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Structure and Mechanism of the Sodium Polyisoprene Battery

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The conductive properties of polyisoprene with sodium chlorate can be used at industrial scale as miniature battery. Polymer material modified with sodium chlorate was used to produce sodium polyisoprene battery. The conduc-tivity of such polymer composites for temperatures ranging 273 to 313 K is at a similar level and amounts to 10^{-4} S cm^{-1} for polyisoprene at 50 kHz. The conductive battery made of butadiene polymer shows an open circuit voltage of 1.2 V with a short circuit current of 43 mA. The lightness, commonly found material (sodium) and environment-friendly energy are main advantages of sodium polyisoprene battery.

Key Words: Polymer electrolytes, Natural rubber, Battery, Sodium chlorate, Metallic sodium.

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 is a cathode, with a conductive polymer, like polyaniline or polypyrole, placed between anode and cathode.

Polyisoprene or natural rubber (*Hevea brasiliensis*), which was used for obtaining polymer electrolytes, originated from a Para rubber tree plantation in Ranni, Kerala State, India and imported into Poland in June 2006.

The present paper gives the characteristics of conductive polymer and the construction of sodium polyisoprene (natural rubber) battery. The idea of constructing a new battery consists of substituting a conductive polymer, like frequently used polypyrole or polyaniline, with a conductive polyisoprene[1-21].

EXPERIMENTAL

Natural rubber (NR) is found in the form of rubber latex and oxidates quickly in the air, producing an elastic and stretchy rubber (India-rubber). In order to avoid this process (since India-rubber dissolves more easily in the form of rubber latex), it was immediately added to toluene (99 % pure). Toluene (Spectrum Chemicals, India) was bought straight before collection of natural rubber in India. Natural rubber latex, preserved this way, was imported into Poland.

To work out a method of natural conductive rubber synthesis, it required in the first stage to precipitate rubber latex from toluene and to dissolve it again in toluene in order to make strictly specific mass recalculations. For precipitating the rubber latex, methanol (99 %, Chempur®, Poland) was used. 40 mL Toluene is added to 3 g of finely cut NR polymer. After two days, the polymer left at room temperature becomes an oily substance. On adding 40 mL of 40 % $NaClO_4$ dissolved in CH_3OH (99.9 %) into the polymer (NR) solution prepared in Stage 1, the polymer electrolyte precipitates almost at once.

After one hour, a composite exposed to atmospheric air is subjected to conductivity testing. Such a modified polymer is elastic and similar to the pure polymer.

Methods for measurements of polymeric electrolytes: The received polyisoprene (NR) electrolyte was subjected to examination with the alternating current at 10 Vpp in order to obtain data for its conductivity (Table-1). The following equipment was used for testing[22-24]: • Alternating-current generator, type Hewlett Packard 33120A 15 MHz Function-Arbitrary Waveform Generator; • Multimeter, type Agilent 3458 A 8.5 Digit Digital Multimeter; • Oscilloscope, type Hewlett Packard Infinium Oscilloscope 500 MHz 1 Gsa/s.

TABLE-1
BREAKDOWN OF CONDUCTIVITY RESULTS FOR THE ISOPRENE POLYMER + $NaClO_4$ SYSTEM FOR 50 AND 100 KHz

Polymer system	Temperature			
	283 K ($S\ cm^{-1}$)	293 K ($S\ cm^{-1}$)	303 K ($S\ cm^{-1}$)	313 K ($S\ cm^{-1}$)
50 KHz – (NR + $NaClO_4$)	2.1×10^{-4}	2.1×10^{-4}	2.3×10^{-4}	2.4×10^{-4}
100 KHz – (NR + $NaClO_4$)	4.0×10^{-3}	4.2×10^{-3}	4.3×10^{-3}	4.6×10^{-3}

RESULTS AND DISCUSSION

Structure and mechanism of sodium polymer battery: Polyisoprene (NR) battery have small voltage and current strength. Therefore, they can be connected in series or in parallel, depending upon the conditions, 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 three months.

Fig. 1 schematic presents a diagram of sodium polyisoprene (NR) 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.

