Change of photoelectric elements power characteristics by silver nanoclusters modification of receiving surface

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Abstract. The values of power characteristics of modern photovoltaic cells are considered. Possibility of their increasing with the aid of surface plasmon resonance reached by modification of the receiving surface with silver nanoclusters is presented. The effect of nano-coating on the power and stability of energy generation is shown.

1. Introduction
Escalating consumption by mankind of electric energy creates need of replacement of the modern systems of electricity generation based on processing of natural resources on the systems using the renewable. One such source is solar energy.

The conversion of solar energy into electric energy is provided by photovoltaic energy converters (PEC) widely used for electrical supply of space stations, population and production facilities in many countries, as well as in number regions of Russia.

However, a significant disadvantage of modern PEC, which makes their propagation difficult, is the low density of the power obtained from the unit area of the photodetector panel. The theoretical efficiency of silicon photo cells is 22-23%, however real conventional PEC have the efficiency equal to 13% [1].

At present, combined solar installations, concentrators, as well as functional coatings of the receiving surface are used to solve this problem. The latter method appears to be most promising as it involves improving the power characteristics without increasing the receiving surface area.

2. Increase of power characteristics of PEC by surface plasmon resonance
The present paper discloses a method based on modifying the surface of solar cells with a coating of plasmon nanoparticles, which have unique optical properties associated with a surface plasmon resonance (SPR) phenomenon.

Excitation of the SPR consists in the following: variation electric field of electromagnetic light wave displaces free electrons and creates uncompensated charges about a particle surface and also the corresponding returning forces, and if the sizes of a particle there is less than the wavelength of radiation, electrons begin to make coherent fluctuations, that is the superficial plasmon (figure 1 [2]) is formed. If the specified fluctuations match the frequency of incident light, then the resonance absorption and optical dispersion which received the name of the SPR [2, 3] is observed. Surface plasmons are waves propagating along the boundary between two media (metal-dielectric) and are
highly localized at the interface of media, making them highly sensitive to any changes in boundary conditions.

Figure 1. Interaction of variation electric field with metal particles: (a) – a spherical particle, (b) – a cylindrical particle.

Formation of plasmon films is a labor-intensive operation for the achievement of regular arrangement of the correct shape particles on the substrate surface. Usually multi-stage processes based on self-organization of colloidal particles on surfaces [4], deposition by thermal evaporation of thin layers of metal followed by annealing [5], sol-gel technologies [6] were applied.

We have tested a method of the plasmon coating forming by electrophoretic deposition on the silicon photodetection surface of nanoparticles from a colloidal solution obtained by pulse-spark dispergation of silver [7].

3. Installation and method for electrophoretic application of nano-coat

In order to form a nanocluster coating, an apparatus for depositing metal nanoparticles on the surface of a photoelectric converter by an electrophoretic method was developed and assembled, the schematic diagram of which is shown in figure 2.

Figure 2. Electrophoretic module for metal nanoparticles deposition: 1 – upper pressure cover; 2 – metal electrode fixed in a frame of organic glass; 3 – silicon wafer; 4 – cuvette; 5 – lower electrode.

Silicon plate 3 is placed between electrodes 2 and 5. The resulting structure is closed by the lid 1 and the cuvette is filled with colloidal silver solution. The electrical potential is connected. Since colloidal particles have a charge, they can move in an electric field. Reaching the electrode, the nanoparticles
lose charge and deposits on the surface of the plate. During a period of several minutes keeping in solution the individual particles are coagulated with a nanocluster structures forming.

4. Power characteristics of PEC

Preliminary tests showed an increase in the power characteristics of PEC by 20%, as shown in figure 3.

![Figure 3](image)

Figure 3. Voltage-ampere and power characteristics of photocells (at illumination of about 950 W/m²): dashed line – commercial photocells without nanocoating; solid line – photocells coated with silver nanoparticles.

In actual operation conditions, the power characteristics are also affected by the angle of the sun’s incident on the receiving surface. Figure 4 shows average values of generated power of photocells with deposited silver nanoparticles and without ones.

![Figure 4](image)

Figure 4. Dependence of change of output power of photovoltaic converters at change of inclination angle to horizon.

As can be seen from the graphs, photocells with nanocoats have higher power characteristics (on average of 20% more) and higher azimuthal stability than without it. The character of power change of the modified PEC is close to theoretical.
5. Conclusions
The study found:
1. Modification of the receiving surface of the photocells with silver nanoparticles leads to increasing in the power characteristics of the PEC by 20%.
2. Nanocoating provides stable power generation even when the angle of incidence of sunlight changes.
3. The obtained data allow to consider said method for improvement of photovoltaic elements without increasing area of receiving surface.

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