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APPLICATION OF DOUBLE NETWORK GEL STRUCTURE PRODUCTION TECHNOLOGY IN ELECTROLYTE HYDROGELS

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Abstract
The article identifies the physical and mechanical properties of two-band solid polymer hydrogel electrolytes used in high-prospect supercapacitors at present time and in the future. The hydrogel of gellan and polyvinyl alcohol was selected as the electrolyte.

Keywords: supercapacitors, electrical capacitance, polyvinyl alcohol, gellan, polymer gel electrolytes, elongation, breaking, strength.

Introduction
Radical changes in the field of electrical engineering, including microelectronics, and the increase in the needs of consumers in this field is causing a sharp increase in the demand for fast-charging, small-sized, but large-capacity, flexible and adaptive energy storage devices. Based on the above requirements, supercapacitors (SC) are receiving a lot of attention as acceptable energy storage devices due to their ability to be quickly charged and used for a long time. Any capacitor electric signals are very important. Relative to the unit mass of the SC, it has a slightly higher value than a single (electrolytic) capacitor, but it is smaller than that of batteries. Despite this, SCs have advantages over batteries in several physical parameters. The table below shows the physical properties of SCs and batteries to compare their performance (Tab.1.). Therefore, the main part of SCs consists of electrodes and electrolytes. Between them, the electrolyte forms an ion-conductive environment and creates double electric layers with the electrode and plays an important role in SCs [1].

Therefore, one of the main tasks in our research is to study the physical and mechanical properties of electrolytes. Electrolytes are usually divided into three large groups: liquid, solid and redox-active electrolytes. Solid electrolytes are widely used compared to liquid and redox-active electrolytes due to their non-leakage and good shape retention.

Table 1. Supercapacitor and battery efficiency comparison

Parameter	Supercapacitor	Lithium-ion battery
Charging time	1–10 sec	10–60 min
Number of charge-discharge (times)	1 million times	500 and more
Tension	or 30,000 hours	3.6 V (nominal)
Relative energy (Wh/kg)	2.3...2.75 V	120–240
Relative power (W/kg)	5 (type)	1,000...3,000
Working time	up to 10,000	5-10 years
Charging temperature	10-15 years	0...45 °C
Discharge temperature	-40...65 °C	-20...60 °C

In particular, gel polymer electrolytes (GPE) have attracted the attention of many researchers due to their good flexibility, corrosion resistance, and ease of preparation. Polymer matrices have a significant effect on the properties of GPEs. Polyacrylic acid, polyethylene oxide, polyvinyl alcohol, and polyacrylamides are widely used as matrices for GPEs.

Polyvinyl alcohol (PVA) is widely used as a polymer base in GPEs due to its good elasticity, harmlessness, chemical stability, and low cost. The mechanical properties of individual polymer bases in GPEs are very low and their use causes inconvenience [2].

In order for GPE to be resistant to various deformations and external influences in use, it should have high mechanical properties such as flexibility, elongation and hardness. Until now, these indicators of GPEs have not been sufficiently and fully studied. Many methods have been used to improve the mechanical properties of natural hydrogels. Including hydrogels with sliding rings [3], hydrophobic binding [4], ion binding [5], microparticle composition [6], nanocomposite [7], and two-band [8] structures have been widely used in medicine and other fields. Two-chain hydrogels consist of two types of mechanical properties, that is, hard and soft polymers, the first chain polymer is hard and brittle, and the second chain polymer is soft and elastic.

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In order to improve the mechanical properties of SC, we chose double-band GPE as a high-performance electrolyte. Cellulose, agar-agar, chitosan, guar gum, chitin, gellan gum and other natural polymers can be used to form the first network. In these studies, we selected gellan gum.

This is because gellan is an anionic polysaccharide, which is biologically pure, heat-resistant, non-toxic, cheap and forms a good gel. For example, gellan gel is 8 times stronger than agar-agar and carrageenan at a concentration of 0.5%, the hardness and strength of the gel strongly depend on its concentration [9].

The figure below shows the chemical structure of gellan-polyvinyl alcohol solid hydrogel.

As a result of the formation of hydrogen bonds between the carboxyl groups in the gellan chain and the hydroxyl groups in the PVA chain, a hard and flexible hydrogel with a macroporous network is formed.

