

CHARGING AND DISCHARGING PROCESSES IN GRAPHITE-ZEOLITE/NaCl/MgCl₂ SYSTEMS

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Abstract: The most important characteristics of stationary battery installations are environmental friendliness and low price. Therefore, widely available and acceptable materials such as zeolite should be the focus of research in this field of science. The properties of a simple system consisting of graphite electrodes and zeolite/water/NaCl/MgCl₂ electrolytes were tested. Energy density and recoverable energy storage were improved by adding a small amount of NaCl and MgCl₂ to the zeolite/water electrolyte. The energy efficiency of the examined electro-capacitive systems in the DC electric field is generally below 10%.

Keywords: zeolite, energy storage, electrolyte, electricity.

1. INTRODUCTION

The scientific community devotes considerable attention to the problems that limit the widespread use of photovoltaic panels. Two basic problems stand out, the first problem is the efficiency of photovoltaic panels, while the second problem is the need for a cheap and environmentally acceptable method of depositing electricity [1,2]. This study is a contribution to a major scientific quest for environmentally friendly and inexpensive batteries. Materials that are readily available and do not conflict with high environmental standards are highly desirable candidates for making batteries. Zeolites are widely available in nature, their production and recycling are processes with very low environmental impact.

Zeolites have already found application in chemical-technological processes and products as adsorbents or catalysts [3]. The peculiarity of zeolites to adsorb ions in a specific way can be suitable for the design of electrodes and electrolytes [4,5].

The results presented in this article are the initial results of a study that should investigate energy phenomena in zeolite electrolyte. The ability for the dominant energy phenomena to occur in the electrolyte rather than at the electrodes could improve existing electrochemical battery designs. The investigated electro-capacitive system consists of identical graphite electrodes and zeolite/water electrolyte with the addition of small concentrations of sodium and magnesium chloride. The described system shows very low values of recoverable energy storage, below 10%. Therefore, it was shown that the presence of the mentioned chlorine salts in the zeolite electrolyte increases the energy efficiency of the described electro-capacitive system.

2. EXPERIMENTAL

The sodium form of LTA Zeolite (Sigma-Aldrich 4A molecular sieves, ~ 44µm) was used as the base electrolyte. The other two electrolytes were ob-

tained by mixing NaCl (0,1 g) or MgCl₂·6H₂O (0,345 g) with 15 g of dry zeolite and 20 ml of distilled water to obtain 0.085 M concentration of salts. The samples are designated as ZE - zeolite/water, ZE/NaCl - zeolite/water/NaCl and ZE/MgCl₂ - zeolite/water/MgCl₂.

The electro-capacitive cell consists of a glass vessel with a zeolite electrolyte in which two identical graphite electrodes are immersed at a distance of 1 cm, the face-to-face surface of the electrodes is 4 cm². The charging and discharging processes were carried out by successive cycles of charging for 30 s, and discharging for the next 100 s. Measurements were made in the direction of charging voltage rise with certain periods of constant charging voltage. In order to record the charge and discharge currents, a Kethley 2700 ammeter was connected in series with the cell. The experiment was conducted using a computer and a relay system that switched the cell from a voltage source (0.4 - 8 V) - charging mode to discharging mode via a resistor $R=220 \Omega$ and vice versa. Energies were obtained by integrating the curves over time, $I \cdot V$ - charging energy and $I^2 \cdot R$ - discharging energy.

3. RESULTS

Figure 1 shows the charge (Fig.1a) and discharge (Fig.1b) power of the cell for two charging voltages, 0.4 and 3.2 V. A voltage of 0.4 V is also the lowest charging voltage applied in this study. At the lowest applied electric field (0.4 V/cm), the presence of MgCl₂ salt ions even led to a decrease in the electrical conductivity of the zeolite mixture (green thin line - Fig. 1a). The loading power was lower than in the case of zeolite (ZE) and zeolite in the presence of NaCl (ZE/NaCl). At a higher charging voltage of 3.2 V, the charging and discharging powers show the expected mutual relationship, the presence of the mentioned chlorine salts in the electrolyte increases the amount of deposited and released energy.

