverized thereby.

Preferably, water is drained from the pulverised metal fractions 66 during sifting thereof. Each dimensional group of metal fractions 77 comprises a range of size groupings of the pulverised metal fractions 66.

The battery scrap processing system 20 further comprises a gravity separator 48 for separating at least a portion of the metal fractions 66 into at least two of steel, copper and aluminum. The gravity separator 48 contributes to better separation of copper and aluminum. Preferably, the battery scrap processing system 20 further comprises a exhaust port coupled to at least the fragmentation assembly 22, the extractor system 24, the wet pulveriser 44 and the gravity separator 48 for extracting air therefrom, and an air scrubber for scrubbing the extracted air for, for example substantially removing VOC therefrom, before exhausting the scrubbed air into the environment.

The battery scrap processing system 20 further comprises a VOC skimmer 50 for separating volatile organic compounds 78 (VOC 78) from water drained from the second sifter 46 prior to providing the water to the chiller system 36, and a filter assembly 52 for filtering the water prior to being provided to the chiller system 36. The chiller system 36 then chills the water and reintroduces it to the fragmentation assembly 22, effectively defining a looped passageway for water flow and for recirculating the water. Preferably, the chilled water is also directed to the wet pulveriser 44. The filter assembly 52 is reverse osmosis (RO) module or comprises an RO module.

The battery scrap processing system 20 applies the battery scrap processing method 100 comprising fragmentizing battery scraps 60 in a wet condition into scrap fragments 62 in a step 102, pre-processing the scrap fragments 62 by the extractor system 24 in a step 104 to obtain the pre-processed mass 64, and sifting the pre-processed mass 64 in a step 106 by the first sifter 26 to extract the metal fractions 66 therefrom and to thereby obtain the processed mass 68.

The battery scrap processing method 100 further comprises a step 108 of separating and extracting water from the processed mass 68 by the separator assembly 28 to obtain the black mass residue 70, and a step 110 of dousing the battery scraps 60 with an aqueous solution prior to fragmentizing, or fragmentation, thereof. Dousing of the battery scraps 60 includes

one or both of spraying/drenching the battery scraps 60 with water and submerging the battery scraps 60 in water. Water may be introduced or presented at a portion of, various portions of or along the entire length of the passageway for dousing the battery scraps 60 with water.

Preferably, the step 102 of fragmentizing the battery scraps 60 in a wet condition comprises a step 120 of one of crushing and shredding the battery scraps 60 into first fragments, and a step 122 of shredding the first fragments into second fragments to thereby obtain the scrap fragments 62.

The battery scraps 60 undergo fragmentizing, which includes crushing and shredding, and subsequent pulverizing steps/processes under a wet condition in water or an aqueous solution so that processing conditions are substantially dustless when compared with dry condition processing. Further, the water or aqueous solution not only help to discharge the battery charge of the battery scraps 60, but also helps balance the solution density to have better effect on paper separation in the extractor system 24. The extractor system 24 removes paper and plastic using one or a combination of approaches. For example, the extractor system 24 can comprise a rotating scraper to remove paper and plastic materials when the scrap fragments 62 are substantially submerged in water. Alternatively, the extractor system 24 can comprise a flotation tank or pathway, with or without minimal agitation of scrap fragments 62 to enable flotation of the paper or plastic materials to the surface of the water in the flotation tank prior to being removed by a rotating scrapper. Further alternatively, the extractor system can comprise a dissolved air floatation system which uses a dissolved tank when by allowing the paper and plastic float to the top of a water mass. Regardless of approaches employed, the paper and plastic materials are then collected in jumbo bags or drum. Transfer of material comprising the paper and the plastics is performed by means of screw conveyors, belt conveyors, water sludge pump and the like displacement means.

Further, the step 108 of separating and extracting water from the processed mass 68 comprises a step 124 of separating the sludge from the water through sedimentation in the

settling thickening tank 30, and a step 126 of dewatering the sludge with the dewatering system 32 to obtain the black mass residue 70.

Preferably, the battery scrap processing method 100 further comprises a step 130 of pulverising the metal fractions 66 by the wet pulveriser 44, and a step 132 of sifting the pulverised metal fractions 66 by the second sifter 46 into a plurality of metal fraction groups 77. The plurality of metal fraction groups 77 contains metal fractions 66 with a particle size of less than 1mm. The second sifter 46 sifts out and redirects any metal fractions 66 with a particle size of 1mm or more back to the wet pulveriser 44 to be pulverized thereby.

The battery scrap processing method 100 further comprises a step 134 of separating at least a portion of the metal fractions 66 into at least two of steel, copper and aluminum by the gravity separator 48.

Also, the battery scrap processing method 100 further comprises a step 136 of separating volatile organic compounds 78 (VOC 78) from water drained from the second sifter 46 by the VOC skimmer 50 prior to providing the water to the chiller system 36, and a step 138 of filtering the water by the filter assembly 52 prior to being provided to the chiller system 36.

The water, or aqueous solution, which is chilled to preferably less than 10 degrees celcius or less than 4 degrees celcius by the chiller system 36 helps to reduce the temperature and to reduce the smell of the VOC 78. The water or aqueous solution is kept recycled saturation. The VOC skimmer 50 reduces concentration of the VOC 78 in the water or aqueous solution to increase the number of times that the water or aqueous solution can be recycled. Once saturation occurs, or when saturation is approached, the water or aqueous solution may be partially or fully discharged and topped-up or replaced with new water or aqueous solution. This is important as saturation and increased temperature of the water or aqueous solution may ignite fire therein.

