
THE PHOTOELECTRICAL PROPERTIES OF BILATERAL PHOTOELECTROCHEMICAL CELL WITH nGaAs PHOTO-ELECTRODE

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1. INTRODUCTION

The conversion of solar energy in electrical one is realized by solar cells as a result of absorption of solar energy and the separation of the photoexcited carriers by potential barriers in different solid state structures such as p-n junctions, Schottky diodes, heterojunctions, MIS and SIS structures. Also, the photoelectrochemical cells are studied intensively, where the processes described above are on the solid-liquid interface, in other words on the electrolyte-semiconductor interface [1,2]. The absence of expensive electrovacuum technologies and high-temperature processes in the fabrication of photoelectrochemical cells (PEC) is an important advantage. Different semiconductor materials and electrolyte based redox couples were used for the fabrication of PEC [3,4], but a big interest presents the photoelectrochemical cells with the III-V compounds semiconductors as photoelectrodes.

For using more efficiently the photoelectrode surface, in the case of GaAs, which is a very expensive material, and for increasing of functional possibilities of PEC, the bilateral photoelectrochemical cells was proposed and realized. The experimental results of photoelectrochemical cells with the photoelectrochemical chain metal - carbon - “negative” colloidal aqua solution - n-GaAs - “positive” colloidal aqua solution - carbon - metal is presented in this paper.

2. EXPERIMENTAL

The scheme of bilateral PEC is shown in Fig. 1. It presents a cell, with optic transparent lateral walls, divided by the photoelectrode in two section I and II filled with the “negative” and “positive” colloidal solutions. Two auxiliary carbon electrodes are situated symmetrical to photoelectrode in the colloidal solutions.

The monocrystalline n-GaAs photoelectrode with the active surface $\sim 1\text{cm}^2$, the thickness $\sim 0,5\text{ mm}$ and concentration $n_0 = 10^{17}\text{ cm}^{-3}$ was used. The active surface has to correspond to the crystallographic plane (111), but as it is related in [3] this one is not easy to be obtained, according to this the active surface contains the atoms of Ga and As. It is necessary to mention as is presented in [4], that after the active surface processing the acceptor type surface states are present on the surface.

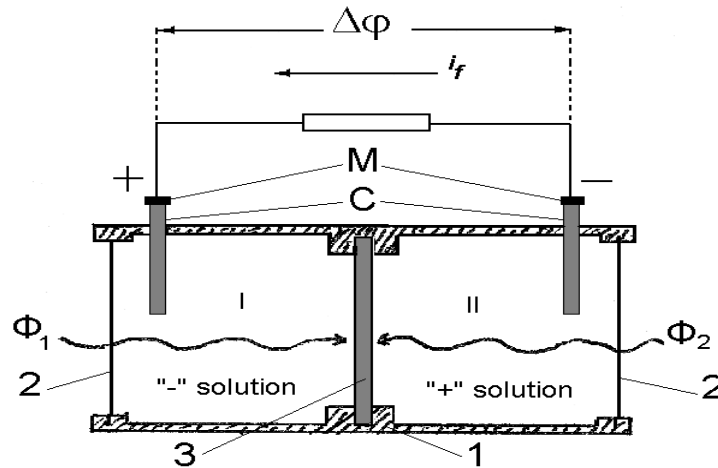


Fig.1 The photoelectrochemical bilateral cell

1. Cell; 2. The lateral walls; 3. Photoelectrode; M- The electrical contacts; C - The carbon counter electrodes

The colloidal aqua solution of hydroxide of iron $\text{Fe}(\text{OH})_3$ and aluminum $\text{Al}(\text{OH})_3$ – with poor acid (pH $\sim 3,5$ and $4,5$ respectively) and the metasilicat of natrium (Na_2SiO_3) with pronounced alkaline properties (pH ~ 11) were used as “negative” and “positive” solutions respectively.

3. RESULTS

The spectral distributions of the optical transparence of the colloidal solution with the 20% (“positive” solution) and 15% (“negative” solution) concentrations were investigated. The “negative” and the “positive” colloidal solutions on the base of Al are uniform transparent in the spectral region of the 400-1000 n, but the positive aquasolution containing Fe intensively absorbed the light with the wavelength less than 600nm.

The photoelectric processes occurring in photoelectrochemical cells at the semiconductor-electrolyte interface are determined by the presence of the depletion layer and consequently by the presence of a double electric layer. In our case the photoelectrode semiconductor material is n-type, having the energy states on the surface caused both by break of crystal lattice and non compensated electron coupling. These surface levels are acceptor one. They can accept electrons both from the InP volume and from the negative charged particles from electrolyte. Also, the semiconductor surface becomes negative and at a small distance from the solution – semiconductor interface in the

volume of the semiconductor appears a layer charged positively with a less number of electrons. The last are non-compensated impurities of donor type, charged positively. Thus, both conductivity band E_c and valence band E_v decline upward [1].

