# Electrophysical properties of layout composition of $n^+$CdsS-nSdS-nSi structure

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# Electrophysical Properties of Layout Composition of $n^+$CdsS-nSdS-nSi Structure

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**Abstract.** A layered composition of *$n^+$CdS–nCdS-nSi* structure was obtained. The temperature-voltage-ampere characteristic of the layered composition of *$n^+$CdS–nCdS-nSi* structure was investigated. The electrophysical parameters of the layered composition of $n^+$CdS-nCdS-nSi structure were determined. The appearance of the sublinear area on the volt-ampere characteristic is conditioned by the appearance of counter directed ambipolar diffusion of nonequilibrium carriers and their ambipolar drift.

## INTRODUCTION

Obtaining thin layered compositions between silicon and cadmium sulfide is currently of particular interest. A positive solution to this issue would be an important step in converting solar energy into electrical energy. Such layered compositions based on heterojunctions would be an important link in creating a new generation of solar cells, combining the real possibility of silicon solar cells with the potential advantage of cadmium sulfide. However, there are fundamental difficulties in obtaining a layered composition based on CdS - Si heterojunction. The lattice constants of cadmium sulfide and silicon differ by 8%, which prevents in obtaining a heterojunction between them without surface states. Nevertheless, the idea of obtaining heterojunctions has recently changed fundamentally. What is meant here is the formation of an intermediate layer during the formation of any two contacts. Naturally, the composition of the intermediate layer depends on the properties of the contacting materials and technological conditions. Taking into account the above stated we obtained the layered composition between CdS and Si with sufficiently good properties.

## SAMPLE PREPARATION

Based on cadmium sulfide, layered compositions of $n^+$CdS-nCdS-nSi structures with the thickness of the base n - layer W = 2 μm were made. During film deposition, the temperature of the source crucible (CdS) was varied in the range $T_{IST} \approx 800 \div 850$C, and the temperature of the substrate (nSi) was maintained within $T_P \approx 250 \div 270$C. At the same time, to ensure the reproducibility of the structures, a slide was used to set the CdS sputtering time, which ensured that the same film thickness was obtained from experiment to experiment. When studying the

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structure by vacuum sputtering, contacts were created - solid on the back side and "U" shaped with an area of 3 $mm^2$ of indium on the CdS surface.

## EXPERIMENTAL AND DISCUSSION

The volt - ampere characteristics (VAC) of the obtained structures in the forward direction, shown in Fig. 1 in semi-logarithmic scale, were studied.

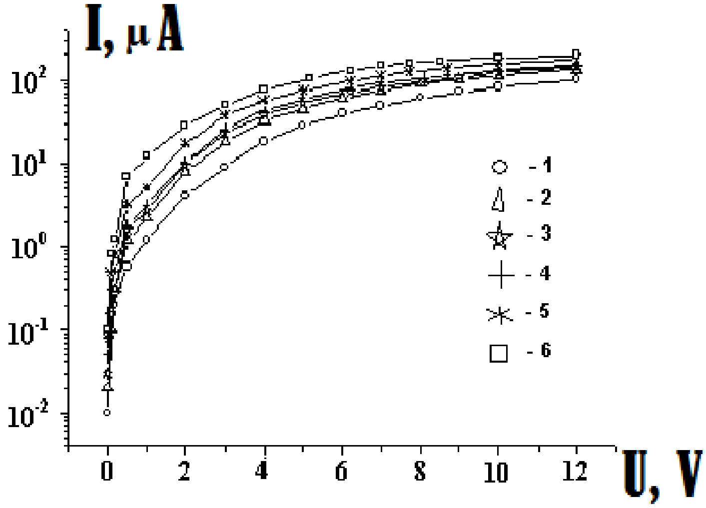


**FIGURE 1.** Volt-ampere characteristic of In-$n^+$CdS - nCdS - nSi-In structure at different temperatures T.$^0$C: 1 - 20, 2 - 40, 3 - 60, 4 - 80, 5 - 100, 6 - 120.

Measurements were carried out in the temperature range 20 - 120$^0$C. The initial section of the (VAC) (up to V) is well approximated by the known Stafeev dependence [1-4]:

$$I = I_0 \cdot e^{\frac{qV}{ckT}} \tag{1}$$

Where the exponent exponent "c", calculated from the VAC, has values c ≈ 12.6, characteristic of the so- called "long diode," i.e. $W/L_p > 1$, where W is the base length, is the diffusion length of non $L_p = \sqrt{D_p \tau_p}$ base carriers. According to the theory of V. I. Stafeev, the exponent exponent "c" is described by the expression:

$$c = \frac{2b + ch(\frac{W}{L}) + 1}{b + 1}, \tag{2}$$

where $b = \frac{\mu_n}{\mu_p}$ - ratio of electron and hole mobility.

