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Lithium-ion batteries

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ABSTRACT

The demand for lithium-ion batteries is growing due to their characteristics (composition, size, charging time, capacity). There are various types that can be found on the market, which mostly depend on their purposes, which depend on their composition. They have different uses, starting with portable devices like mobile phones, cameras, and even smaller electric cars. They are being developed and improved (capacity, voltage, charging); additionally, their size is being reduced, which is particularly important in car industry where more rechargeable lithium-ion batteries are connected to get desired capacity. Similarly, to other types of batteries, these consist of cathodes, anodes and electrolytes, where gel or solid electrolyte is preferable to avoid the release of gas (hydrogen), and therefore their explosion or damage. From 2000 to 2010, the annual production of lithium-ion batteries in the world increased about 800%.

Keywords: *capacity, voltage, charging, electrolytes*

The cells that are the source of direct current have been found even in ancient Egypt: a pear-shaped copper cylinder wrapped around an iron rod (https://www.conopljanews.net/tajanstvene_stvari.html). However, the first modern battery was invented by Alessandro Volta around 1800, and consisted of two tiles of different metals in an electrolyte where they were connected to the upper part by an electrical connection and a one-way current (http://www.bibnum.education.fr/sites/default/files/volta-analysis-5.pdf). Batteries nowadays are based on the same principle. Rechargeable batteries are made of electrodes and electrolytes, which are usually made from mixtures of lithium-ion or nickel-metal hydride. As an unwanted effect of chemical reactions, heating of the batteries occurs during operation, which affects unfavourably electrolytes (http://inovatori.hr/wp-content/uploads/sites/225/2017/01/Punjenje_baterija-1.pdf; http://www.fer.unizg.hr/_download/forum/INEU_Seminar_Matija_Mikolcic.pdf). It is not recommended to empty the battery completely, as there is a degree after which they should not be discharged. Depending on the application, there are rechargeable lithium-ion and lithium polymer batteries. The greatest advantage of lithium batteries in comparison to others is easy and fast charging; however, their adverse environmental impact is not reduced due to the application or incorporation of various metals in their structure in order to improve certain properties (http://www.doiserbia.nb.rs/img/doi/0367-598X/2017/0367-598X1600031S.pdf). To reduce environmental pollution, it is, therefore, necessary to raise awareness of the recycling of batteries (Maschler et al., 2012; Xu et al., 2008).

Composition of lithium-ion batteries

Like other types of batteries, lithium ion batteries consist of a protective jacket, anode, cathode, and a separator with an electrolyte or gel separator. Cathodic material is applied to the aluminium collector, as a conductive additive; carbon and polyvinyl-difluoride (PVDF) are used as a binder. The ratio of these components is usually 85: 10: 5. The binder, which is usually PVDF, serves to cathode material to tightly bonds to the aluminium substrate, and carbon to increase the electrical conductivity of the material. The anode lithium ion battery makes a Cu collector, where an anode material made of graphite is applied using a small PVDF additive. Poly-tetrafluoroethylene (PTFE) is sometimes used as a binder. For the separator, polypropylene, which is soaked with electrolyte, is used. As an electrolyte, a solution of lithium salt ($LiPF_6$, $LiBF_4$, $LiAsF_6$ or $LiClO_4$, $LiCoO_2$, $LiNiO_2$,

$LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$, $LiMn_2O_4$ and $LiFePO_4$) is used in some organic solvents, usually dimethyl carbonate (DMC), ethylene-carbonate (EC), or propylene carbonate (PC). In commercial batteries, $LiPF_6$ is often used as electrolyte which is dissolved in a mixture of ethylene carbonate and dimethyl carbonate (Espinosa et al., 2004).

During charging and discharging, the lithium ions move through the electrolyte to the electrode, while the electrons generated by the reaction Li = Li^+ + e- go from one to the other current collector by an external electric circuit. During the discharge, the lithium ions are released from the structure of the negative electrode with the simultaneous oxidation of the host A and enter the structure of the positive electrode K, which is reduced. The reverse process occurs during charging (Zhang et al., 2014). The porous separator has the role of preventing contact between the cathode and the anode and the formation of a short circuit. Li-ion batteries contain inflammable and toxic organic electrolytes, so for this reason the organic electrolyte was replaced by aqueous electrolyte. The advantages of aqueous electrolytes are higher ionic conductivity that is about two orders of magnitude greater than for non-aqueous electrolytes; it cannot lead to ignition or battery explosion; it is more environmentally friendly, simplifies battery production and is cheaper. The biggest problem is to find an electrode pair in which lithium ions can be intercalated/deintercalated in the potential area where there is no water electrolysis, having good cyclic behaviour during a large number of charge/discharge cycles. For this reason, this type of battery cannot have a voltage greater than 2V (Li et al., 2014). Li-Polymer batteries differ from Li-ion by the type of electrolyte used. The first batteries using dry and solid polymer electrolytes were developed in the 1970s, and the first commercial Li-polymer batteries appeared relatively recently. They are using electrolytes on a plastic film that does not carry electricity within, but allows an uninterrupted exchange of ions (electrically charged by atoms or groups of atoms). Roughly speaking, the polymer electrolyte is replaced by the traditional porous separator, which is impregnated with liquid electrolyte. Dry polymer provides small cell thickness (up to 1 mm), relative simplicity of production and safety (lack of liquid or gel electrolyte eliminates the possibility of poisoning or burns). The disadvantages of the Li-polymer batteries in relation to Li-ion are that the use of high temperatures is required to achieve optimum performance from 60 to 100 ° C whereas Li-ion sometimes requires cooling, as the optimum temperature moves around 15° C. The main difference from Li-ion batteries is that Li-Pol have a porous separator, which causes a gradual degradation of the battery. The polymeric gel electrolyte is simply added here to expand the ionic conductivity (Basu, 1983; Mizushima et al., 1980).

Lithium as the basis for the production of batteries is used because it is very light metal; in addition, it has high electrochemical potential and provides the highest specific energy, so scientists come to the conclusion that it is suitable for making lithium-ion batteries. There is a problem because lithium batteries due to more charging and discharging become temperature-unstable and there may be an explosive reaction. Today's Li-ion rechargeable batteries are additionally protected (https://tanders.ru/bs/about-batteries-batteries-their-differences-and-features-types-of-modern-batteries-for-cars-and-prospects-for-development/).

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