THE INVESTIGATION OF STRUCTURAL, ELECTRIC AND PHOTOELECTRIC PROPERTIES OF *n*-CdS-*p*-CdTe HETEROJUNCTION, OBTAINED BY THE DIFFUSION ANNEALING

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In the present work the original experimental results on properties of *n*-CdS-*p*-CdTe heterostructures, obtained by the diffusion annealing of two-layer CdS-Te structures are presented. It has been established that the CdTe layer is created in the vacuum or the inert atmosphere on the CdS and Te boundary by annealing of the CdS-Te structures. Electric and photoelectric properties of CdS-CdTe-Te structures have been investigated. The CdS-CdTe-Te structures band energy diagram explaining the photoelectric properties of these structures has been constructed.

INTRODUCTION

The A^2B^6-CdS, CdTe compounds are of the special interest for their use as components of the cheap and effective thin-film solar converters [1,2].

Works, devoted to the creation of the heterojunction in the CdS-Te system are few [3,4]. The creation of the *n*-CdS-*p*-CdTe by means of the diffusion annealing in the CdS and Te system is of the great interest because of the opportunity to create the two-phase wurtzite-sphalerite systems in an one crystal. The choice of the method for the production of the given heterojunction has been dictated by the simplicity and technological availability.

THE METHODS OF THE EXPERIMENT

The *n*-CdS-*p*-CdTe heterojunction has been created by the following methods:

1. The tellurium film of 1-2 μm thickness has been produced by the vacuum evaporation on a substrait of the monocrystal CdS of the specific resistance ρ =0.01 Ωcm. Then these structures have been placed in the ampoule and have been annealed in the inert atmosphere at temperatures 380-500°C during 10-30 minutes with the following sharp cooling.

Ohmic contacts have been produced on the CdS and Te by the vacuum evaporation of the indium. The air has been evacuated from the ampoule and this ampoule has been connected with the special system, which was providing the inert medium.

2. The Te film has been produced on the glass substrate by the vacuum evaporation at the room temperature. Then the CdS film has been put on this film by the vacuum evaporation of the monocrystal CdS of the specific resistance 15 Ohm. cm; moreover the mask configuration has been chosen so, that the CdS film would partially cover the Te film. The substrate temperature has been 170-190°C at the covering. Later the annealing of the obtained structure in the vacuum has been carried out at the temperature 330°C during 30 minutes with the following cooling in an hour. Ohmic contacts were prepared by means of the vacuum evaporation of the In (indium) on the CdS film and the deposition of the In-Ga alloy on the Te layer.

3. The piece of the monocrystal Te has been melted into the monocrystal CdS at the temperature 450°C. The melting has been carried out in the vacuum camera of VUD-4 device in the inert atmosphere 10^{-1} mm mercury column during 10 min. with the following slow cooling (at the rate of 14,2 grade/min.). The temperature was controlled by the chromel-aluminium (C-A) thermocouple attached to the sample Indium to *n* CdS and In-Ga alloy to the tellurium have been used as ohmic contacts.

EXPERIMENTAL RESULTS AND THEIR DISCUSSION

The investigation of the *X*-ray diffraction and also electric and photoelectric characteristics shows, that the CdTe layer is created between the tellurium and cadmium sulphide in all three types of CdS-Te structures, described above. *X*-ray diffractograms of the CdTe structure of the type 2 are shown on the fig. 1. Diffractograms have been registered both at the presence of the CdS layer (fig. 1a, the Cu K_α radiation was used), and after the selective etching of the CdS layer in the HCl solution (the Co K_α radiation was used on the fig.1b). Three lines of 2θ≈23,80°, 26, 45°, 27, 20° are given on the fig. 1.a. Lines of 2θ ≈26,45°,27,20° correspond to the reflection from (002) and (101) planes of the hexagonal CdS with the principal orientation of grains in the direction of *c*; and to the perpendicular plane of the bulk. The weak line of 2θ ≈23,80° is identified with the (111) plane of the cubic granecentred CdTe.

