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BATTERY AND CAPACITIVE SYSTEMS FOR STORING ELECTRICAL ENERGY

Danijela Vuković[1], Petar S. Matavulj[1], Blanka Škipina[2], Duško Dudić[3*]

[1] School of Electrical Engineering, University of Belgrade, Belgrade, Serbia
[2] Faculty of Technology, University of Banja Luka, Banja Luka, Republic of Srpska, Bosnia and Herzegovina
[3] Vinča Institute of Nuclear Sciences - National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia

[*] Corresponding author: ddudic@vinca.rs

Abstract: One of the important factors that hinders the widespread adoption of green technologies is the lack of environmentally friendly batteries. The electrochemical batteries are currently the best choice for storing electricity for most industrial needs and products. Unfortunately, the production of the metals needed to make the electrodes for electrochemical batteries is a serious environmental problem. Electrolytic capacitors that show high energy densities are acceptable to the industry, but they contain, in addition to metals, very harmful organic substances. Polymer and ceramic capacitors show very low energy density compared to the conventional batteries and therefore cannot be widely used for electricity disposal. At the same time, all other features of that capacitors that characterize battery systems are ideal. A brief comparison of the basic properties of electrochemical and physical batteries was presented. Some economic aspects were also described.

Keywords: energy, electricity storage, battery, capacitor.

1. INTRODUCTION

Electricity storage is a crucial component of a large number and variety of industrial products. The problem of electricity storage is a significant limiting factor for the use of autonomous electric vehicles and the application of electricity from solar panels. The success of the application of green technologies depends on the ability of scientists and engineers to develop sufficiently cheap and environmentally friendly rechargeable batteries. Due to their high energy capacity, the electrochemical batteries are in intensive use today. Rechargeable lithium batteries are currently the best choice for storing electricity for most industrial needs and products. The good features of these batteries are a large specific capacity for energy disposal (about 150 Wh/kg) and a weak memory effect [1-3]. Environmental and safety risks associated with this type of battery, their price and a limited lifespan are the reasons why great efforts are being made in the search for a more suitable type of battery [3,4]. The development of physical batteries in which electricity is deposited without electrochemical processes is one of the perspectives. The absence of chemical processes would dramatically extend the life of such batteries compared to the electrochemical batteries, and the choice of materials for their manufacture could be more environmentally friendly. Polymer capacitor is a typical example of a physical battery. Compared to rechargeable lithium batteries, polymer capacitors show very low energy density (~ 0.1 Wh/kg) and significantly higher power density [5-7]. Due to the mentioned characteristics, polymer capacitors are used primarily in low-energy electronics, they can also be easily designed for high-voltage applications. Unless a significant increase in the energy density of polymer capacitors is achieved, they will not find application in massive storage of electrical energy.

The energy density of a polymer capacitor with a certain geometry is proportional to the applied voltage (electric field - quadratic dependence) and the permittivity (polarity) of the polymer used. The voltage that can be applied to the polymer capacitor is limited by the voltage of the polymer breakdown. Increasing the polarity of a polymeric material by blending or adding fillers is usually accompanied by a decrease in the dielectric strength of such a material relative to the pure polymer, and this topic is common in studies dealing with the storage of electricity in polymeric materials [8,9]. Linear polymers show lower dielectric permittivity compared to ceramics, but due to the possibility of applying very large electric fields, polymer capacitors generally show higher energy densities compared to ceramic capacitors [7]. The energy densities of polymer capacitors range from 1.1 J/cm^3 (~ 0.05 Wh/kg) - polypropylene (PP) capacitor to 11 J/cm^3 - polyvinylidene fluoride (PVDF) capacitor [5,7-9]. Polymer composites based on fluoro polymers and ceramic fillers have so far shown the highest energy densities, slightly exceeding the value of 30 J/cm^3 [7]. An insight into the data collected in this study could help in the development of a strategy for a more environmentally acceptable storage of electrical energy.

2. RECHARGEABLE BATTERIES - COMPARISON

The development of rechargeable batteries over the past 100 years has gone in the direction of increasing their energy density. The presence of heavy metals and their salts in the electrochemical batteries is common. Due to the intensive growth of battery consumption, the environmental aspects of battery production and recycling are becoming imperative [3,4,10]. The battery life is also important, not only because of the price of the battery calculated by the year of use, but also because of the environmental damage, which should also be calculated according to the period of use. The most important characteristics of electrochemical and physical rechargeable batteries are presented in Table 1.