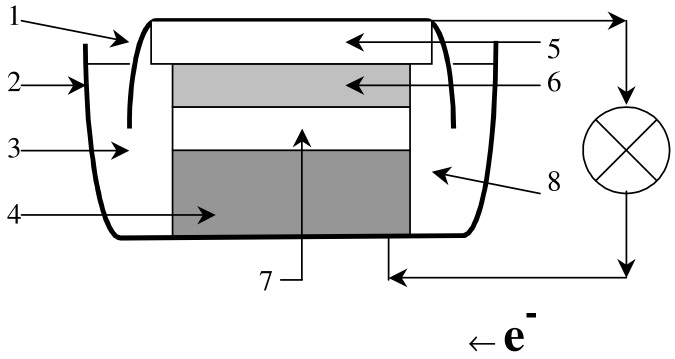


Fig. 1. Structure of the sodium polymer battery schematic: 1 = metallic casing - negative pole, 2 = metallic casing- positive pole, 3 = isolator, 4 = manganese dioxide, 5 = terminal electrode, 6 = metallic sodium, 7 = natural rubber + $NaClO_4$, 8 = isolator

Electron conduction occurs in such a system[5]. In the middle of this terminal electrode, metallic sodium is placed[6].

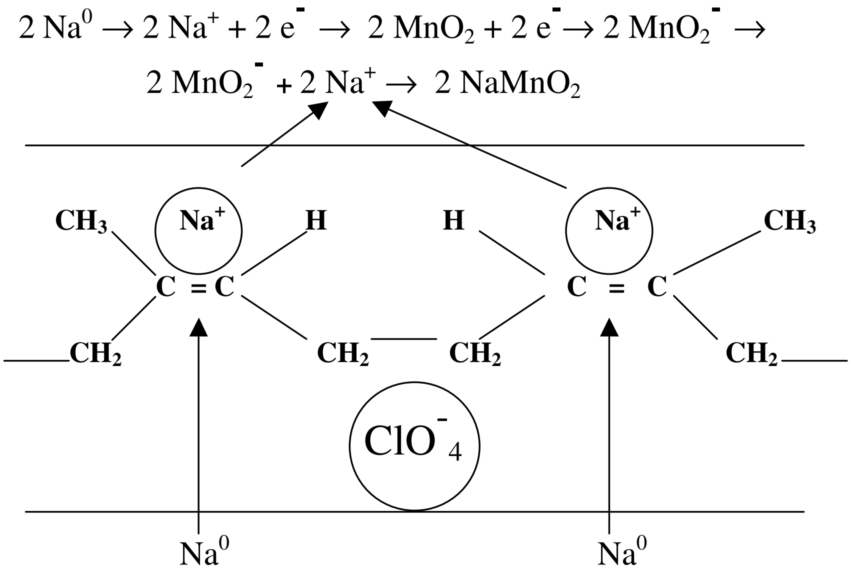
In the metal casing - of the positive end[2], manganese dioxide (MnO_2) is placed, which is mixed with active carbon supplement.

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) is a conductive polymer, composed of NR with sodium chlorate[7]. Negative electrode (metallic sodium)[6] has to be connected only with the cathode (manganese dioxide)[4], through a conductive polyisoprene (NR) with sodium chlorate supplement[7].

Fig. 2 below presents a diagram and the mechanism of internal work of sodium polyisoprene (NR) battery.

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.



$$2\,Na^0 \rightarrow 2\,Na^+ + 2\,e^- \rightarrow 2\,MnO_2 + 2\,e^- \rightarrow 2\,MnO_2^- \rightarrow$$

$$2\,MnO_2^- + 2\,Na^+ \rightarrow 2\,NaMnO_2$$

Fig. 2. Diagram and mechanism of the internal work of sodium polyisoprene (1,4-*cis* polyisoprene, NR)

It may be stated that polyisoprene (NR) system supplemented with sodium ions, which are commonly found in nature, make such system to be cheaper when compared with lithium polymer system. Further research work with regard to this issue can be carried on by determining maximum interfacial surface between polyisoprene (NR) composite and metallic sodium in order to obtain maximum voltage-current strength values.

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