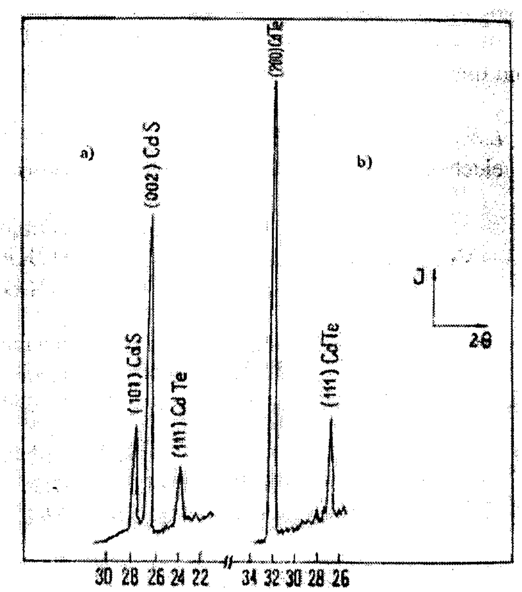

Fig. 1. *X*-ray diffractograms of the CdS-Te structures of the type 2 before (a; Cu K_α=1,5418 Å radiation) and after (b; Co K_α λ =1,7002 Å radiation).

Two intensive lines of $2\theta \approx 23{,}80°$ and $32{,}05°$ are given on the fig. 1.b. Calculations of interplanar distances show, that these lines are identified with (111) and (200) planes of the cubic CdTe.

Therefore, the analysis of *X*-ray diffractional figures of CdTe structures of the type 2 points to the presence of the CdTe layer between CdS and Te films.

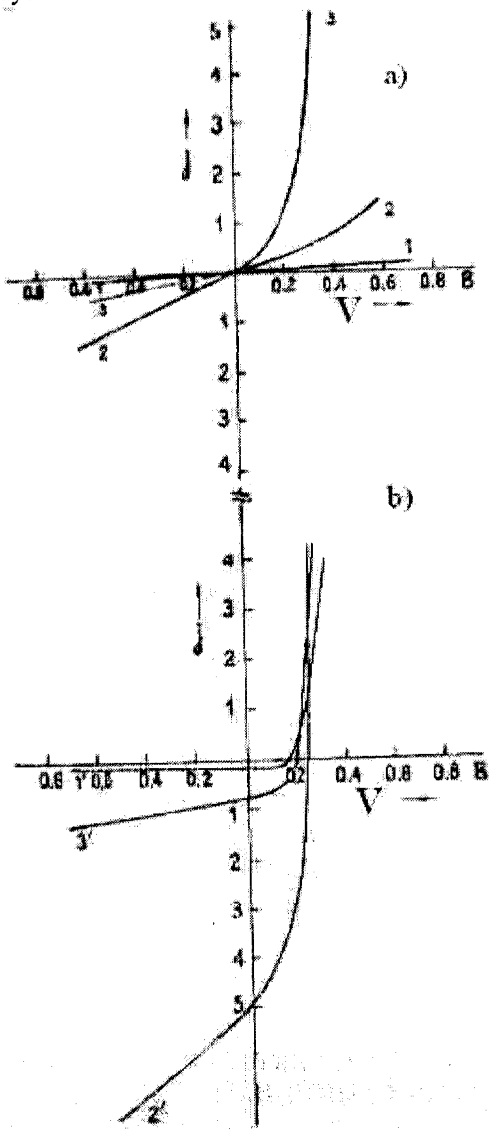

Fig. 2. Dark (a) and light (b) VAC of *p*-CdS-*n*-CdTe structures of the type 1,2,3. The lighting by the sun simulation of *W*=100 mW/cm².

