PHYSICAL PROPERTIES OF PHOTOELECTRIC SOLAR CELLS BASED ON AlGaAs/GaAs SEMICONDUCTOR HETEROSTRUCTURES

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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 was conducted. Technological challenges and prospects for each option are discussed. 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.

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 pn junctions in semiconductors to four, five and even six. The photoelectric method is one of the most promising ways of converting solar energy. 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. Under environmental conditions, the efficiency of silicon elements decreases by about 20% with direct solar radiation and 25-27% with solar radiation (30-50) times concentration. With a further increase in illumination intensity, the efficiency of silicon elements decreases due to an increase in operating temperature and an increase in ohmic losses. 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 .

For the first time HST Solar cells based on GaAs heterostructures were proposed and developed at the Ioffe FTI. 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 [1-3], 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 vapor phase epitaxy) method has been widely used to produce AlGaAs/GaAs heterostructures for solar cells [3]. The heterostructure of a solar cell obtained with a Bragg mirror installed by this method 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 widely used in solar cells due to their high efficiency and increased radiation resistance.

1. Cascade solar elements

Most solar cells are basically large area p-n junctions. The solar cell is now forward-biased and current flows from the p-type side to the n-type side, as in a p-n junction in the dark. This forward current is in the opposite direction to the light generated current described above. Both streams flow simultaneously. As the voltage across the solar cell increases, it eventually reaches a point where the direct light completely balances the current produced. These two internal currents flow inside the solar cell and mutually compensate each other. The voltage at which this occurs is called the "open circuit voltage". To generate large amounts of energy from solar cells, it is enough to connect many solar cells together. Common elements It can generate a lot of power. In fact, many solar cells can be connected together to create a large solar power plant. Then, with the generated electricity, you can power a whole city. Most modern solar cells have a single pn 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].

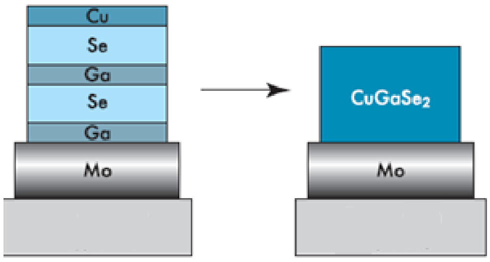

Fig1. Cascade photoelement

The main problem in the way of widespread distribution of photovoltaic products is still their relatively high cost. For 1997, the price/performance ratio increased from $4.15 to $4.20/W. However, this trend is short-term and is related to the expansion of production. Thus, technology development, application and solar energy converters show that they have a promising future.

2. Results and their analysis

The photoelectric effect, which is the basis of the operation of the solar cell, consists in the formation of current carriers - electrons and holes - in semiconductor materials when irradiated with light. The nature of the relatively low efficiency of cascaded materials in comparison with bulk materials lies in the different mechanism of photogeneration of free charge carriers in such structures (Fig. 2) [2]. When inorganic semiconductors are irradiated by photons with energy greater than the energy difference between the band gap and the conduction band, free charge carriers (electrons and holes) are formed, which are then separated from each other. As a result of the absorption of photons in semiconductors, electrons are excited from the highest occupied molecular orbitals to the lowest unoccupied molecular orbitals. An important difference in photogeneration mechanisms in cascade materials is that free charge carriers are formed in the main part of the material as a result of photoexcitation in inorganic SCs, and in others as a result of their relatively low dielectric conductivity. materials, electron-hole pairs connected by Coulomb interaction, exciton are formed. Additional excitation dissociation energy (binding energy) is required to obtain free charges , which is 0.2-1.0 eV for various organic semiconductors. Due to the dissociation of excitons , the formation of charges can be carried out at the interface between two semiconductors (donor and acceptor), i.e. heterojunction. The concept of a planar bilayer g heterojunction, consisting of two organic materials whose energy levels have changed to perform the process of exciton separation into free charges, was first demonstrated in 1986 [1]. Organic materials can act as electron donors or acceptors due to energy level shifts between the corresponding orbitals. A charge transfer process occurs at the donor-ac ts eptor interface, which leads to the appearance of holes in the material with low ionization potential (donor) and electrons in the material with high electron affinity (acceptor) (Fig. 2).

