SOLAR PHOTOCELLS

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Abstract. A comparative analysis of the prospects of creating ultra-thin, light and highly efficient solar cells based on AlGaAs/GaAs heterostructures has been provided. A micron - scale thinning of AlGaAs/GaAs heterostructures using efficient technological methods has been proposed, which has been shown to significantly increase the yield percentage of solar cells. As we know that the photocurrent flow in the element depends on constant temperature radiation.

Keywords: heterostructure, solar energy, alternative energy sources, electricity, photovoltaics, solar cell, monocrystalline and polycrystalline silicon, cascade elements, amorphous silicon, solar module.

Introduction

Currently, the need to increase the energy-mass characteristics of solar batteries is of urgent importance. The main ways to solve this problem are to increase the efficiency of solar cells based on AlGaAs/GaAs compounds, which have the highest efficiency, and to reduce their size and weight. Achieving such efficiency requires new optimized photovoltaic system architectures and high-quality semiconductor materials. In the world, intensive research is being conducted to increase the efficiency of solar cells up to 35% in promising heterostructures by increasing the number of p-n junctions in semiconductors to four, five and even six. Currently, silicon is the main material for solar cells. The efficiency of silicon-based solar cells is 15-16% under direct irradiation in near-Earth space conditions. Solar cells based on heterostructures provide high efficiency and have high radiation resistance. An important advantage of heterophotoconverters is their ability to efficiently convert high-concentration solar radiation (up to 1000 - 2000 times), which opens up the prospect of significantly reducing the area and cost of solar cells (proportional to the concentration level) and, as a result, leads to a decrease in the price of "solar" electricity.

Solar cells based on GaAs heterostructures were presented for the first time by A.F. Ioffe and it was created at the Institute of Physics and Technology. The use of a wide - gap "window" made of a thin layer of AlGaAs solid solution, which is almost completely transparent to solar radiation, ensures the passivation of the surface of the photoactive region . Multilayer AlGaAs/GaAs heterostructures were created using low-temperature liquid-phase epitaxy [1-5], which ensured record efficiency for solar cells with a single p-n junction. Such performance indicators were achieved due to the reduction of the AlGaAs/GaAs front layer thickness to 30-50 nm, the crystallization of high-quality material in the active region, and the creation of a back potential barrier made of GaAs. In recent years, the MOS-hydride epitaxy (metal- organic phase epitaxy) method has been widely used to produce AlGaAs/GaAs heterostructures for solar cells [6]. A heterostructural solar cell obtained by this method with a Br e gg mirror is of great interest (Fig .1). The reflection coefficient from such glass is ~ 95% in the 750 - 900 nm spectral range.

This ensures that part of the solar radiation not absorbed in the base layer is reflected in the active region, which ensures that the thickness of the base region decreases and the diffusion is maintained with small values of the bending length. As a result, the radiation resistance of solar cells increases. Solar cells based on AlGaAs/GaAs heterostructures are currently widely used in solar cells due to their high efficiency and increased radiation resistance.

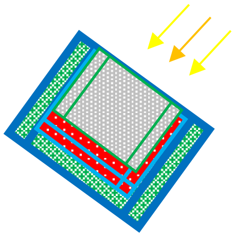


Fig.1. Hetero-structured photocell

1. Cascade photoelements

A further increase in efficiency is provided by cascade solar cells manufactured on the basis of multilayer heterostructures with two or more p-n junctions in materials with different band gaps (Fig. 2). This design uses GaAs as the wide-gap element material and InGaAs or GaSb as the narrow-gap element. In such cells, the "top" p-n junction, made of a wider-gap material, is designed to efficiently convert the short-wavelength portion of solar radiation into energy , and the "bottom" p-n-junction, a narrow-gap material, is optimized to convert the long-wavelength radiation that passes through the broadband element into energy. Theoretical calculations show that more than 40% energy efficiency can be achieved in such complex photoconverters. As we mentioned above, one of the most promising materials for creating highly efficient solar cells is gallium arsenide. Gallium arsenide and a photocell based on it can consist of several layers - heterostructures of different composition. Usually, a very thin layer of AlGaAs is obtained as a GaAs-based heterostructure mirror. But the main disadvantage of gallium arsenide is its high cost. In order to reduce the cost of production, it is necessary to form solar cells on other cheaper substrates.