As it is known the mechanicm of the CdTe creation is connected to the exothemicity of the creation of Cd and Te atoms [3]. The temperature gradient, directed from the boundary to the volume of the tellurium film, arises at the expense of the local heat release on the boundary. The distribution of the vacancies concentration in the tellurium has the identical nature. At the first moment atoms of Cd diffuse in Te with the creation of the CdTe combination. The vacancies concentration in the growing layer, directed to the opposite direction, stimulates the diffusion of cadmium atoms through the growing layer of the CdTe in the tellurium and leads to the growth of the layer thickness of the cadmium telluride in consequence of the reactive diffusion. By this the boundary between the cadmium telluride and tellurium moves in the direction of the Te [3]. As the excess of Cd atoms always exists in the CdS, then the creation of the CdTe layer between Te and CdS may be also explained by the previous mechanism. Dark (fig.2a) and light (fig. 2b) volt-ampere characteristics of three types of *n*-CdS-*p*-CdTe samples are shown on the fig.2. As it is seen from the figure, volt-ampere characteristics of three types of samples are asymmetric and manifest the sufficient photosensitivity (fig.2b).

Photoelectric parameters of samples of types 1,2,3 have the value $j_{sc}\approx 0{,}14$ mA/cm²; $V_{oc}\approx 0{,}18$V; $j_{sc}\approx 5$mA/cm²; $V_{oc}\approx 0{,}24$ V and $j_{sc}\approx 0{,}8$ mA/ cm²; $V_{oc}\approx 0{,}21$ V, respectively.

Let us note, that all three types of the CdS-Te sample had not manifested the rectifiable properties before the realization of the thermal treatment and were non-photosensitive. It is the confirmation of the fact, that the new CdTe combination is created between CdS and Te.

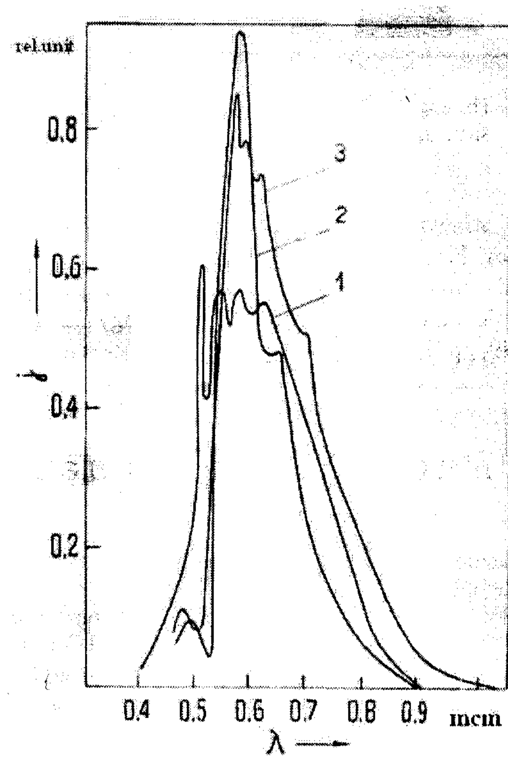

Fig. 3 The spectral distribution of the density of the photocurrent of the short circuit of j_{sc} structures of the type 1, 2, 3.

The spectral distribution of the density of the photoelectric current of the short circuits, j_{sc} of the CdS-CdTe structure is shown on the fig.3. It is seen, that the form of the j_{sc} spectra is identical for all types of samples, the short-wave maximum is caused by the absorption in CdS at $< 0{,}5\mu$m and the long-wave boundary of the photosensitivity corresponds to the width of the forbidden band of the CdTe layer; $E\approx 1.44$eV (λ=0.86μm), which is created between CdS and Te. As it is seen from the fig.3, this layer is enough photoactive and the photosensitivity is caused by the light absorption in CdTe in the interval of the length of waves 0,5-0,9μm. As it is concern the oscillation j_{sc} in this region, then it is obviously connected with the interference of the incident light in the CdTe layer. The thickness of the CdTe layer, determined from the interference patterns (for example, for sample of type 2) makes ≈1μm.