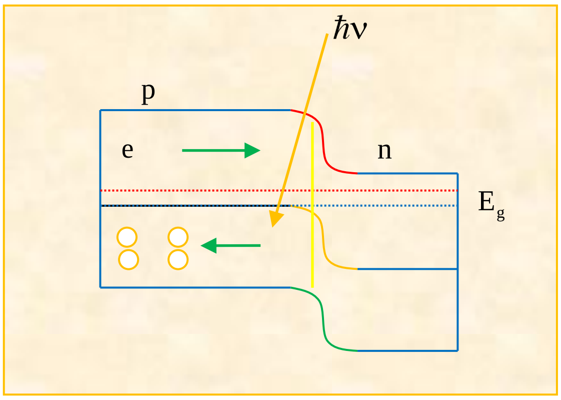

Fig. 2. Photogeneration of charge carriers in organic solar cells based on double-layer heterojunction

These carriers are still connected by the Columb interaction, but can be separated by the internal electric field (or set potential) of G C created by the difference in the work function of the two different electrodes in the sandwich configuration. Holes (electrons) pass through the donor (acceptor) material to electrodes with a high (low) work function (Fig. 3). In organic semiconductors, the characteristic distance traveled by the exciton itself, that is, the diffusion length, is limited to distances of about 10 nm due to their short lifetime and low mobility [3]. Therefore, only the photons absorbed at the characteristic excitation diffusion length near the heterojunction plane can contribute to the photocurrent and effectively move towards the interface, G is determined by the electrical resistance of C and indicates the efficiency of the charge carrier collection process, which depends on the magnitude of the leakage currents in the device. It can be calculated as the ratio of GS to the theoretical maximum power density:

$$J_c = \int E \cdot Q \cdot E(\lambda) \cdot P_s \cdot \frac{e\lambda}{\hbar c} d\lambda \qquad (1)$$

where E is the electron charge, ħ is the Planck's constant, c is the speed of light. Then the volt-ampere characteristics are determined by

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

$$I = I_s \left[\exp\left(\frac{qU}{kT} \right) - 1 \right] \qquad (3)$$

where I_{ph} element represents the photocurrent; I_s - array output current; U array output voltage; q is the charge of the electron; T - element temperature (K). The figure below shows the characteristic IV curve for a given level of solar radiation and temperature.

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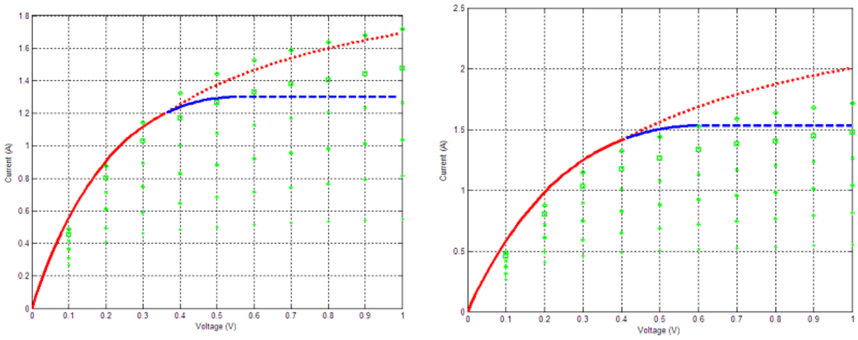

Fig.3 . Voltage characteristics of semiconductor AlGaAs/GaAs heterostructures at a constant temperature of 25 ^{o}C.

The gray line is displayed in Fig.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.

CONCLUSION

The physical properties of photocells based on the heterostructure of the solar energy device were studied. The efficiency, power, and electric current values of the G heterostructure solar cell photocell were calculated analytically. Today, cells made of heterostructured photovoltaic systems, such as $A_3 V_5$, 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 mono or polycrystalline silicon photovoltaic cells. From the results obtained from the last formula, it can be seen that the electric driving force of the heterostructured solar cell is the given constant parameters 3V . At present, 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.

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