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Short communication

Prototype sodium polybutadiene and poly(butadiene-styrene) batteries

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Abstract

The conductive properties of butadiene polymer (BR) and styrene-butadiene polymer (SBR) with sodium chlorate (VII) can be used at industrial scale as miniature batteries. Polymer material modified with sodium chlorate (VII) was used to produce sodium polybutadiene and poly(styrene-butadiene) batteries. The conductivity of such polymer composites for temperatures ranging 243–313 K is at a similar level and amounts to 10^{-4} S cm^{-1} for butadiene polymer and to 10^{-3} S cm^{-1} for styrene-butadiene polymer at 100 kHz. The conductive battery made of butadiene polymer shows a open circuit voltage of 0.9 V with a short-circuit current of 40 mA, whereas that made of styrene-butadiene polymer shows a open circuit voltage of 1.2 V with a short-circuit current of 38 mA. The lightness, commonly found material (sodium), and environment-friendly energy are main advantages of sodium polybutadiene and poly(styrene-butadiene) batteries.

Keywords: Polymer electrolytes; Sodium chlorate(VII); Metallic sodium; Manganese dioxide(IV); Butadiene polymer (BR); Styrene-butadiene polymer (SBR)

1. Introduction

Lithium polymer batteries are known by now, which have found practical application as miniature batteries, among others in small electronic watches. In such batteries, metallic lithium is an anode and manganese dioxide(IV) is a cathode, with a conductive polymer, e.g. polyaniline or polypyrole, placed between anode and cathode.

The present paper gives the characteristics of conductive polymers and the construction of sodium polybutadiene and poly(styrene-butadiene) battery. The idea of constructing a new battery consists in substituting a conductive polymer, like frequently used polypyrrole or polyaniline, for a conductive butadiene or styrene-butadiene polymer [1–11].

2. Preparation of conductive butadiene polymer (BR) and conductive styrene-butadiene polymer (SBR)

2.1. Stage 1

The (1,4-*trans*) butadiene polymer (BR) and the (1,4-*trans*) styrene-butadiene polymer (SBR) are easily soluble in toluene; 40 cm^3 toluene is added to 3 g of finely cut BR or SBR polymer. After 3 days, the polymer left at room temperature becomes an oily substance.

2.2. Stage 2

One should add 40 cm^3 of 40% $NaClO_4$ dissolved in CH_3OH (99.9%) into the polymer (BR or SBR) solution prepared in *Stage 1*. The polymer electrolyte precipitates almost at once. After 1 h, a composite exposed to atmospheric air is subjected to conductivity testing. Such a modified polymer is elastic and similar to the pure polymer.

Fig. 1 presents a structural diagram of polymer (BR) and a point of ion introduction into the polymer structure. Positive sodium ions are found at maximum electron density in the polymer. These spots are found at a double bond (π). On the other hand, negative chlorate(VII) ions are found at a point of least electron density, i.e. between sp^3 carbons in the polymer.

3. The results of conductive polybutadiene testing

The received polybutadiene and poly(styrene-butadiene) electrolyte was subjected to examination with the alternating current at 10 Vpp in order to obtain data for conductivity of this polymer electrolyte (Fig. 2, Table 1).

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Table 1
Breakdown of conductivity results for the butadiene polymer + $NaClO_4$ system and the butadiene-styrene polymer + $NaClO_4$ system for 1 and 100 kHz

Polymer system	Temperature, 273 K ($S\,cm^{-1}$)	Temperature, 293 K ($S\,cm^{-1}$)	Temperature, 303 K ($S\,cm^{-1}$)	Temperature, 323 K ($S\,cm^{-1}$)
1 kHz—(BR + $NaClO_4$)	3.7×10^{-5}	3.8×10^{-5}	4.0×10^{-5}	6.6×10^{-5}
100 kHz—(BR + $NaClO_4$)	3.5×10^{-4}	3.7×10^{-4}	3.8×10^{-4}	4.3×10^{-4}
1 kHz—(SBR + $NaClO_4$)	4.1×10^{-2}	4.8×10^{-2}	7.1×10^{-2}	7.3×10^{-2}
100 kHz—(SBR + $NaClO_4$)	4.1×10^{-3}	4.4×10^{-3}	4.6×10^{-3}	4.9×10^{-3}

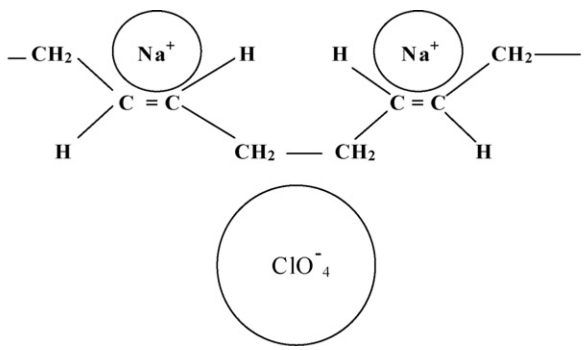

Fig. 1. Diagram of conductive polymer system (BR).

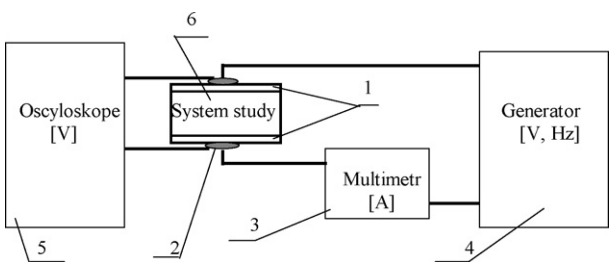

Fig. 2. Measuring diagram of the conductivity of the polymer system being tested: (1) copper plates, (2) junction of a conductor with a copper plate, (3) multimeter, (4) alternator, (5) oscilloscope, (6) polymeric electrolyte.