The type of the conductivity and the specific resistance of the rest of the CdTe layer have been measured for samples of the type 2 after the selective etching in the HCl solution of the CdS film. Measurements showed, that the CdTe layer has the p-type of the conductivity of the specific resistance ≈0,1Ωcm. The specific resistance of the CdS film has made 10^2Ωcm. The estimation of the carriers concentration in CdS and CdTe gives the value $n \approx 2 \cdot 10^{16}cm^{-3}$ and $p \approx 7 \cdot 10^{17}cm^{-3}$.

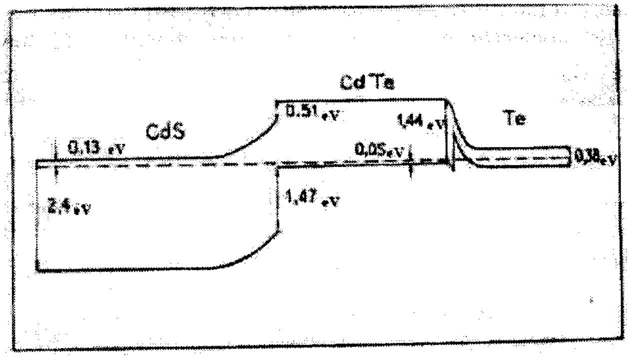

Fig.4. The supposed band energy diagram of CdS-CdTe-Te structures.

Using these data, we show the supposed band energy diagram of n-CdS-p-CdTe-Te structure on the fig.4. As it is seen from the diagram, the band bends have identical signs to the right and left of the CdTe layer, in other words, fields signs are opposite on boundaries of CdS-CdTe and CdTe-Te. Obviously, low values of photoelectric parameters of the obtained CdS-CdTe heterostructure are explained by this.

CONCLUSION

1. It has been established, that the CdTe layer is created on the boundary of CdS and Te at the annealing of the CdS-Te structure in the vacuum or the inert atmosphere.
2. Electric and photoelectric properties of the CdS-CdTe-Te structure have been investigated, the band energy diagram of the CdS-CdTe-Te structure has been constructed, explaining photoelectric properties of these structures.

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DİFFUZİON İŞLƏNMƏ YOLU İLƏ ALINMIŞ *n* CdS - *p* CdTe HETEROKEÇİDLƏRİNİN STRUKTUR, ELEKTRİK VƏ FOTOELEKTRİK XASSƏLƏRİNİN TƏDQİQİ

Məqalədə ikiqat Te-CdS strukturunun termik işlənməsi nəticəsində alınmış CdS-CdTe heterokeçidinin xassələri üzrə orijinal eksperimental nəticələr alınmışdır.

Müəyyən olunmuşdur ki, CdS-Te strukturunun vakuumda və ya təsirsiz qaz mühitində işlənməsi zamanı CdS ilə Te təbəqəsinin sərhəddində CdTe təbəqəsi yaranır. CdS-CdTe-Te strukturunun elektrik və fotoelektrik xassələri tədqiq olunmuşdur. Alınan nəticələr əsasında bu strukturun fotoelektrik xassələrini izah eden zona diaqramı qurulmuşdur.

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ИССЛЕДОВАНИЕ СТРУКТУРНЫХ, ЭЛЕКТРИЧЕСКИХ И ФОТОЭЛЕКТРИЧЕСКИХ СВОЙСТВ ГЕТЕРОПЕРЕХОДОВ *n*- CdS-*p*-CdTe, ПОЛУЧЕННЫХ ДИФФУЗИОННЫМ ОТЖИГОМ

В настоящей работе приведены оригинальные экспериментальные результаты по свойствам n-CdS-p-CdTe гетероструктур, полученных диффузионным отжигом двухслойных CdS-Te- структур. Установлено, что при отжиге CdS-Te структуры в вакууме или инертной атмосфере на границе CdS и Te образуется слой CdTe. Исследованы электрические и фотоэлектрические свойства CdS-CdTe-Te структуры. Построена энергетическая зонная диаграмма CdS-CdTe-Te структуры, объясняющая фотоэлектрические свойства этих структур.

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