ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
MATHEMATICS, PHYSICS, THEORETICAL MECHANICS
FASCICLE II, YEAR XIV (XLV) 2022, No. 2
DOI: https://doi.org/10.35219/ann-ugal-math-phys-mec.2022.2.07

New trends in battery technologies

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Abstract
For reducing the carbon print electrical energy storing is essential. The current political agenda is high on environmental, economic, and social consequences of the battery fabrication technology and safety, recyclability, and all environmental consequences. The European Union (EU) has proposed a new Battery Regulation that intends to ensure sustainability for batteries placed on the EU market, developing a robust European battery industry and value chain. This study consists in providing information regarding the new trends and studies for new technologies regarding the development of batteries construction and use.

Keywords: batteries; technologies; construction; parameters; characteristics.

1. INTRODUCTION

Important strategies for the development and production of batteries are considered for Europe in the context of the clean energy transition. It is also a major component of the automotive sector in Europe. In the EU, transport is responsible for about a quarter of greenhouse gas (GHG) emissions and is the leading cause of air pollution in cities [1].

Batteries were among the first products to be regulated according to their life cycle, from product design and safety to transportation and recycling. Batteries bring benefits in the current energy crisis due to the war in the Ukraine. The objective of a future Battery Regulation is very important and its net environmental or social benefits must be clearly established, efficient and significant and applicable to batteries [2].

There are also several environmental issues related to the production, use and end-of-life management of batteries. Environmental issues that are not directly covered by the EU environmental laws and thus require intervention and regulation, all of which can be linked to the functioning of the single market. One such problem is managing the negative environmental impact of hazardous substances in batteries when they are recycled, a problem that can be solved by properly collecting and recycling portable batteries. One of the concerns about the method of collecting portable batteries is low because the installation of collection systems has a cost and the single market does not implement the "polluter pays" principle in an appropriate and harmonized way. Sub-optimal collection levels are problematic in terms of business profitability. This is because recycling technologies are heavily invested in capital and thus require major savings, in some cases beyond EU national markets. Another problem is the difficulty of management to reduce the total impact on the environment of the batteries by circularly increasing the value chain of the batteries [1].

A new regulatory framework is one of the first initiatives proposed under the Commission's new circular economy action plan (the "Action Plan"), which was published on 11 March 2020 and is an essential part of the European Green Agreement and the Commission's plan [3].

Climate change and environmental degradation are a real threat to Europe and to the world. To address these challenges, the European Green Agreement will transform the EU into a modern and resource-efficient and, of course, competitive economy, ensuring: net low greenhouse gas emissions by 2050, independent economic growth of use resources and implementation of the concept no person and no place left behind [4].

As half of total greenhouse gas emissions are responsible for more than 90% of biodiversity loss and water quality from resource extraction and processing, the European Green Agreement has launched a concerted strategy for a non-greenhouse gas economy, climate-friendly, resource-efficient and competitive. To achieve this ambitious goal, the EU must accelerate the transition to a regenerative growth model that further reduces the planet's stress, moves the resource consumer beyond the limits of the planet, and therefore strives to reduce its footprint consumption and double the utilization rate of extracted materials over the next decade [5].

Durable and efficient batteries and vehicles are the basis of the mobility of the future. To make rapid progress in improving the sustainability of the battery value chain based on new technologies for electric vehicles and increasing the circular potential of all batteries, the Commission will propose a new regulatory framework for batteries. This legislative proposal will be based on the evaluation of the Batteries Directive and the work of the Battery Alliance, taking into account: regulations on recycled content and measures to improve collection and recycling rates of all batteries, ensuring the recovery of valuable materials and providing guidance to consumers, addressing non-rechargeable batteries in order to phase out their use where there are alternatives and requirements for durability and transparency for batteries, taking into account the carbon footprint of battery manufacturing, which is currently problematic, the supply of raw materials and security of supply, and facilitating reuse and recycling [5][6].

Batteries and accumulators are crucial elements in ensuring the use of countless products, devices and services used daily, being an indispensable source of energy in our society. Every year, about 800,000 tons of car batteries, 190,000 tons of industrial batteries and 160,000 tons of consumer batteries enter the EU [2].

With the advent of information society and the rapid development of electronic industry, energy storage systems with high energy density are urgently demanded to power modern electronic devices. The energy density of the state-of-the-art lithium-ion batteries (LIBs), which are widely used in portable electronic products, is close to the upper limit of its theoretical value [7].

The present paper shows in the next sections information regarding batteries characteristics, application areas and integration of new technologies.

