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Alternative energy sources for mobile systems

Alternatywne źródła zasilania układów mobilnych

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The paper presents the current power source in mobile systems such as small electronic devices and mobile robots. Alternative power sources are discussed. The general guidelines for the selection of power sources in this type of system are has been given.
KEYWORDS: fuel cell, photovoltaic cell, batteries, power source

With the development of technology, progressing miniaturization and increasing demands on ecology, the popularity of alternative power sources is growing rapidly. This also applies to widely understood mobile systems, in which the power demand is relatively small, and at the same time it is necessary to place the power source in the device. Examples are mobile robots or small electronic equipment. Selection of an appropriate source is crucial from the point of view of the design of the system, because it introduces significant limitations and influences the mobility of this system. There are many types of power sources that are used in mobile solutions, including: batteries, capacitors, photovoltaic cells and fuel cells.

In spite of the dynamic development of storage technology and electricity generation in many areas, the problem is still constraints on power sources.

Available solutions for power systems

Accumulator accumulating electricity is a traditional and currently the most common method of powering mobile systems. There are three basic types of batteries: lithium, nickel and lead-acid.

Lead-acid batteries (Pb) are the oldest and less frequently used. This is mainly due to their low energy density (about 30 Wh/kg). The power density is around 180 W/kg, and the number of charging cycles varies between 1200 and 1800. The advantage of these batteries is the low price.

In the group of nickel accumulators, NiCd and NiMH batteries have a basic meaning with a power density of approx. 50 and 120 Wh/kg, respectively. The number of charge cycles for this group is similar to that of lead-acid type batteries.

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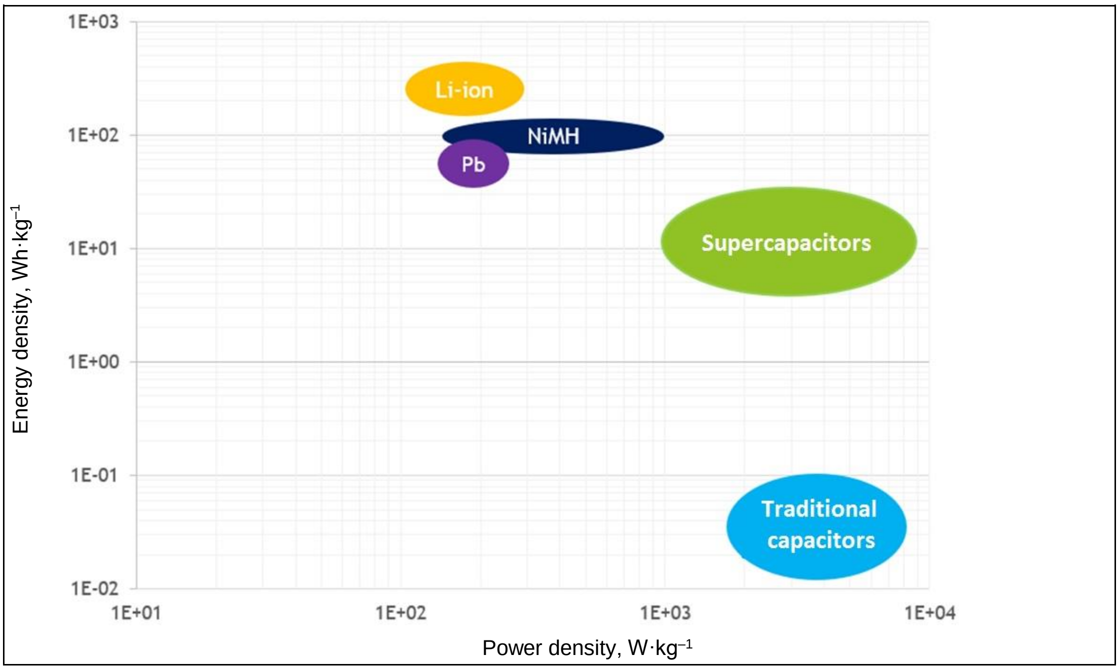

Fig. 1. Comparison of energy density and power for different batteries

Recently, lithium-based batteries are by far the most popular. Among them the most significant are Li-ion batteries. They are characterized by far the highest energy density of all the discussed batteries, reaching even 250 Wh/kg. The power density is about 150 W/kg, and the service life is about 2000 charging cycles. Keep in mind that the lifetime of lithium-ion batteries depends on the temperature at which they work.