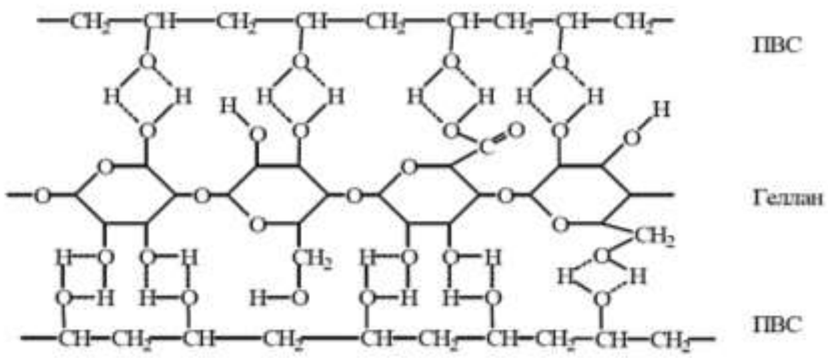

Figure 1. Gellan-polyvinyl alcohol hydrogel structure

Preparation of two-stranded hydrogel is carried out with the participation of KON. The most important feature of the formation of a rigid flexible hydrogel is that even at low temperature, without any chemical reaction, K+ ions cross-link the chains of gellan and PVA and ensure the formation of a double-stranded gel.

As a result, K+ ions act as ion binders and charge carriers, important for the two networks. In addition, it allows to increase the mechanical properties of the sample. To determine the mechanical properties of the samples, we used the "Universal testing machine" (WSM-10kN, Changchun Intelligent Instrument Equipment Co. Ltd. China) with a movement speed of 100 mm/min and a maximum load of 10 N. The ionic conductivity of the sample was calculated using the following formula:

$$\sigma = L / (A \times R_b) \quad (1)$$

where, L- sample thickness, A- sample surface, R_b- total resistance. The following formula was used to determine the water absorption index or water content of the samples:

$$W_c(\%) = (W_t - W_d) / W_t \times 100\% \quad (2)$$

Here: W_c water pants indicator, , W_t – mass of the sample before drying and W_d mass of the sample after drying in a vacuum drying oven at 60°C for 4 hours.

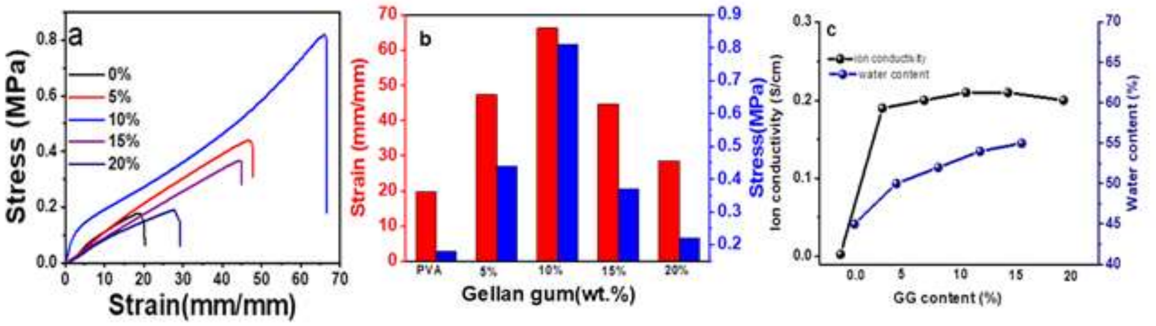

Figure 2. Effect of different concentrations of gellan on physical and mechanical properties of hydrogel. A) in breaking strength curves, B) comparing breaking strength, C) ionic conductivity and water absorption.

Based on the above analysis, two-stranded GPE was prepared from polyvinyl alcohol and gellan, and during the experiment, the mass of gellan was increased until its mechanical properties decreased, and the physical-mechanical properties of the samples were tested (Fig. 2). From the obtained results, it can be seen that the best performance of GPE is when the mass fraction of gellan is 10%. We can see that mm/mm increases (Fig. 2. a, b).
The reason for this is that due to the formation of bonds between gellan and pure PVS chains under the influence of mutual electrostatic forces, a hard hydrogel is formed, and its mechanical strength is 4 times higher than that of pure PVA.
According to the results calculated using formulas 1 and 2, the ion conductivity and water absorption of GPE increased uniformly with the increase of the amount of gellan in the sample. In particular, the ionic

conductivity increased from 0.03 to 0.21 cm/cm and the water absorption increased from 45% to 55% (Fig. 1, p). According to the results of the experiment, the tensile stress of GPE is 0.8 MPa (a), the elongation break is 66.3 mm/mm (b) and the ionic conductivity is 0.21 cm/cm (c). had values.
In conclusion, it can be said that this new double-stranded rigid polymer hydrogel can be used as an electrolyte for flexible supercapacitors, and its future use as a high-performance electrolyte for SCs will open wide opportunities in the field of microelectronics.

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