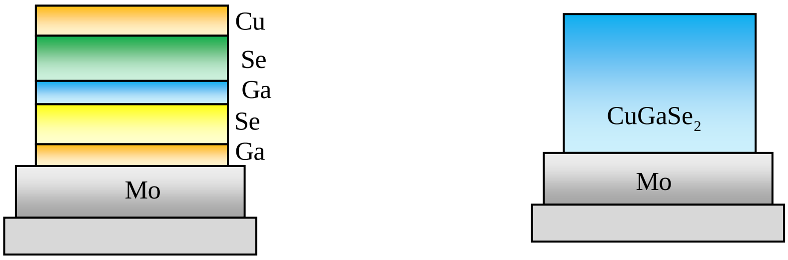
Copper and indium diselenide ($SuSe_2$) has an extremely high ability to absorb solar radiation - 99% of light is absorbed in the first micron of this material (band gap 1.0 eV) [2,5]. At the moment, intensive efforts have been started to produce solar cell glass based on $SuSe_2$. Sometimes zinc is added to cadmium sulfide to improve the transparency of the glass. $SuInSe_2$ increases the band gap in layer , which leads to an increase in the open-circuit voltage and, as a result, to an increase in the efficiency of the device.

Physical processes of cascade photocells

Most solar cells are basically large area p-n junctions. When light shines on them, they can generate current and voltage. The reason this happens is between p-type and n-type material is the generated electric field. First let's see what happens if a silicon solar cell (pn junction) has a low resistance wire externally connected between the p and n contacts. In the dark, the solar cell does not generate current. When light shines on the solar cell, current flows through the wire from the p-type side to the n-type side (conventional current). The light has enough energy to break some of the chemical bonds in the silicon crystal. What this means is that the electrons normally involved in the silicon bond move to a higher energy state when exposed to light and the bond is broken. The intensity of the sun's light on the earth 's surface is strong enough to break about 1 bond for every 100 million silicon atoms in the solar cell. Excited electrons are similar to electrons of additional phosphorus atoms - they move freely through the material. Similarly, the vacancies created by light act as holes, just like the unpaired electrons in the bonds between silicon and boron atoms and these holes can also move freely through the material. Electrons and holes created in this way are physically close to each other: for each electron excited by light, a corresponding hole is created. These electrons and holes can only remain excited for a short time . In the recombination process, the excited electrons come very close to the holes, and both are placed in bonded positions. As this process occurs, the electrical energy of the pair is lost as heat. If there is too much recombination, the efficiency of the solar cell decreases.

In a solar cell, electrons and holes excited by light appear throughout the volume of the material, in the p-region, n-region, and in the field region where the generated electric field exists. Due to the "set" electric field, the electrons are attracted to the positive charge from the side of the p -type material . Similarly, holes are attracted to the negative charge on the n -type material side. This separation of charges causes current to flow across the junction. The direction of current (conventional current) is the same as the movement of holes (because they are positively charged). That is, the current flows across the field from the n-type side to the p-type side. Now there is voltage across the solar cell but no current from the solar cell. The "open circuit voltage" is measured by placing a voltmeter across the illuminated solar cell. For example, for a solar cell, it measures about 0.6 volts in strong sunlight. When an open-junction solar cell is illuminated, the light-generated electrons and holes orbiting near the junction are separated by an "embedded" electric field. Electrons are pushed into the n -type region and holes into the p -type region. The current produced by the light depends only on how intense the sunlight is and how much recombination takes place inside the solar cell. This charge pack creates a voltage across the solar cell. It can be imagined that this division of charge continues indefinitely, resulting in an infinite voltage across the solar cell.

To generate large amounts of energy from solar cells, it is enough to connect many solar cells together. It can generate a lot of power. In fact, many solar cells can be connected together to create a large solar power plant. Most modern solar cells have a single p-n junction. In such an element, free charge carriers are generated only by photons with energy greater than or equal to the bandgap. In other words, the photoelectric reaction of a single junction element is limited to the part of the solar spectrum with energy above the band gap, and low-energy photons are not used. This limitation can be overcome by multilayer structures of two or more elements with different band gaps. Such elements are called *cascade or tandem* [2].



FFig 2. The system of cascade photocell

OBTAINED SCIENTIFIC RESULTS AND THEIR ANALYSIS

1. Current characteristics of heterostructured photoelectric systems

Each photocell is characterized by a number of parameters and properties that determine not only its characteristics, but also the limits of its use in technology: current - voltage, light, frequency and spectral sensitivity, efficiency. Similarly, heterostructured photoconductors have the above physical properties. Studies have shown that these physical properties have almost the same meaning in both cases. Current-voltage and voltage-power characteristics of the system considered in Figure 3. It can be seen from the graph that the photocurrent flow in the element depends on constant temperature radiation. However, as the irradiance increases, the photocurrent and voltage increase. This leads to an increase in total power. In this case, for the characteristics of the heterostructure system, when the operating temperature increases, the current output increases slightly, while the voltage output decreases sharply, which affects the decrease in net power with the increase of temperature. The nominal voltage and current of the structure we are studying are described by the following general formulas

