International Journal of Energy Optimization and Engineering
Volume 9 • Issue 2 • April-June 2020

Photovoltaic Solar Modules of Different Types and Designs for Energy Supply

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ABSTRACT

The article presents photovoltaic solar modules that have a different design and purpose. The principles of photoconversion in solar cells, materials used in their manufacture and basic characteristics of solar cells are described. Solar cells of amorphous silicon and two-sided solar cells are considered. Photovoltaic planar and matrix solar modules with extended lifetime are presented. Solar tiles and compact folding photovoltaic solar modules, as well as paraboloid concentrator of solar radiation for solar cogeneration plants are presented. Also considered cascade solar cells and solar modules with the decomposition of the light. The considered photovoltaic solar modules are investigated and manufactured in the All-Russian Research Institute of Electrification of Agriculture and Federal Scientific Agroengineering Center VIM, Moscow, Russia.

KEYWORDS

Concentrators of Solar Radiation, Extended Live Time, Folding Compact Modules, FSAC VIM, Matrix Solar Cells, Photovoltaic Thermal Solar Modules, Silicon Solar Cells, Solar Tiles

INTRODUCTION

Currently, a gradual decrease in the cost of converting solar energy is observed, which is associated with a decrease in capital costs for production, an increase in production volumes, the use of more efficient structural materials and an increase in the efficiency of the power plant. One of the methods for converting solar energy into electrical energy is the direct conversion method using planar and matrix solar cells. In solar energy, when using planar and matrix solar cells, two directions are distinguished – photoelectric conversion of non-concentrated and concentrated solar radiation. There are two ways to reduce the cost of solar photovoltaic stations: improving the technical and economic characteristics of planar solar modules and creating stations with concentrators. The use of concentrating systems reduces the consumption of semiconductor material.

DOI: 10.4018/IJEOE.2020040106

In the present work, we consider some of the most interesting, in the opinion of the authors, designs and technological methods aimed for increasing the efficiency and reliability of solar energy systems, as well as reducing their cost and simplifying the operation procedure.

PROPERTIES OF SILICON PHOTOVOLTAIC CONVERTERS

Photovoltaic conversion of solar radiation into electrical energy occurs in semiconductor photovoltaic (PV) cells. PV cells based on crystalline silicon are most widely used.

Semiconductors can exist as intrinsic as well as doped, in case existing in the material any impurities. Accordance with the type of impurities nature of the charge carriers may be of different type. Doped semiconductors can be N-type (with electrons as main charge carriers) or P-type (with holes that behave like positively charged particles as the main charge carriers).

In the electric field, both free electrons and electrons, jumping from the valence band, move against the direction of the electric field, since they have a negative electric charge. This means that the free places move in the direction of the electric field. Vacant place, thus, behaves like a particle with a positive charge and mass, which differs from the mass of the free electron. This quasiparticle is usually called a "hole" (Strebkov, 2010a; Strebkov, 2010b; Strebkov, 2010c; Kharchenko et al., 2010; Kharchenko et al., 2019; Panchenko et al., 2015; Strebkov et al., 2013).

In the intrinsic semiconductor, the escape of one electron from the valence band leads to the formation of one hole, the number of free electrons and holes is equal. The crystal as a whole remains electrically neutral. If the electron-hole pair is formed by a falling photon (that is, a quantum of light), then the photon energy should be equal to or larger than the band gap width. Photons with lower energy pass through the semiconductor and photons with higher or equal energy generate electron-hole pairs. The band gap in silicon is approximately $\Delta E_G \approx 1{,}1$ eV. That is, silicon is transparent to photons of lower energies that pass through the material without hindrance. The wavelengths corresponding to these energies are greater than about $\lambda \geq 1100$ nm.

If we replace Si atoms in a silicon crystal with atoms of some elements of the fifth group of the periodic system, which have 5 valence electrons (for example, As, P, Sb), then four of these valence electrons form covalent bonds with neighboring silicon atoms. The fifth electron will be weakly bound to the impurity atom. This doped semiconductor is called an n-type semiconductor ("negative"). When a relatively small amount of energy is supplied, this electron "breaks away" from the atom. These pentavalent atoms are called donors, since they supply free electrons. As a result of the interaction of photons of solar radiation with a semiconductor, electron-hole pairs are formed.

If two layers of a semiconductor with different types of conductivity are connected, a so-called p-n junction is formed. It is here that the carriers (electrons and holes) are separated, as a result of which a potential difference is created on the plates of these layers. If these layers are connected, an electric current will flow through the wire. In this case p-n junction functions as a simple semiconductor diode.

Solar cells (SC) are the main components of any solar power generating system. Today SCs and panels obtained by different technologies and on the basis of different semiconductor materials are used in world practice. A classic example of a SC is a device created on a single-crystal silicon wafer using the technology of manufacturing classical diodes.

The SC is a large semiconductor diode with a p-n junction. It is manufactured on a plate of semiconductor material, mainly silicon. In the plate regions with p- and n-type conductivity are created. The basis of the SC is the p-n junction, which performs the function of separating the electron-hole pairs formed as a result of the action of solar photons. The technological cycle of obtaining a SC is a complex of operations, similar to the operations of the technological cycle of manufacturing semiconductor diodes.

The raw material for manufacturing SCs is a single-crystal silicon ingot, often grown from the melt by the Czochralski method. The technological chain of manufacturing silicon for solar cells is quite long.

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