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A Modern Approach to Recycling of Lithium-Ion Batteries

Akhil Jain V[1], Ved Prakash G[1], Dr. Ganesh kumar AG[1]
(Mechanical, St.Peter's Engineering College, JNTUH, Hyderabad, India.)

Abstract *: The increasing public concern about the environment in the last decade has resulted in stricter regulations worldwide on those related to the adequate destination of hazardous residues containing heavy metals such as spent portable batteries. The principle of this paper is to find a modern approach to the current status of the recycling technologies of spent lithium-ion secondary batteries. Based on the arrangement of lithium-ion batteries, the electrode resources were divided from spent lithium ion batteries with aim to reprocess all valuable components as possible. The spent LIBs were dismantled first, then the mechanical pulverization and sieving process was adopted in the separation of anodes, and dissolution method was used to partition active components from cathodes. The selected organic solvent N, Ndimethylformamide (DMF) could be successfully applied to dissolve the polyvinylidene fluoride (PVDF) adhesive that the cathode active materials LiCoO2 be effectively separated from the aluminum current collector.*

Keywords - Spent lithium-ion batteries, recycling, copper, pulverization, sieving and chemical Dissolution.

I INTRODUCTION

Lithium-ion secondary rechargeable batteries (LIBs) were firstly produced by Sony in early 1990s. Because of their high energy density, low auto-discharge rate, excellent life cycle and acceptable properties in environmental terms, LIBs have substituted Ni-Cd and Ni-MH batteries in many applications, and been extensively used as electrochemical power sources in mobile telephones, personal computers, video cameras and other modern life appliances. The life-span of LIBs is about one to three years. The tremendous growth in the use of LIBs has resulted in a great amount of spent LIBs. Spent LIBs, if not acceptably treated, can cause serious environmental problems due to the hazardous apparatus such as heavy metal, electrolyte, etc. On the other hand, spent LIBs also have high residual values. Co, Li, Cu Al and other metals, shell plastic and graphite carbon in spent LIBs can all be recycled. Especially Co (5–15 wt. %), a rare and precious metal, is an admittedly strategic resource. The cobalt is the most valuable component in LIBs and lithium is also important in many industrial applications, most of the established technologies focus on recycling them. Considering the ever aggravated global problems of resource shortage and environment pollution with rapid economic growth and population increase, all valuable components in spent LIBs should be recovered besides Co or Li. In the present work, based on the structure of LIBs, the spent LIBs were dismantled first and then the components of anode and cathode were separated with aim to recycle all valuable components from spent Li-ion batteries aspossible.

2 Experimental

Materials and reagents: The materials used in this work are discarded lithium-ion batteries for mobile-phones. N, N-dimethylformamide (DMF), N, N-dimethylacetamide (DMAC) and N-methylpyrrolidone (NMP), are used as organic solvents for separation of active materials from cathodes. All reagents are utilized as received without any further purification. Equipment and Devices: Mechanical equipment like hammers are used for dismantling the batteries. Chemical dissolution process can be carried out by using the chemical, organic solvents and maintaining optimum temperature in the induction furnace. Methods: A LIB comprises an anode, a cathode, organic electrolyte and a separator. The anode is a copper plate coated with a mixture of graphite carbon, acetylene black electric conductor and additives through PVDF binder. Similar to the anode, the cathode is composed of aluminium foil, active cathode materials, PVDF binder, electric conductor and additives. In the experiment, it was discovered that the bonding force between copper foils and adhered graphite carbon is loose, and the mixture coating easily dropped off from their support substrate when anodes

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were struck. Compared to anode, the mixture of $LiCoO_2$ and acetylene black electric conductor are well-knit to the aluminium foil. It is difficult for the mixture coating to be dropped off from the aluminiumfoil the cathodes are pulverized however, with the physicochemical property of PVDF; the active materials could be successfully separated from cathodes by dissolution of PVDF in an organic solvent. Based on the fact above and the structure of the LIBs, the strategy of recycling the spent LIBs is as follows layout of recycling process Fig.1