Preferably, all equipment constituents of the battery scrap processing system are substantially enclosed to help in the reduction of smell of VOC 78 and to reduce dust. The battery scrap processing system 20 is preferably automated, or substantially automated, to reduce human exposure to VOC 78 and dust during human intervention. This protects the human from dust, toxic gas and chemical contamination.

Aspects of particular embodiments of the present disclosure address at least one aspect, problem, limitation, and/or disadvantage associated with existing battery scrap processing methods. While features, aspects, and/or advantages associated with certain embodiments have been described in the disclosure, other embodiments may also exhibit such features, aspects, and/or advantages, and not all embodiments need necessarily exhibit such features, aspects, and/or advantages to fall within the scope of the disclosure. It will be appreciated by a person of ordinary skill in the art that several of the above-disclosed structures, components, or alternatives thereof, can be desirably combined into alternative structures, components, and/or applications. In addition, various modifications, alterations, and/or improvements may be made to various embodiments that are disclosed by a person of ordinary skill in the art within the scope of the present disclosure, which is limited only by the following claims.

Claims

1. A battery scrap processing method comprising:

dousing the battery scraps with an aqueous solution, the aqueous solution being an electrolyte and being chilled with a chiller system prior to dousing of the battery scraps;

fragmentizing battery scraps in a wet condition into scrap fragments, the battery scraps comprising lithium-ion battery scraps;

pre-processing the scrap fragments by an extractor system to extract at least one of cellulosic material and plastic material therefrom to thereby obtain pre-processed mass;

sifting the pre-processed mass by a first sifter to extract metal fractions therefrom to thereby obtain a processed mass;

pulverising the metal fractions by a wet pulveriser;

sifting the pulverised metal fractions by a second sifter into a plurality of metal fraction groups, wherein water is drained from the pulverised metal fractions during sifting thereof;

separating volatile organic compounds (VOC) from water drained from the second sifter by a VOC skimmer prior to providing the water to a chiller system; and

filtering the water by a filter assembly prior to being provided to the chiller system,

wherein the metal fractions comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass comprising at least one of lithium and a lithium derivative.

2. The battery scrap processing method as in claim 1, further comprising:

separating and extracting water from the processed mass by a separator assembly to obtain black mass residue.

3. The battery scrap processing method as in claim 2, separating and extracting water from the processed mass comprising:

settling sludge from water through sedimentation in a settling thickening tank; and

dewatering the sludge with a dewatering system to obtain the black mass residue,

wherein water drained from dewatering the sludge is filtered prior to being provided to a chiller system.

4. The battery scrap processing method as in claim 1, fragmentizing battery scraps in a wet condition comprises:

one of crushing and shredding the battery scraps into first fragments by one of a crusher and a primary shredder; and

shredding the first fragments into second fragments by a secondary shredder to thereby obtain the scrap fragments, the second scrap fragments being substantially dimensionally smaller than the first scrap fragments.

5. The battery scrap processing method as in claim 1, further comprising:

separating at least a portion of the metal fractions into at least two of steel, copper and aluminum by a gravity separator.

6. A battery scrap processing system comprising:

a dispenser assembly for dousing the battery scraps with an aqueous solution prior to fragmentising thereof, the aqueous solution being an electrolyte;

a chiller system for chilling the aqueous solution prior to dousing of the battery scraps;

a fragmentation assembly for fragmentizing battery scraps in a wet condition into scrap fragments, the battery scraps comprising lithium-ion battery scraps;

an extractor system for pre-processing the scrap fragments to extract at least one of cellulosic material and plastic material therefrom to thereby obtain pre-processed mass;

a first sifter for sifting the pre-processed mass to extract metal fractions therefrom to thereby obtain a processed mass;

a wet pulveriser for pulverising the metal fractions;

a second sifter for sifting the pulverised metal fractions into a plurality of metal fraction groups, wherein water is drained from the pulverised metal fractions during sifting thereof;

a VOC skimmer for separating volatile organic compounds (VOC) from water drained from the second sifter prior to providing the water to a chiller system; and

a filter assembly filtering the water prior to being provided to the chiller system,

wherein the metal fractions comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass comprising at least one of lithium and a lithium derivative.

7. The battery scrap processing system as in claim 6, further comprising:

a separator assembly for separating and extracting water from the processed mass to obtain black mass residue.

8. The battery scrap processing system as in claim 7, the separator assembly comprising:

a settling thickening tank for settling sludge from water in the processed mass through sedimentation; and

a dewatering system for dewatering the sludge to obtain the black mass residue,

wherein water drained from dewatering the sludge is filtered prior to being provided to a chiller system.

9. The battery scrap processing system as in claim 7, the fragmentation assembly comprising:

one of a crusher and a primary shredder for one of crushing and shredding the battery scraps into first fragments; and

a secondary shredder for shredding the first fragments into second fragments to thereby obtain the scrap fragments, the second scrap fragments being substantially dimensionally smaller than the first scrap fragments.

10. The battery scrap processing system as in claim 7, further comprising:

a gravity separator for separating at least a portion of the metal fractions into at least two of steel, copper and aluminum.

LITHIUM-ION BATTERY SCRAP PROCESSING METHOD

Abstract

Disclosed herein is a battery scrap processing method comprising fragmentizing battery scraps in a wet condition into scrap fragments, the battery scraps comprising lithium-ion battery scraps, pre-processing the scrap fragments by an extractor system to extract at least one of cellulosic material and plastic material therefrom to thereby obtained pre-processed mass, and sifting the pre-processed mass by a first sifter to extract metal fractions therefrom to thereby obtain a processed mass. The metal fractions comprise at least one of copper, aluminum, iron and derivatives thereof, and the processed mass comprising at least one of lithium and a lithium derivative.

Figure 1