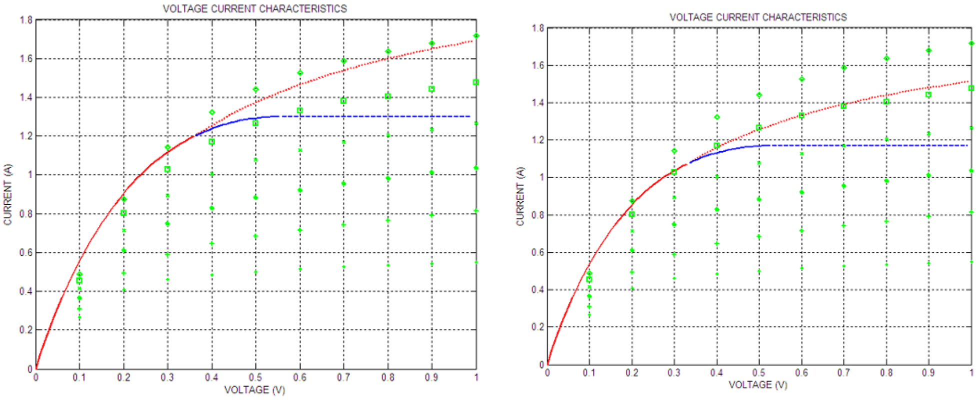
$$I = I_{ph}\left(\frac{T}{T_r}\right)^3 \exp\left[\frac{qE_g}{kA}\left(\frac{1}{T_r - T}\right)\right]. \qquad (1)$$

$$E_g = E_g(0) - \frac{\alpha T^2}{T+\beta}$$

where T_r represents the initial temperature and the constant photocurrent of the element; I_{rr} q is the charge of the electron; E_g - the main energy level of the conductor, T is the temperature of the element (K). The nominal voltage of the element is expressed by the following formula

$$U = \frac{kT}{q}\ln\frac{I_{ph}}{I_s} + I. \qquad (2)$$

Here I_s is the output current of the array; U array output voltage. The figure below shows the characteristic curves of the element for a given level of solar radiation and temperature.



3 . Volt-amperes characteristics of the system in varying radiation with a temperature of 25^{o} - 30^{o} .

2. Useful efficiency of photoelectric systems with heterostructure

Today, cells made of heterostructured photovoltaic systems, such as A_3V_5, make up 80% of systems installed worldwide. Their efficiency is 35-40 percent. Later, GaAs-AlGaAs heterostructure photoelectric systems began to be prepared in the form of amorphous silicon, cadmium-telluride thin films. Their efficiency is about 9 percent, but they are cheaper to manufacture than photovoltaic cells made of mono or polycrystalline silicon [3,7]. For example, let a heterostructured solar photovoltaic cell consist of several hundred (for example, 100) cells. Let its power be 1.5 W. In this case, the size of the photocell is 20·30 cm. We assume that the current density in the photocell is E = 500 W/m ^{2} and we find the useful efficiency of the photocell. In that case, we find the efficiency of the photocell using the following formula

$$\eta = \frac{P}{ES}.$$

Here, P b is the power of the battery, which is calculated using the following formula

$$P = n \cdot 15.$$

Here, n is the total number of photovoltaic cells in the heterostructure solar cell. Putting the values of the necessary quantities in the formula $P = 900 \cdot 15 = 1350\ \text{Вт}$, $S = 0.06\,\text{m}^2 \cdot 900 = 54\,\text{m}^2$ we find the useful efficiency of the photocell

$$\eta = 135054 \cdot 500 = 0.05\%$$

The value of the efficiency of the photocell is determined by the energy losses, which depend on the materials used and the design of the photocell, as well as the choice of the operation mode of the photocell (load resistance, light and temperature). In the process of converting radiation energy into electrical energy released in the photocell load, energy losses can be divided into light and energy losses. Light losses are primarily losses due to the reflection of the light flux from the surface photocell and depend on the wavelength of the incident light. They are also determined by the photoelectric inactive absorption of light: absorption of the excitation, photon generation, absorption with excitation within the band transitions, absorption of the fraction of the light flux that has passed to a large depth along with the lower metal electrode.

Energy losses are the number of excited pairs of electrons and holes or the energy losses they carry. These losses are related to the recombination of carriers that do not reach p - n - depending on the construction of the transition and photocell, the thickness of the outer layer of the conductor and the condition of its surface. In addition, if the energy of light quanta significantly exceeds the band gap, then the excess energy is used to heat the photocell.

At the same time, scientific and research work is being carried out to increase the efficiency of heterostructured solar photovoltaic cells by 50-60%. For this, it is necessary to install heterostructured films 4÷8 times. As a result of these studies, the power of the device will be increased and the cost of production will decrease dramatically. It is estimated that, due to their simplicity and low-cost materials, in the future, the production of devices consisting of heterostructures will require even less money.

CONCLUSION

In this article, the physical properties of photocells based on the heterostructure of the solar energy device were studied. The volt-ampere characteristics of the G heterostructure solar cell photocell and the values of the useful work coefficient were determined. Our studies have shown that the photocurrent flow in the element depends on constant temperature radiation. As the irradiance increases, the photocurrent and voltage increase. This leads to an increase in total power. It can be concluded that, the solar cells based on heterostructures have very high efficiency and high radiation resistance.

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