A higher concentration of ions in the electrolyte due to the presence of salt contributes to its greater polarity and electrical conductivity. An increase in polarity contributes to a greater energy deposit achieved by the electrolyte in the presence of electrodes, while an increase in electrical conductivity, i.e. more intensive movement of ions can increase energy losses. Amounts of invested and released

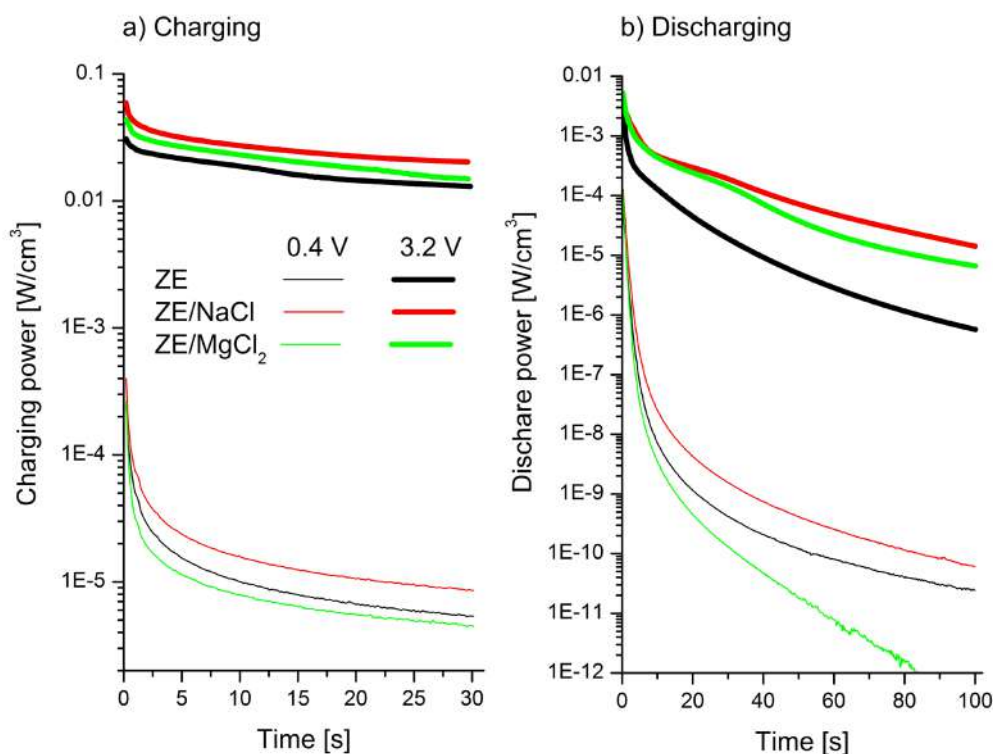


Figure 1. a) Charge and b) discharge curves for charge voltages of 0.4 V (thin line) and 3.2 V (thick line). The results are normalized to the volume of the electrolyte.

energy of the described capacitive systems depending on the charging voltage are shown in Figure 2.

The charging voltages were successively raised from 0.4 to 3.2 V, and then 8 charging and discharging cycles were performed at a charging voltage of 3.6 V (Figure 2). For the ZE/MgCl₂ electrolyte, testing was extended by further raising the charging voltage as shown in Figure 2. Electrolysis processes on the electrodes were observed in this experiment at cell voltages higher than 4 V, this is clearly seen through the increased charging energy at voltages of 5 V and higher (Figure 2 - ZE/MgCl₂). All electrolytes before and after the test show a pH value of around 8.5, this did not change even after the application of higher charging voltages and the clear appearance of gases on the electrodes. Based on this, it can be concluded that when a voltage above 4 V was applied, oxygen and hydrogen were released on the electrodes.