2. BATTERY CHARACTERISTICS

An important role in the future of energy storage belongs to lithium−sulfur (Li-S) batteries, the main reason for this is due to their high discharge capacity and the fact that sulfur is quite cheap.[13] The run time of all electronic devices depends on their batteries discharge capacity. Conventional Li-ion batteries use lithiated transition metals such as LiCoO2 (lithium cobalt oxide) [8] and LiFePO4 (lithium iron phosphate) as lithium insertion cathode materials [9]. These transition metals are expensive, rare and toxic to the environment. There are many advantages in using sulfur as a cathode material, like low prices, low toxicity levels, high gravimetric capacity, high energy density, and low operating voltage. There are also a number of disadvantages, one of them being known as shuttling effect (i.e., polysulfide migration), there are also other disadvantages that need to be taken into consideration, like low volumetric density, limited cyclability, and poor safety, these issues need to be amended in order to make Li−S cells more widely usable. Another fact that needs to be considered regarding Li−S batteries is the abundance of sulfur found in countries considered large producers of oil due to their large stocks of pure sulfur accumulated as a result of oil purification and refining. [17].

Batteries which use a positive nickel electrode, and a negative cadmium electrode are called NiCd batteries. The electrolyte is an aqueous solution. The advantages of the NiCd batteries are their fast charge and discharge times: it is possible to charge a battery in 10 min and large currents can be supplied. NiCd batteries have a cell voltage of 1.2 V and can be used in many devices [13][14].

The Zn–MnO2 (Zinc – Magnesium - oxide) primary batteries are a well-established and mature technology widely used in lots of fields such as small electronic devices, electronic toys, and portable electronic devices. The ZMPB (Zinc Magnesium primary batteries) consists of manganese dioxide (MnO2) used as the positive electrode, metal zinc (Zn) as the negative electrode, an aqueous solutions of potassium hydroxide (KOH) or ammonium chloride (NH4Cl) as the electrolyte, and a small amount of conductive and corrosion inhibiting additives. Due to the advantages of low cost and simple production process, the ZMPB occupies more than 75% of the portable battery market[15].

One can find at [10] a good presentation with pros and con's for different types of batteries existent on the market today. Electrochemical cells and batteries are categorized into two types. Although there are several other classifications, these two are the basics, primary are non-rechargeable ones and secondary batteries which are ideal for recharging [11]. In figure 1 we can find a presentation of the existing types of batteries.

Fig. 1. Battery types existent on the market [10]

An accurate description of reliability in use can be found at [11]. According to [11], in Figure 2, a brief description consisting of the use domain and special characteristics of different battery types is presented.

Battery Type	***Characteristics***	***Applications***
Alkaline (Zn/Alkaline/MnO2)	Very popular, moderate cost, high performance	Most popular primary batteries
Magnesium (Mg/MnO2)	High capacity, long shelf life	Military and aircraft Radios
Mercury (Zn/HgO)	Very high capacity, long shelf life	Medical (hearing aids, pacemakers), photography
Lithium/Solid Cathode	High energy density, low temp performance, long shelf life	Replacement for button and cylindrical cells
Lithium/Soluble Cathode	High energy density, good performance, wide temp range	Wide range of applications with a capacity between 1 – 10,000 Ah
Lithium/Solid Electrolyte	Low power, extremely long shelf life	Memory circuits, medical electronics
Silver/Zinc (Zn/Ag2O)	Highest capacity, costly, flat discharge	Hearing aids, photography, pagers
Zinc – Carbon	Common, low cost, variety of sizes	Radios, toys, instruments

Fig. 2. Characteristics and application domain [11]

The following subchapters present the useful characteristics to be taking into account when choosing a battery.

A. Temperature of Operation

The temperature of operation plays a very significant role in the degradation of the health of the battery. If the operating temperature is higher than the maximum operating temperature as defined by the manufacturer, then the health of the battery degrades exponentially. Similarly, if the temperature is below the minimum operating temperature, the health of the battery decreases [14,15].

According to [12] the standard rating for batteries is at room temperature 25 °C. At approximately -30 °C, battery Ah capacity drops to 50%. At freezing, capacity is reduced by 20%. Capacity is increased at higher temperatures – at 50 °C, battery capacity would be about 12% higher.

Temperature generation due to chemical reaction is a common problem for all batteries. Unusual temperature damages the chemical properties and kills the battery. Generally, the battery has to be operated at both low and high temperatures. For the low temperature effect, the charging and discharging current, as well as power handling capacities of the battery, are reduced due to the decreased rate of chemical reactions and the transformation of active chemicals with respect to temperature [16,19].

