Optical and photoelectric characteristics of the ZnS / por-Si / Si structure performed by different technological routes

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Abstract. The research object is multilayer photosensitive structures with a porous silicon working layer and a semiconductor zinc sulphide. The purpose of this work is to study the effect of the zinc sulphide coating thickness on the structure optical properties. The reflection and photosensitivity spectral characteristics of structures with various thicknesses zinc sulphide coating were studied. It was shown that the optimal coating thickness is 0.056 micrometers.

1. Introduction
A promising direction to improve the efficiency of silicon solar cells is the transition to multilayer structures with anti-reflective coatings. The main losses in structures based on single crystal silicon (c-Si) are associated with the inability to absorb photons whose energy is less than the width of the silicon band gap and thermalize photons with energy greater than the band gap width. To eliminate these losses in the construction of silicon solar cells, the strategy of using multilayer structures of materials with different density is applied. Nanocrystalline silicon is a material with a band gap greater than that of monocrystalline silicon.

A simple and effective way to obtain nanocrystalline silicon is to create a layer of porous silicon on a monocrystalline silicon substrate [1]. The advantages of the resulting porous layer are a high degree of absorption of incident light on the surface, reducing the rate of surface charge recombination. A significant light reflection coefficient (35-40%) from the silicon surface in the spectral sensitivity range of photovoltaic devices (400-1100 nm) necessitates the clarification of the working surface of the silicon solar cell. At the heart of the action of most antireflective coatings is the phenomenon of interference of light waves. For silicon solar cell, a semiconductor coating of zinc sulfide is often used, which is also a sub-alloying layer that reduces contact resistance. Experiments with porous silicon conducted by a number of researchers have shown that it exhibits good anti-reflective properties [2]. However, the combined effect of the porous layer and the interference coating on the properties of solar cells has not been investigated.

The working surface of a light-sensitive structure can be represented as a system of films with different refractive and absorption indices on a textured silicon substrate [1]. The refractive index of the porous layers varies from 2.4 to 3.2, and each layer is about 2 micrometers thick. In practice, the total thickness of porous silicon is 6-10 microns. The textured substrate is a regular quadrilateral pyramid with side faces that are the natural surfaces of a single crystal and an angle at the top of 70.5 degrees. This surface reduces optical losses due to the combined effects of multiple reflections of the incident beam from the front surface and multiple total internal reflections from the back and side surfaces. Light falling perpendicular to the surface is subjected to multiple reflections, resulting in the intensity of the reflected light being reduced as a degree of multiplicity. As long as the geometric size of the microrelief exceeds the wavelength of radiation, the laws of geometric optics are applied, that is, the effects of multiple reflections take place. If the height of the terrain is comparable to the wavelength or
significantly less than the latter, then in relation to this radiation, the surface is completely smooth and manifests itself as highly reflective.

Figure 1. Scheme and SEM image of a multilayer structure.

2. Experimental technique

In this paper, the optical and photoelectric properties of multilayer photosensitive structures containing layers of porous silicon and zinc sulfide are investigated.

To study the spectral characteristics of semiconductor structures, samples with a porous layer created on the textured surface of single-crystal silicon wafers were used. The porous layer was prepared by electrochemical etching (Figure 2) in an alcoholic solution of hydrofluoric acid. In photosensitive structures, plates with a previously created p-n-junction were used. Zinc sulfide films were deposited by thermal evaporation in vacuum at different deposition times. The thickness of the porous layer was about 8 microns, the thickness of zinc sulfide films ranged from 0.027 to 0.063 microns.

Figure 2. Cells for electrochemical etching: vertical; horizontal.

The spectral dependences of the reflection coefficients were studied using a Shimadzu UV-2450 spectrophotometer with a prefix 206-14046. The measurement range was 0.3 - 1 μm, the measurement step and the spectral width of the monochromator slit were 2 nm, the scanning rate was slow. The angle of radiation incidence having an elliptical polarization of about 3: 1 - 4: 1 was 5° with an aperture of not more than 5 °. The radiation receiver of the Shimadzu UV-2450 spectrophotometer is a photoelectric multiplier. This causes significant noise measurements of the instrument in the near infrared region.
Investigation of photosensitivity was carried out on a measuring stand, which included a mercury lamp, a monochromator and a sensitive microammeter. Photosensitivity was determined taking into account the spectrum of the lamp as the ratio of the photocurrent to the power of the incident radiation. All measurements were carried out in air at room temperature.

3. Results and discussion
Studies of the spectral characteristics of reflection have shown that the thickness of the ZnS film has little effect on the course of the curve in the visible range, indicating a high transparency of zinc sulfide in this region of the spectrum (Figure 3). At the same time, the reflection in the infrared part of the spectrum decreases with increasing thickness.

![Figure 3. Spectral reflection characteristic of structures with different ZnS thickness.](image)

A thin layer of ZnS (0.027 µm) and a thick layer (0.063 µm) reduce the sensitivity of the samples. Better sensitivity was shown by structures with a film thickness of about 0.056 microns. This thickness is the optimal antireflection and alloying layer (Figure 4).

![Figure 3. Spectral characteristic of photosensitivity of structures with different ZnS thickness.](image)

4. Conclusion
Thus, for the porous textured photosensitive structure, the optimum zinc sulfide coating was selected. This coating will increase the photosensitivity of the structure without increasing the reflection from its surface.
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References

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