The results shown in Figure 2 indicate that the energy efficiency of the investigated electrolytes is low and that the presence of the mentioned chlorine salts in the zeolite increases the values of the energy invested and released in relation to the application of pure zeolite in the electro-capacitive cell. It should

be emphasized that during the application of a constant charging voltage of 3.2 V (central part of Figure 2) there is a simultaneous decrease in the invested energy and an increase in the released energy. The mentioned increase in the efficiency of the capacitive cell at the successive application of a voltage of 3.2 V is more clearly presented in Figure 3.

Figure 3 shows the ratios of invested and released energy, the recoverable energy storage, depending on the charging voltage. As the charging voltage increases, the energy efficiency of zeolite capacitive systems decreases, while zeolitic electrolytes containing NaCl and MgCl₂ showed significantly higher efficiency compared to zeolite/water electrolyte. The increase of recoverable energy storage during the successive application of the charging voltage of 3.2 V is shown by all three capacitive systems, and this is especially pronounced in the case of electrolytes containing chlorine salts. Bearing in mind that no changes were observed on the surfaces of the used electrodes, the reason for the mentioned increase of recoverable energy storage during the successive application of a constant charging voltage is primarily in the creation of a more energetically fa-

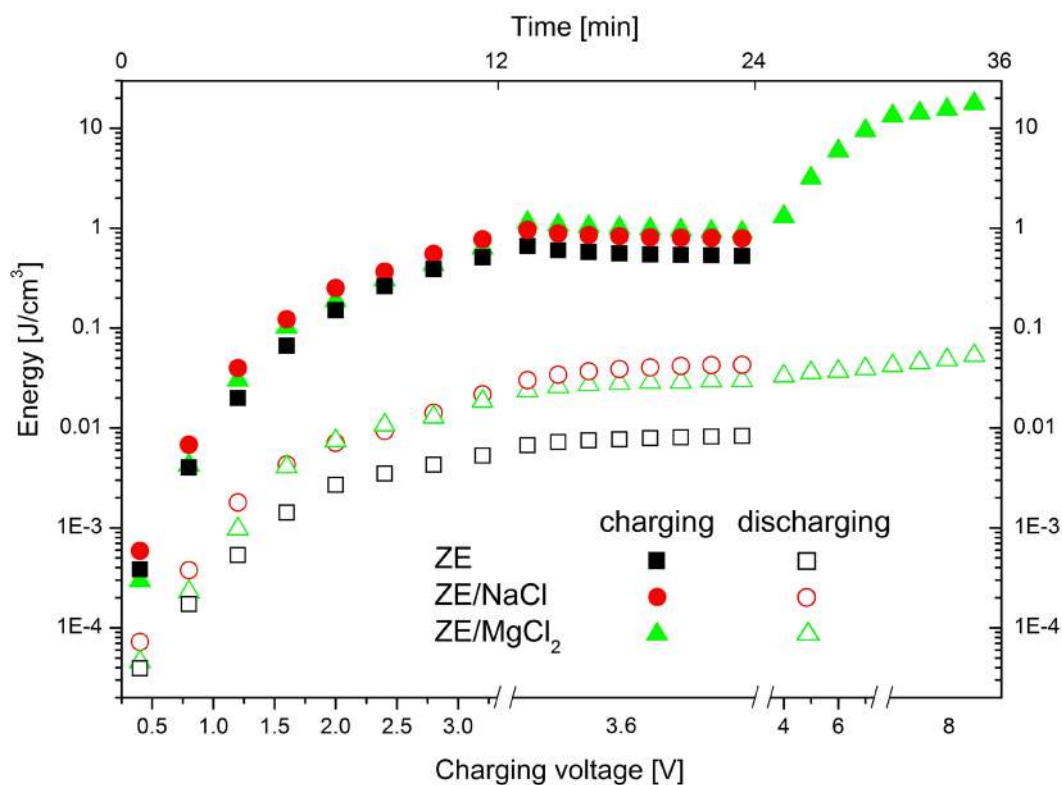


Figure 2. Used energy during the charging process - full symbols and released energy during discharge (empty symbols) depending on the charging voltage. The results are normalized to the volume of the electrolyte.