B. Charge/Discharge Cycles

Charging and discharging are important processes in the efficient use of the battery. However, they affect the performance of the battery, too. During the discharging process, the lithium ion moves from the cathode into the electrolyte and the lithium ion from the electrolyte moves into the anode and releases an electron. This process is reversed during charging. As this process takes place, it leads to breaking or wearing down of the electrode and results in capacity loss [18,20].

In its simplest definition, a battery is a device capable of converting chemical energy into electrical energy and vice versa. This can be seen in Figure 3 [13].

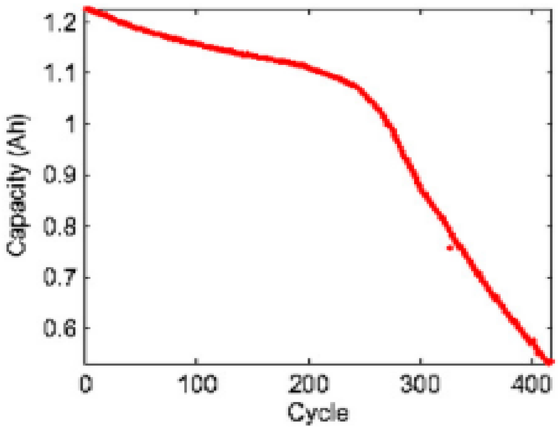


Fig. 3. Capacity loss during cycling of a CGR18500 battery [13]

The chemical energy is stored in the electro- active species of the two electrodes inside the battery. The conversions occur through electrochemical reduction– oxidation (redox) or charge-transfer reactions [13,20].

The loss of cell function due to voltage and heat effects has been discussed; however, this loss has a negative effect on the cycle life of the battery. It is worth mentioning that if a battery cell operates out of its standard operating range, an irrevocable capacity loss occurs [19].

C. Calendar Ageing

Calendar ageing is defined as the decrease in the ability of the battery to provide the power it was able to provide when it was new. This usually happens as the battery is used over time because of the decrease in the potency of the chemicals that are used to develop the battery [18].

Aging of Lithium-ion batteries is a complicated process, which is caused by interactions of various factors. This process may occur: (1) on the positive and negative electrodes, electrolytic solution, and contact surfaces of batteries; (2) in active materials of batteries; and (3) in current collectors and binders of batteries [21].

D. State of charge (SOC)

Considering an analysis of the characteristics of lithium-ion battery, this will show that the essence of the inconsistency of lithium-ion battery is State-Of-Charge (SOC) inconsistency [22].

According to [22] about 80% of the discharging process is in the voltage plateau period, where the voltage drop rate is slow. The larger the discharging rate is, the lower the voltage is.

For the charging period, the voltage – capacity graphic is shown in Figure 4.

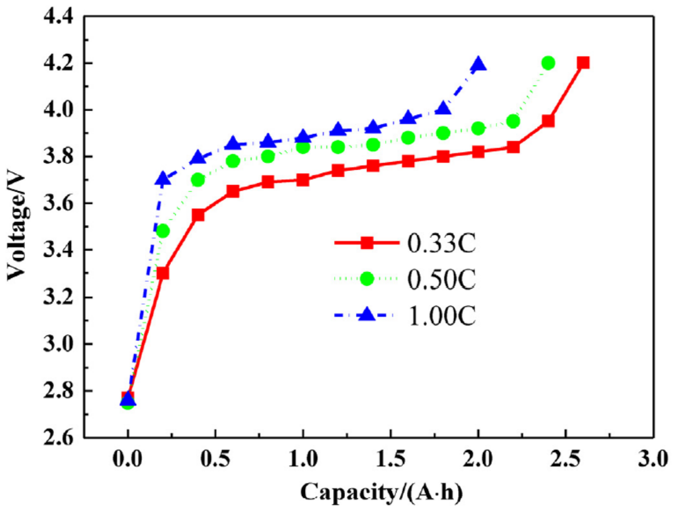
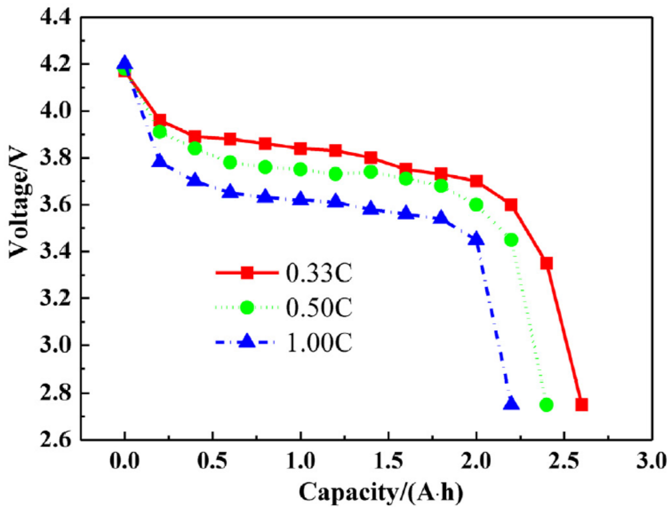


Fig. 4. Voltage curve at charging [22]

For the discharging period, the voltage – capacity graphic is shown in figure 5.