The following equipment was used for testing:

- Alternating-current generator, type Hewlett Packard 33120A 15 MHz Function-Arbitrary Waveform Generator.
- Multimeter, type Agilent 3458A 8.5 Digit Digital Multimeter.
- Oscilloscope, type Hewlett Packard Infinium Oscilloscope 500 MHz 1 Gsa/s.

4. Sodium polybutadiene and poly(styrene-butadiene) battery

Fig. 3 presents a diagram of sodium polybutadiene and poly(styrene-butadiene) battery. This battery consists of two metal electrodes (1, 2) isolated from each other by a non-conductor [an isolator] (3, 8). In the metal casing (negative end), a terminal electrode is placed. It is the pure polymer supplemented with a large amount of active carbon. Electron conduction occurs in such a system (5). In the middle of this terminal electrode, metallic sodium is placed (6). In the metal casing—of the positive end (2), manganese dioxide (MnO_2) is placed, which is mixed with active carbon supplement.

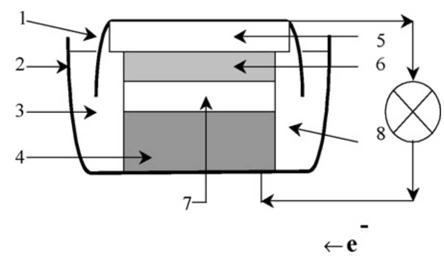

Fig. 3. Structure of the sodium polimers battery schematic: (1) metallic casing—negative pole, (2) metallic casing—positive pole, (3) isolator, (4) manganium(IV) dioxide, (5) terminal electrode, (6) metallic sodium, (7) polimer + $NaClO_4$, (8) isolator.

Such a mixture of MnO_2 with active carbon should be firmly pressed prior to inserting it into the battery in order to form a single solid material (4).

Basic element connecting the anode (metallic sodium) with the cathode (manganese dioxide(IV)) is a conductive polymer, composed of BR and BSR with sodium chlorate (VII) (7).

Negative electrode (metallic sodium) (6) has to be connected only with the cathode (manganese dioxide(IV)) (4), through a conductive butadiene polymer (BR) or styrene-butadiene polymer (SBR) with sodium chlorate(VII) supplement (7). In Fig. 3, a structure diagram of sodium polybutadiene and poly(styrene-butadiene) battery is presented.

5. Discussion and conclusions

A distinctive feature of the conductive polymers obtained is their stable electrolytic conductivity within a temperature range of 273–323 K. Sodium polybutadiene batteries (BR) and sodium poly(styrene-butadiene) batteries (SBR) are composed among others of conductive polymers, which show constant voltage and current strength, irrespective of temperature (273–323 K). The process of gaining energy by electrochemical reaction is as follows:

$$Na^0 + MnO_2 \rightarrow Na^+ + e^- + MnO_2 \rightarrow NaMnO_2$$

On the anode, metallic sodium gives up an electron to energy receiver and passes to the cathode. On the cathode, manganese dioxide (MnO_2) becomes reduced to the manganate anion (MnO_2^-). Sodium, in the form of cation (Na^+), diffuses through conductive polymer, which is BR or SBR with chlorate (VII), and builds into the crystal lattice of manganese dioxide.

Such prototype rubber batteries have similar parameters, which have been determined through a short-circuit current:

(a) for sodium polybutadiene battery—40 mA/0.9 V;

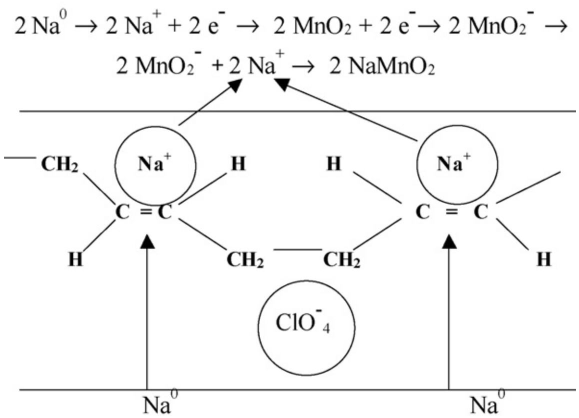

Fig. 4. Conductive mechanism in the sodium battery (BR).

(b) for sodium poly(styrene-butadiene) battery—48 mA/1.2 V.

Polybutadiene and poly(styrene-butadiene) batteries have small voltage and current strength. Therefore, they can be connected in series or in parallel, depending upon needs, in order to receive higher voltage–current strength values.

The length of working time of such batteries by means of short-circuit current is relatively long. With maximum current drawing (short-circuit current), such a battery is discharged after 3 months. Fig. 4 below presents a diagram and the mechanism of internal work of sodium polybutadiene and poly(styrene-butadiene) battery.

6. Conclusions

Summing up, one may state that polybutadiene and poly(styrene-butadiene) systems supplemented with sodium ions, which are commonly found in nature, make such systems to be cheaper when compared with lithium polymer systems. Further research work with regard to this issue can be carried on by determining maximum interfacial surface between polybutadiene and poly(butadiene-styrene) composite and metallic sodium in order to obtain maximum voltage–current strength values.

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