INFORMATION ABOUT MATERIALS USED FOR SOLID-STATE BATTERIES OF ELECTRIC ENERGY AND FUEL CELLS

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Abstract. *The main characteristics of various types of electrochemical batteries are presented, including their power class and discharge time. The issue of finding an alternative to such a battery is considered. It is shown that the real alternative is to create solid-state batteries. It is reported that solid electrolytes are a special class of substances with high ion conductivity at room temperatures, and the characteristics of some materials used as solid electrolytes are given. The requirements for anode and cathode materials are considered.*

Keywords: *superionic materials, solid-state batteries, cathode materials, anode materials, energy density.*

INTRODUCTION

In modern environments of depletion of natural carbon resources and environmental pollution, one of the most important tasks of energy is the widespread use of renewable energy sources and the conservation of electricity produced.

Figure 1 shows a diagram of the growth of annual installed capacities of renewable sources in recent years [1].

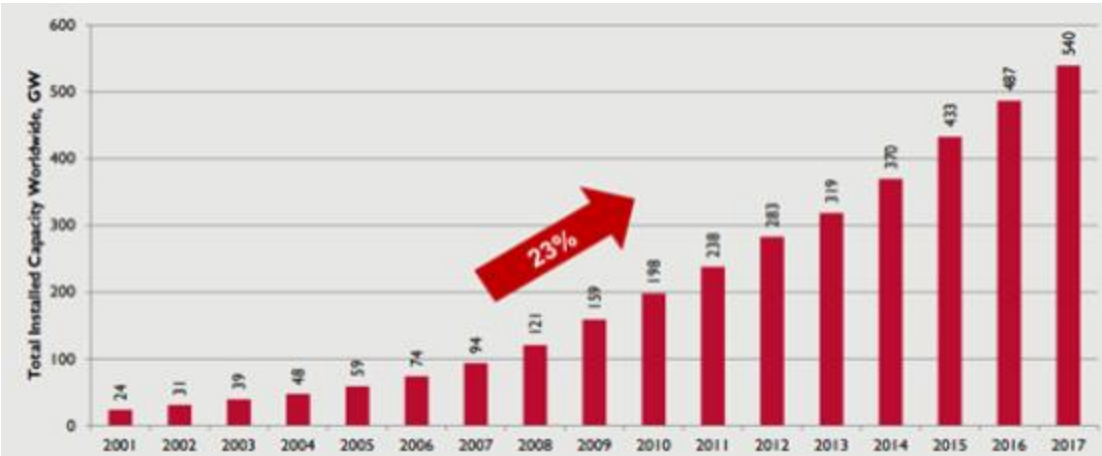

Figure 1. The growth of the installed capacity of the WPP by year.

As can be seen from the diagram, there is a significant increase in the annual installed capacity of renewable energy sources. In this regard, the issue of developing modern energy storage devices is acute.

METHODS

To date, a large number of varieties of electrochemical batteries have been created [2]. Let's consider the main characteristics of various types of electrochemical batteries, including their power class and discharge time. Lead-acid batteries are the most widely used due to their cheapness, simplicity of production technology and accumulated operational experience.

Currently, the production of lead-acid batteries with a wide range of rated capacities (up to 100 MW) has been established. In addition, one of the components of such batteries is toxic lead, which creates additional problems both in terms of ecology and negative health effects. In addition, they have insufficient energy consumption and a low level of permissible discharge and insufficient discharge time (up to 1 hour). The next type of batteries are nickel-cadmium batteries with a fairly high energy consumption, the ability to operate at low temperatures and high charge/discharge currents.

In addition, they have a memory effect that negatively affects their performance. However, their discharge time is only about half an hour, which makes them suitable only for maintaining electricity from low-power consumers. The excessive toxicity of their cadmium electrodes and far from ideal capacity indicators have led to the fact that nickel-cadmium batteries have recently been used quite rarely. The only thing that leaves NiCd batteries still "afloat" is their relatively low cost to the consumer [3]. Sodium-sulfur batteries are characterized by high resource characteristics (2000-4000 cycles) and a deep discharge level of 80-90%. However, they are unable to accumulate energy for a long time due to the energy consumption to maintain the operating temperature of the electrolyte. Another option, more suitable for small-capacity solar power plants, may be gel batteries. They contain not a liquid electrolyte, but a conductive suspension in the form of a gel. Such batteries do not require additional maintenance, but when charged above a certain level, they quickly become unusable. However, the problem can be eliminated by placing electronic charge level controllers. The advantage of gel batteries is their operating temperature range up to -15 °C. In recent years, lithium has attracted the attention of researchers as a material for batteries, due to its high activity, as well as other characteristics. Thus, the melting point of lithium is only 180.540 C. One of the characteristic characteristics of lithium-ion batteries is high energy consumption, a deep discharge cycle (70-80%), as well as the absence of a memory effect.