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ig. 5. Voltage curve at discharging [22]

Active equalization control not only can improve cell inconsistency but also can improve the energy utilization of the battery pack in the process of charging and discharging [23].

E. State of health (SOH)

The SOH determines the health of the battery. It is generally defined in terms of capacity degradation [23].

This parameter consists of analyzing all the previous ones presented above.

F. End of life (EOL)

EOL (End Of Life) EV batteries represent a valuable secondary source for some materials used in traction batteries, which are not available in many countries. Globally, 60% of cobalt production is controlled by Congo, while 80% of lithium is sourced from Chile and Australia (USGS, 2020). At the EOL stage, if not being controlled properly, the leaked harmful materials would pose a huge threat to soil, groundwater, and even public health. [24]

3. APPLICATION AREAS

A. Electric vehicles (EV)

Electric vehicles (EVs) have been promoted heavily across the world as a promising solution to tackle climate change and air pollution from the transport sector [24][25].

Lithium-ion cell stacks for electric vehicle (EV) batteries are compressed by either a module frame or a rigid cell housing, as it is typically the case with cylindrical cells or prismatic hardcase cells [26].

B. Renewable power supplies

The excessive use of fossil fuels has triggered the energy crisis and caused a series of severe environmental problems. The exploitation of clean and new energy and the matching energy storage technologies is thus of great significance to the sustainable development of human society. Rechargeable batteries stand out as the main powering technologies over the past few decades because of their high specific capacity, long cycle life, and environmental friendliness. There are many types of rechargeable batteries, including lithium-ion batteries (LIBs), sodium-ion batteries (NIBs), potassium-ion batteries (KIBs), aluminum-ion batteries (AIBs) and zinc-ion batteries (ZIBs), etc. [27].

The rapid growth of solar PV power faces challenges due to its variable generation resulting in a decline in its economic value [28].

One major option for the provision of flexibility to better accommodate solar PV electricity is short-term storage. Li-Ion batteries are one of the most prominent short-term storage technology largely due to their plummeting costs and high potential [28].

C. Portable electronic devices

Portable electronic devices include cellular phones, tablets, laptops, cordless phones, digital cameras, camcorders, MP3 players, video games and toys, among others. In terms of battery market share, cell phones, tablets and laptops are by far the major applications. The global market for portable electronics continues to grow strongly. Currently, 31% of the world population uses smartphones, but national level statistics for smartphone penetration are very diverse, reaching a record of 88% of the population in South Korea, while being under 10% in several Sub-Saharan African countries [25].

4. INTEGRATION OF NEW TECHNOLOGIES

Recently, the emphasis in research has shifted progressively towards the integration of different components, full cell battery functionality and scalability of manufacturing processes [29][30].

A. Electrolyte-electrode interface stability enabled by inhibition of anion mobility in hybrid gel polymer electrolyte based Li–O2 batteries

In [7], the PPM-5 (a new composite material) based Li–O2 battery can run stably for more than 200 cycles at room temperature. PPM-5 was used as the gel polymer electrolyte in Li–O2 battery [7].

This study is of great significance for improving the safety and cyclability of Li–O2 batteries and promoting its commercial application [7].

B. Flower-like tin/carbon composite microspheres for lithium ion batteries

Graphite and carbonaceous materials have been commonly used as anode materials in lithium-ion batteries (LIBs), because of their low cost, long-lasting cyclability, and safety. For the fabrication of the flower-like tin/carbon (Sn/C) composite microspheres using sulfonated semi-interpenetrating polystyrene (SPS) microspheres as a carbon precursor relies mostly on the sulfonation degree of SPS [31].

It was found that the sulfonation degree of SPS microspheres depends on the sulfonation time. When the electrochemical tests of the flower-like Sn/C composite microspheres were performed, the sample using SPS microspheres prepared by longest sulfonation time exhibited the highest charge-discharge capacities at all current rates because of large amounts of Sn (tin) nanocrystals [31].

In addition, these composite electrodes have a long-lasting cyclability, even at high current rates. These results are attributed to the uniform distribution of Sn nanocrystals in the carbon phase, high electronic conductivity, and large specific surface area resulting from the unique particle morphology [31].

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