The degree of self-discharge for all types of batteries is very similar and amounts to a few percent per month [1]. Regardless of the type and characteristics of individual batteries, they all have such disadvantages as a relatively long charging time and occurring self-discharge phenomenon.

Fig. 1 shows the dependence of energy density on the power density for these technologies. Currently, a lot of research is being done on new types of batteries. An example can be lithium-air batteries with energy density several times higher in comparison with Li-ion batteries [2].

Alternative power systems

Photovoltaic cells (fig. 2) are an interesting alternative to traditional power sources. There are three basic groups of cells: silicon, semiconductor based on the p-n connector and the other.

The efficiency of traditional photovoltaic cells based on silicon reaches 20÷25%. Of all the types of links, they are by far the most popular. The most commonly used silicon solar cells are polycrystalline and monocrystalline cells. They have the highest efficiency and it is estimated that they can effectively produce electricity for at least 30 years. The disadvantages of these links are: aging, relatively high price, dependence of efficiency on atmospheric conditions and low ratio of current efficiency to the required surface.

Modern photovoltaic cells are still at the stage of research or very early commercialization. They can include thin-film cells, manufactured from both more traditional and novel materials, allowing to obtain fully flexible cells with wider application possibilities. Solar cells from semiconductor materials are characterized by higher efficiency. This applies in particular to the cells based on compounds of elements from groups III–V of the periodic table. A link with a record efficiency of 46% was created from this type of material. By increasing the efficiency, it is possible to reduce the required solar area. Such links, however, are extremely expensive to produce. Cheaper links, however, have lower efficiency – around 10%. Lowering the price of the cell is connected with increasing its required area [3].

One of the ways to achieve high energy density is to use hydrogen as a fuel. It has an almost higher energy density than gasoline.

Due to the low price, good power density and the lack of the requirement to work at an elevated temperature, the best possible solution for feeding mobile systems seems to be Fuel Cells with a Proton Exchange Membrane (PEM FC). The work of a fuel cell can be described by several processes: two H_2 molecules are oxidized to four protons at the anode, while the cathode O_2 molecule is reduced to two oxygen anions; then the electrons from the H_2 molecules travel through the receiver connected to the cell as electric current, and the protons migrate through the electrolyte separating the electrodes and connect with the oxygen anions to form water. The efficiency of PEM cells is approx. 50÷60%. The power density obtained from the cell may exceed 1 kW/kg, which is comparable with Ni-MH or Li-ion batteries [4].

A decisive disadvantage of fuel cells is their high price. Using hydrogen involves the problem of storage, because it is a dangerous, explosive gas. There are two traditional ways of storing hydrogen: in the gaseous state after compression and in liquid form after cooling below –240.18°C. The first method requires the use of tanks with large dimensions and not much of a mass, while the weight of the hydrogen itself is small. In turn, for storage of liquid hydrogen it is necessary to cool the tank, which means energy loss. So far, none of these methods was suitable for use in mobile systems. Alternative hydrogen storage methods are currently being intensively developed, such as hydrogen chemical bonding to solid chemical compounds and absorption on the surface of materials designed for this purpose. Hydrogen binding to metal hydrides is the most popular. Such solutions, adapted to small devices, are already commercially available. The release of hydrogen takes place gradually, with consumption, at room temperature. During storage, hydrogen has a safe, solid form [5]. Fuel cells are a great opportunity to efficiently store energy and create an alternative power supply in relation to batteries in electronic devices.

