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RENEWABLE ENERGY SOURCES

8.3. Solar power plants and heat supply systems

8.3.1. Photoelectric converters and power installations on their basis

8.3.1.1. Silicon photoelectric converters and modules

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At present flat-panel modules, made of crystal silicon, form more than 90% of the total volume of solar elements (SEs) production. The forecast shows that in medium-term perspective there is no any alternative for using silicon.

Considering the current situation relating to silicon SE efficiency, it is necessary to mention that in laboratory conditions SE efficiency reached 24,7% [1]. It is an absolute record for silicon SEs. But efficiency of industrial SEs makes 12…16%, and it is mainly connected with technological possibilities of developers.

In the basis of any technology, used today, there is a technology of silicon padding production, either in case of more effective and stable single-crystal silicon, or cheaper polycrystal, belt silicon or the cheapest, but less stable, thin-film amorphous α-Si one.

Key factors at SE production are [2]:

- creation of defect-free surface (chemical or chemical-mechanic polishing and texture etching);
- forming of potential barrier (*p-n* transfer);
- passivation of the frontal surface (heat treatment);
- contacting, as a rule, detecting "a face" of SEs. Nowadays in the industry prevails a technology on the basis of stencil printing and surprint of the plated pastes. But, in spite of simplicity, it restricts efficiency of industrial SEs, especially when it concerns thin SEs. Record efficiency is obtained, using ECO technology (evaporated contacts), that is, contacting in vacuum. In this case losses due to shadowing from contacts do not exceed 4%, but ohmic losses are 1%;
- coating of clearing surface.

These basic operations, which are used by different firms, depending on their technological facilities and purposes, define directions of works on creation of perspective technologies of SE production.

Technology of SE with the buried contact with laser scribing of chases allows increasing the efficiency by 10…20 % due to selective alloying and decrease frontal surface shadowing by contact strips. It also allows forming contacts at back side of SE. However, the cost of its production increases in proportion. The company BP Solar has been successfully developing this technology for more than 10 years, increasing for the last five years the output of photoelectrical modules (PEMs) by a factor of 5 with the expected efficiency of SEs up to 20% [3,4].

Technology of HIT elements production combines advantages of amorphous and crystallized silicon in the same structure. HIT element is a thin crystallized padding of *n*-type with amorphous silicon layers of *i*-type, formed at the padding and amorphous silicon layers of *p*-type and *n*-type. Application of HIT technology in production of photoelectric converters, allowed the firm SANYO to increase its average efficiency to 19,7 % at the maximum reached efficiency of 21,3 % [5]. Modules, produced from HIT elements, have efficiency of 17 % and excellent temperature characteristics, providing higher energy output at high temperatures.

The greatest SE efficiency of single-crystallized silicon of more than 24 % was reached by a group of Professor Martin Green from the University of New South Wales. The PERL SE made of single-crystallized silicon was grown by a method of zone melting with frontal surface, which has a relief in a form of reverse pyramids that are passivated by the doped layer with contacts at the back side of a surface, created by the local diffusion. In construction of these SEs the best technological solutions are combined. Maximum photosensitivity in construction of PERL SE is moved to the zone of the greater wave lengths and is higher in comparison with other SEs.

Design of high-effective photoelectric converters (PECs) was simultaneously conducted in Farunhofer Institute for Solar Energy systems (ISE), where LBSF-elements with efficiency of 20…24% were gained. The elements got the common name of LBSF/PERL. To minimize losses at shadowing and recombination at metalized contacts, very thin contacts, under which high-doped areas exist, are needed. These thin structures can be gained only with the help of photolithography. In spite of high efficiency of PECs, technology of their production is very effortful and couldn't be used in large-scale manufacturing [2].

An example of successful commercialization of production technology of high-effective SEs with efficiency of 20% is a line of the firm Sun Power with capacity of 40 MW per year. This firm produces PEMs with efficiency of 17…18% that is by a quarter higher than of common modules. Cost of photoelectric systems of such modules will make 6,5…6,75 US $/W [6].

In 2004 in Australia a production line with annual capacity of 20 MW for manufacturing PEMs on a basis of solar elements SLIVER, which allow saving up to 90 % of silicon, was put into operation. By this, SE SLIVER have double-sided sensitivity with efficiency to 19,4% and can operate even in the concentrated flow of solar radiation. According to preliminary calculations, module cost will not exceed one US $/W and electricity cost will be 10 cents/(kW·h) [7,8].

European association of photoelectric installation manufacturers stakes on flat-paneled PEMs and plans the following:

- increase SE efficiency from 12…16% to 20% in production (especially by effective contacts);
- decrease silicon consumption from 16 g/W (today) to 8 g/W, because the cost of silicon is about half a price ;
- apply bifacial and concentrator SEs.

In Russia the largest manufacturer of PEMs and systems is the firm "Solar wind". The firm was successful in developing of its unique technology of high-effective SEs with efficiency to 17 % and increasing of production to 5 MW per year, which is now the largest in Russia. The output products meet technical and economic requirements of the world market [10].

The company "Solar wind" is one of the first firms in the world, which succeed in production of PEMs with bifacial sensitivity. This allowed increasing power generation of the modules and producing a wide spectrum of frame modules in a range from 6 to 240 W with efficiency of 12…14 % of single- and double-sided sensitivity and photoelectric systems on their basis. In Russia the SPF “Quark” created double-sided SEs with facial efficiency factor of more than 17 % and back one of more than 14 %., that is a record parameter for SEs of such class. For creation of SE structures on a basis of single-crystallized silicon were used. A structure of current accumulating system includes a conductive oxide, bus bars, located near the structure, and a wire contact net. It allows decreasing the electric losses and losses due to shadowing of contacts, simplifying the process of PEM assembly and it is applicable for different materials [9].

Scientific-production firm CJSC “Telecom-STV” [11] developed its own technology of effective SE production of 100×100 mm and 103×103 mm in size (efficiency factor is 14…16 %) and PEMs with capacity of 0,75 …110 W with efficiency of 12…13 %, annual production of which is 1,5 MW.

Solar elements (round ones with diameter of 100 mm and on a basis of pseudoquadrat of 100×100 mm) with efficiency of more than 12 % and PEM with efficiency of 10…12 % are produced by All-Russia Research Institute of Agriculture Electrification.

Ryazan factory of ceramic-metal apparatus produces pseudoquadratic single-crystallized silicon PEMs of 102,8×102,8 mm and 125×125 mm in size with efficiency of 12…15 % and PEMs of 4…150 W with efficiency of 11…13 % [12] (fig.8.9). Since 2006 the Ryazan factory plans to increase the output of photoelectric installations by several times.

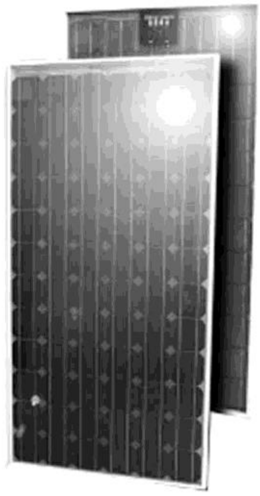

Fig. 8.9. Flat frame photoelectric modules produced by Ryazan factory of ceramic-metal apparatus