The mobility of basic carriers, determined by the Hall method, was $\mu_n$ = 286 $cm^2/(V{\cdot}s)$ at room temperature. Assuming that, as usual in $A^{II}B^{VI}$ group materials, hole mobility is much less than electron mobility [5], the value of $\mu_p$ = 8 $cm^2/(V{\cdot}s)$ was taken for evaluation. In this case b = 36, from relation (2) we can find the ratio $W/L_p \approx 6.7$, which really turns out to be greater than 1. Then we can find the diffusion length of non-basic carriers.

This allows us to determine the product of mobility by the lifetime of the non-basic carriers $\mu_p\tau_p$ [6].

$$\mu_P \tau_P = \frac{qL_P^2}{kT} \tag{3}$$

The values of these parameters calculated at different temperatures are shown in Table 1.

**TABLE 1.** Characteristic parameters of the $n^+$ - n structure as a function of temperature.

| T, K | 293 | 313 | 333 | 353 | 373 | 393 |
|---|---|---|---|---|---|---|
| c | 12.6 | 13.9 | 15.6 | 17 | 16.2 | 15.7 |
| $I_0$, $10^{-8}$ A | 1.31 | 2.31 | 2.9 | 3.3 | 3.8 | 4.2 |
| $L_P$, μm | 0.3 | 0.294 | 0.289 | 0.285 | 0.287 | 0.289 |

At room temperature, the product $\mu_p\tau_p$ has values ~3.6-$10^{-8}$ $cm^2/V$. Table I shows that in the temperature range - 293-403 K the diffusion length of non-base carriers weakly depend on the temperature. Figure 2 shows the dependence of the product $\mu_p\tau_p$ on temperature. As can be seen from this figure, the value of $\mu_p\tau_p$ decreases with increasing temperature, which is associated with the scattering of nonequilibrium carriers on the thermal vibrations of the lattice, and this leads to a decrease in the mobility of nonessential carriers

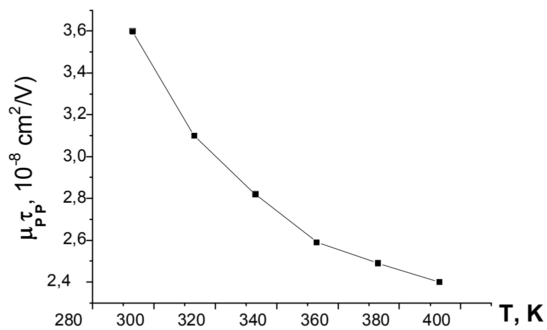


**FIGURE 2.** The dependence of the mobility product ($\mu_P$) on the lifetime ($\tau_P$) of non-basic carriers - holes of the $n^+$ - n structure on the temperature.

From the VAC shown in Fig. 1, that following the usual exponential dependence, extended sublinear sections (in the range from V > 0.2 to 6 V) appear on all VAC, regardless of temperature. These sections of the I-V curves can be well described within the framework of the so-called "injection depletion effect," which was first predicted theoretically in [7]. In the cases of this effect, the VAC has a very specific character and is described by a law of the form [7]

$$V \approx V_0 e^{JaW}, \tag{4}$$

where

$$a = \frac{1}{2qD_P N} \tag{5}$$

- a parameter that depends only on the diffusion coefficient of non-base carriers (i.e., their mobility, $D_p = (kT/q)\mu_p$) and the concentration of deep impurities N, J is the current density. The values of this parameter calculated at different temperatures are shown in Table 2.

**TABLE 2.** Values of the parameter a as a function of temperature

| T, K | 293 | 313 | 333 | 353 | 373 | 393 |
|---|---|---|---|---|---|---|
| $a$, $10^9$ cm/A | 4.6 | 4.66 | 4.64 | 4.62 | 4.8 | 5 |

One of the most important conditions for observing the sublinear section of the VAC (5) is the requirement [8]

$$JaW > 2 \quad (6)$$

which is freely performed at all temperatures (e.g., at T =20$^0$C, S = 0.8 cm$^2$, $JaW \approx 2.3$ ).

Theoretically, the appearance of such a VAC is possible only when the directions of ambipolar diffusion of nonequilibrium carriers and their ambipolar drift, which in this case is determined by the injection modulation of the deep impurity charge [7,9], are opposite.

## CONCLUSION

We have obtained a layered composition based on $n^+$CdS-nCdS-nSi structure. The technology of obtaining showed that when obtaining the film of cadmium sulfide on the surface of a silicon substrate, the film thickness depended on the temperature of the substrate and the source. The electrophysical parameters of the layered composition of $n^+$CdS-nCdS-nSi structure were determined from the temperature volt- ampere characteristics. The determined these parameters showed that the appearance of sublinear section on the volt-ampere characteristic is due to the appearance of counter directed ambipolar diffusion of nonequilibrium carriers and their ambipolar drift. And this shows that the current transfer mechanism in this case is determined by the injection modulation of the deep impurity charge.

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