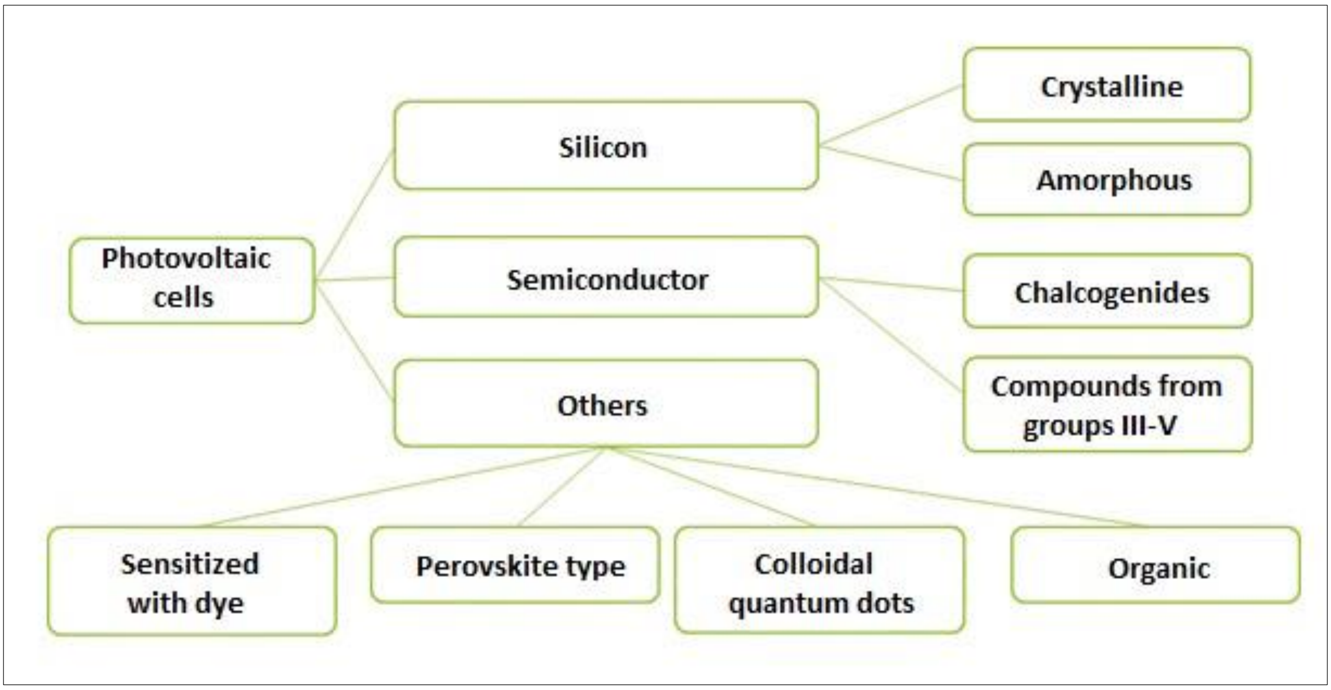

Fig. 2. Division of photovoltaic cells

Hybrid systems

The limitations typical of individual solutions can be eliminated by combining several types of power sources. A good example is a water cell enriched with a set of batteries, e.g. lithium-ion batteries, acting as energy storage. This arrangement is more complicated, but it allows energy to be accumulated and given back when the load is highest, which allows to reduce the power and thus the cost of the cell. It can be used in periodically operating systems [6].

Conclusions

Despite the wide selection of power sources, there is no universal solution. In the case of mobile systems, the dimensions and weight of the source are of particular importance, i.e. density of energy and the power of the source. This is usually the basic criterion for selecting the power source for mobile systems. However, one should also remember about other aspects, such as price or the opportunity to work in various environmental conditions.

In most situations, traditional power sources do pass the exam, but with the development of technology this may change.

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