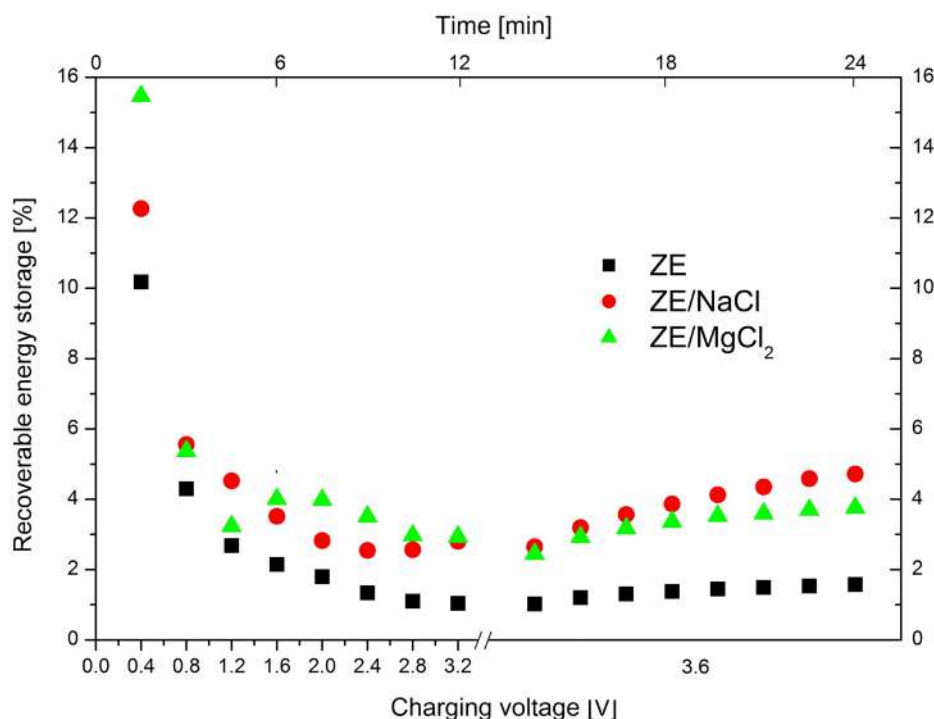


Figure 3. Recoverable energy storage versus charging voltage.

favorable distribution of ion concentrations in the electrolyte during the charging and discharging process.

4. CONCLUSION

The recoverable energy storage of the simple systems consisting of graphite electrodes immersed in zeolite/water/NaCl/MgCl₂ electrolytes was tested. The described electro-capacitive systems show very low values of the recoverable energy storage in a constant electric field, below 10%. Therefore, it was shown that the presence of the mentioned chlorine salts in the zeolite electrolyte increases the energy efficiency of the described electro-capacitive system. Electrolysis of the electrolyte occurs when a voltage above 4 V is applied.

5. REFERENCES

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ПРОЦЕСИ ПУЊЕЊА И ПРАЖЊЕЊА У ГРАФИТ-ЗЕОЛИТ/NaCl/MgCl₂ СИСТЕМИМА

Сажетак: Најважније карактеристике стационарних батеријских инсталација су еколошка прихватљивост и ниска цена. Стога би широко доступни и прихватљиви материјали као што је зеолит требало да буду у фокусу истраживања у овој области науке. Испитивана су својства једноставног система који се састоји од графитних електрода и електролита зеолит/вода/NaCl/MgCl₂. Густина енергије и ефикасност су побољшани додавањем мале количине NaCl и MgCl₂ у зеолит/вода електролит. Енергетска ефикасност испитиваних електрокапацитивних система у сталном електричном пољу је углавном испод 10%.

Кључне речи: зеолит, депоновање енергије, електролит, електрична енергија.

Paper received: 6 May 2024

Paper accepted: 28 May 2024



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