The electric field intensity at the semiconductor-solution interface was estimated $\sim 10^4 \text{V/cm}$. Surface energy levels can influence greatly the kinetics of the processes taking place with the participations of electrons and holes. They form additional recombination centers, generate charge carriers and simultaneously they can play the role of intermediate energetic levels in the process of electric charge transfer through electrolyte-semiconductor interface.

In the dark (300K), when the counter electrode is placed in the aquasolution, the potential difference appeared: $\Delta\varphi_{\text{dk}}^0 = 110\text{mV}$. The $\Delta\varphi_{\text{dk}}^0$ diminish exponentially in time and after 24 hours trend to zero.

The dependence of the photopotential $\Delta\varphi_f$ on the integral illumination intensity is presented in Fig. 2.

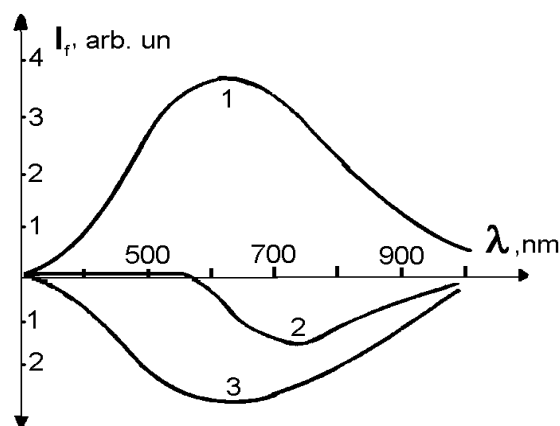


Fig. 2 The dependence of the photopotential $\Delta\varphi_f$ on the integral illumination intensity:

1. – photoelectrode- “negative” colloidal aquasolution at the Φ_1 illumination;
2. – photoelectrode- “positive” colloidal aquasolution on the base of $\text{Fe}(\text{OH})_3$ at the Φ_2 illumination;
3. – photoelectrode- “positive” colloidal aquasolution on the base of $\text{Al}(\text{OH})_3$ at the Φ_2 illumination.

In our case of the bilateral photoelectrochemical cell, at the interfaces n-InP- “negative” colloidal aquasolution and n-InP- “positive” colloidal aquasolution the electrical field is formed with opus sign. Also, in the case of the illumination at the opus parts of photoelrctrodes with the illuminations Φ_1 and Φ_2 the photopotentials with different sign appears, which is neutralized in the case of simultanios illumination of both opposite sides of photoelectrode.

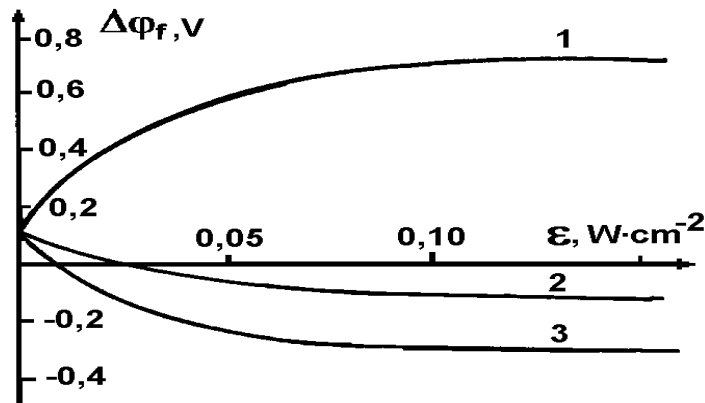


Fig. 3. The spectral distribution of shortcircuit photocurrent density

1. The incident light Φ_1 on the “negative” colloidal aqua solution on the base of Na_2SiO_3 photoelectrode interface
2. The incident light Φ_2 on the “positive” colloidal aqua solution on the base of $\text{Fe}(\text{OH})_3$ - photoelectrode interface
3. The incident light Φ_2 on the “positive” colloidal aqua solution on the base of $\text{Al}(\text{OH})_3$ - photoelectrode interface

The spectral distribution shortcircuit photocurrent density i_f in the interval of the wavelength 315 ... 1000nm of incident light at the photoelectrode-“negative” and “positive” solution interfaces are presented in the Fig. 3. The spectral distribution shows that the short photocurrent is determined by the band gap E_g .

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