Therefore, lithium-ion (Li-Ion) batteries remain the most popular so far. Lithium batteries are in most cases used in storage devices installed by consumers, for example, electronic devices, cell phones, and electric vehicles [4]. But lithium batteries are explosive at high power. In general, the smaller the serial number of a chemical element, the more explosive it is (for example, hydrogen in combination with oxygen forms an explosive compound with a large release of heat in an exothermic reaction). Therefore, there is a question of finding an alternative to such batteries. The most realistic alternative is to create solid-state batteries. Significant progress is currently being made in this area [4]. Increasing attention to batteries based on solid-state batteries places increased demands on them, which they are more or less able to satisfy. Promising batteries must meet the following requirements: have a long shelf life of electrical energy and a high energy density of more than 100 Wh/ kg. Solid electrolyte batteries are increasingly meeting these requirements. Let's consider what a solid-state battery is. An electrolyte in an acid battery is a conductive chemical mixture (acid, electrolyte, conductive gel) that conducts current from the anode to the cathode. Separators between the anode and cathode serve to prevent short circuits. Solid-state batteries are electrochemical devices with the same set of elements: anode, cathode and electrolyte. However, unlike acid-containing batteries, in solid-state batteries, the electrodes and electrolyte are made of solids (Fig.2).

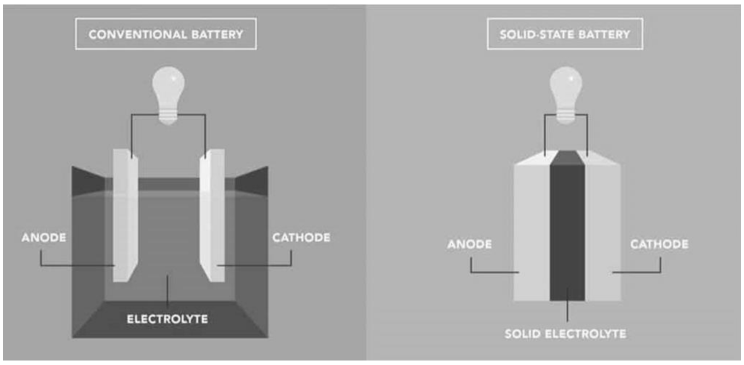

Fig.2. Comparative diagram of an acidic and solid-state battery

Solid-state electrolyte is a special class of substances with high ion conductivity at room temperatures, comparable to the conductivity of molten salts and acids. Solid electrolytes were discovered by Michael Faraday more than 150 years ago. Currently, solid electrolytes (or as they are also called, superionic conductors) make up a wide class of substances. These are solid electrolytes such as lithium garnet, sulfide-based electrolytes, oxide-based electrolytes, polymer electrolytes, ceramic electrolytes and composite electrolytes, ion conductors (carbon tubes with a nanostructure), have high ionic conductivity and thermal stability [5-13]. These materials allow the use of lithium metal anodes, which can significantly increase the energy density of batteries. In addition, the use of solid electrolytes significantly increases the safe mode of battery use, reduces the risk of overheating and the formation of dendrites. The selection of the optimal electrolyte composition allows you to increase the capacity of stored energy, and this in turn makes it possible to create more durable and powerful batteries.

RESULTS

Thus, solid electrolytes are a wide class of substances, both crystalline and ion-conducting glasses and polymers, thin films on substrates, ion-conducting ceramics, and all kinds of gels. Despite the fact that a fairly wide range of superionic materials has been created, the researchers' search continues and is directed towards obtaining high values of ionic conductivity at room temperatures. In addition, it is quite obvious that in order to create solid-state batteries, special requirements are imposed on electrode materials, which must have a high collecting capacity of charge carriers. That is, they must have a developed surface - have a sufficiently high surface area with small dimensions. Porous materials obviously meet such requirements. Let's briefly consider the general requirements for anode materials. This class of materials includes varieties of graphite, silicon and lithium titanate. Graphite is widely used due to its stability and ability to intercalate lithium ions (i.e. reversibly embed mobile lithium ions). This, in turn, leads to mechanical stability. Silicon and lithium titanate also have their own positive and negative sides. And in this direction, an optimal search is also required. Special requirements are also imposed on cathode materials. They must provide high levels of energy storage and high energy density. Currently, attempts have been made to use the following materials as cathode materials:

lithium-cobalt oxide (LiCoO2), lithium-iron phosphate (LiFePO4) and lithium, nickel, manganese, cobalt oxide (LiNiMnCoO2).

Naturally, batteries based on solid electrolytes (or as they are called in the English literature solid state batteries SSB) represent the most optimal solution for new generation batteries. They exhibit higher thermal stability when operating in different temperature ranges. Solid electrolyte batteries do not fail due to freezing, boiling or thermal decomposition.

DISCUSSION

In connection with the above, we have led studies of some superionic materials in order to use them as a solid electrolyte in batteries. These are helium materials based on the natural material agar (C12H18O9)n [14], as well as a modified composite material based on α- and β-aluminate. Preliminary studies have yielded satisfactory results in terms of energy density and charge time.
As the conclusions: In the near-term years, the main trend in the global battery industry will be the development of portable energy-intensive solid-state batteries necessary for various fields of science and technology - healthcare, defense, space technology, automotive and much more. The need to develop solid-state energy sources and solid-state batteries covers all spheres of human activity. In this regard, the issue of developing and implementing new superionic and electrode materials that are attractive in their technical and commercial characteristics is important. Solid-state batteries are capable of making significant changes in the field of energy storage.

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