The price of batteries is not mentioned in Table 1 because it can vary significantly depending on the method of manufacture. Taking into account the other essential characteristics of rechargeable batteries, listed in Table 1, only the polymer capacitors can be rated with three maximum ratings. The low energy density of polymer capacitors prevents their wider application. Any improvement in the energy deposit of polymer capacitors, which can be achieved without dirty technologies, brings this type of battery closer to the concept of an ideal battery.

Polyolefins, polymers composed only of carbon and hydrogen, are cheap and environmentally friendly materials for making batteries. Isotactic polypropylene (iPP) is a polyolefin that finds application in all branches of industry due to its suitable thermomechanical, chemical and electrical (insulation) properties [11]. A more detailed insight into the economic aspects of the application of rechargeable batteries, on the example of iPP/metal capacitor and electrochemical batteries, is given in Table 2.

Table 1. *Some characteristics of electrochemical and physical rechargeable batteries [2,6,7]*

	Type	Energy density	Power density	Lifespan	Ecology
electrochemical	Metal-water/salt	medium	low	low	bad
	Ni-metal (hydride)	medium	low	low	bad
	Li-metal oxide	high	medium	medium	bad
	Na-metal oxide	high	medium	medium	moderate
	Supercapacitor	high	medium	medium	bad
physical	Ceramic capacitor	low	high	high	moderate
	Polymer capacitor	low	high	high	the best

Table 2. *Battery economy: iPP/metal capacitor versus electrochemical battery [2,7].*

	iPP/metal capacitor	electrochemical battery
Energy density [Wh/kg]	0.05	10-150
Power density [W/kg]	250 000	100
Lifespan [years]	100	5-10
Battery weight required to deposit 1 kWh [kg]	20 000	7 (Li-bat.)
Recycling	100%, cheap and clean technology	50-90%, dirty technology
Battery price [EUR/kg]	3	31 (Li-bat.)
Disposal price of 1 kWh calculated per year of use without recycling [EUR]	600 EUR	22 EUR (Li-battery)

The last row of Table 2 shows the prices of batteries with a capacity of 1 kWh, which are divided by the estimated time of use (iPP/metal 100 years and Li-bat. 10 years). Although the impact of the recycling price was not taken into account, the prices and weights shown in Table 2 clearly indicate the advantages of electrochemical batteries over polymer capacitors. The mentioned ratio, shown in Table 2, can be improved in favor of the polymer capacitors only in the case of a significant improvement in their energy density. In doing so, all environmental aspects of that improvement must be acceptable.

3. CONCLUSION

The price of depositing electricity in polymer and ceramic capacitors is extremely high compared to the price of depositing electricity in electrochemical batteries, the reason for that is the very low energy density of polymer and ceramic capacitors. At the same time, polymer capacitors show higher power density and significant environmental advantages in comparison with electrochemical and electrolytic systems for depositing electrical energy. Economic reasons determine the widespread use of electrochemical batteries, while legal regulations and science should direct “battery streams” in the direction of a cleaner environment. Depositing larger amounts of electricity in polymer capacitors would contribute to a cleaner planet and it’s probably a good choice that needs more development resources.

4. ACKNOWLEDGMENTS

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БАТЕРИЈСКИ И КАПАЦИТИВНИ СИСТЕМИ ЗА СКЛАДИШТЕЊЕ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ

Сажетак: Један од важних фактора који омета широко усвајање зелених технологија је недостатак еколошки прихватљивих батерија. Електрохемијске батерије тренутно су најбољи избор за складиштење електричне енергије за већину индустријских потреба и производа. Нажалост, производња метала потребних за израду електрода за електрохемијске батерије представља озбиљан еколошки проблем. Електролитички кондензатори који показују високу густину енергије прихватљиви су за индустрију, али поред метала садрже и веома штетне органске супстанце. Полимерски и керамички кондензатори показују веома ниску густину енергије у поређењу са конвенционалним батеријама и стога се не могу широко користити за одлагање електричне енергије. Истовремено, све остале карактеристике тих кондензатора које карактеришу батеријске системе су идеалне. Дато је кратко поређење основних својстава електрохемијских и физичких батерија. Описани су и неки економски аспекти.

Кључне речи: енергија, складиштење електричне енергије, батерија, кондензатор.

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