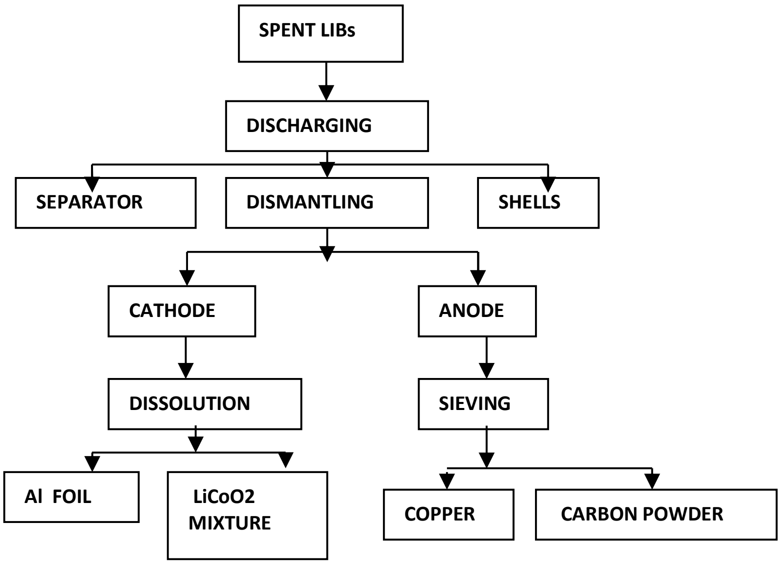

Fig.1

3 Procedure

Discharging: The small amount of charges in the battery is discharged by connecting the positive and negative terminals to a load like electric bulbs. Dismantling: The batteries to be recycled are dismantled manually by the means of mechanical equipments like hammer, pliers. After discharged, the spent LIBs were first dismantled with screwdrivers, pliers, or other mechanical tools, and then the partitioned shell, separator, anode and cathode were further treated separately. Because of the complicated components of electrode materials, a separation process of different materials was carried out to simplify the recovery procedure. However, the separator and shell could be reused directly to their single components. The equipments and dismantled parts are shown in figures 2, 3 and 4 respectively.

Fig.2

Fig.3

Fig-4

3 .1 Recycling of Anode (Copper)

Owing to low bonding force between graphite carbon particles and copper foil, graphite carbon can easily drop off and be separated when anode materials were struck. Cleaned copper is shown in figure.5.

Fig.5

3.2 Recycling of Cathode (Al)

Dissolution process was adopted to separate aluminum foil and $LiCoO_2$ mixture on cathodes. N, N dimethylformamide is used as a dissolution reagent to separate the PVDF binder from the aluminium. After the removal of PVDF from the aluminum, $LiCoO_2$ is filtered from the organic solvent after treating it at 60^0c. The step by step recycling process of cathode is shown in figures 6.(a,b,c,d,e,f)

6(a) 6(b) 6(c) 6(d) 6(e)

3.3 Application of Recycled Materials: Copper

- Raw materials for battery industries.
- Commercial supply for electrical components.
- Electroplating of metals.

Electroplating is a plating direction in which metal ions in a declaration are stimulated by an electric field to cover an electrode. The progression uses electrical current to reduce cations of a desired substance from a solution and coat a conductive object with a lean layer of the substance, such as a metal figure.7.

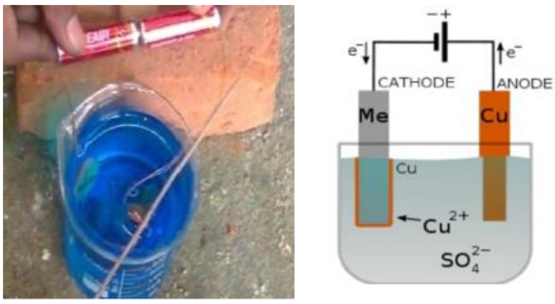

Fig 7. Electro Plating

Electroplating of a metal (Me) with copper in a copper sulfate bath

3.4 Aluminium

- Raw materials for battery industries.
- An ideal material for reflectors in light fittings.
- Aluminium foils in packaging food materials.

4. CONCLUSION:

Mechanical pulverization and sieving process were used to separate graphite carbon and copper foil on anodes. And recovery rate for copper. And the chemical dissolution process has removed the $LicoO_2$ from cathode. This recycling process helps to reduce the unwanted landfills of spent batteries and avoids the toxic substances from contaminating the environment.

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