American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-01, pp-32-35
www.ajer.org
Research Paper Open Access

Analysis of Serial Resistance of Film Photoconverters with Sis Structure Based On Polycrystalline Cadmium Telluride

Utamuradova Sharifa Bekmuradovna *, *Doctor of Physical **and** Mathematical Sciences (DSc), Professor, Director of the Scientific Research Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan, Tashkent, Uzbekistan.*

Muzafarova Sultanpasha Anvarovna , *Ph.D., Scientific Research Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan, Tashkent, Uzbekistan.*

Kenzhaeva Zarifa Suyunovna , *junior researcher Scientific Research Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan, Tashkent, Uzbekistan.*

Annotation *. The operational parameters and efficiency of the* SnO_2 */ pCdTe, ITO / pCdTe and* In_2O_3 */ pCdTe photo converters have been investigated. The significant influence of the output parameters of the structures on the series resistance (*R_n*) is shown. The real values of the series resistance of the structures under study are calculated. In film photo converters, a significant contribution to the resistance* R_n *is made by the resistance of the transition dielectric (d) layer between the semiconductor and the rear omic contact of the structures.*

Keywords. *Photo converter, structure, dielectric layer, series resistance, output parameters.*

Date of Submission: 01-01-2022 Date of acceptance: 10-01-2022

I. INTRODUCTION.

Operational parameters and efficiency (efficiency) of photo converters significantly depend on series resistance (R_n), which mainly consists of spreading resistance (R_s) and base resistance (R_b). In film photo converters, a significant contribution to the resistance R_n is made by the resistance of the transition dielectric (d) layer between the semiconductor and the rear ohmic contact with the structure.

In efficient photo converters (PCs) with a semiconductor-insulator-semiconductor (SIS) structure, the dielectric layer (d) is transparent, which is common for minority photo carriers, and therefore its resistance does not affect the value of R_n. However, in most real film PCs, the thickness of the dielectric layer can be significant and its resistance can also be significant. Let us analyze the main components of series resistance for each structure SnO_2 / pCdTe, ITO / pCdTe and In_2O_3 / pCdTe separately. The efficiency of the structures, as well as the filling factor, and the photocurrent remain constant up to a thickness of d ≈ 20 Å, after which their values sharply drop to zero, and the open circuit voltage decreases linearly from 0.65 to 0.60 V. A decrease in the operating parameters of structures with an increase in the thickness of the oxide layer is associated with an increase in the series resistance [4].

II. EXPERIMENT

PCs structure SnO_2 */ pCdTe.* For this, the load characteristic was taken at three values of light density: 60 mW / cm^2; 180 mW / cm^2; and 280 mW / cm^2; then a point were marked on each curve that differed from the short-circuit current by 10 mA. Then, connecting these points, the value of series resistance Rs was determined from the slope of the straight line. in this way, the determined value of the series resistance Rs = 1.86 Om. Note that the experimental value of the sequential structure for ITO / pCdTe is also relatively small. This is primarily due to the factors listed above, namely, the insignificant value of the spreading resistance R_S and the dielectric layer (TeO_2), as well as the relatively low value of the base resistance pCdTe ($\rho = 10^2$ Om. cm).First, consider the spreading resistance, the analytical expression of which has the following form [1, 765-775]

$$R_S = \frac{R_S}{1 + \frac{R_c}{R_P}} \qquad (1)$$

Where

$$Rc = \left\{ 1 + \frac{R_1}{R_3 + \frac{1}{3}(R_3 + R_5)} + \frac{R_1}{R_1 + R_2 + R_3} \right\} x \frac{(R_2 + R_4)}{2 + \frac{R_1 + R_2 + R_4}{R_3 + \frac{1}{2}(R_2 + R_5)}} \qquad (2)$$

$$R_P = \frac{2\,\mathrm{Re}\,(R_C + R_1)}{(n-1)(2\,\mathrm{Re} + R_1)}, R_4 = \frac{\rho_S r_S}{Sd} \qquad R_5 = R_4 \frac{r_S}{2W - r_S} \qquad (3)$$

ρ $_x$ is the resistivity of the upper wide-gap heavily doped oxide layer; S is the distance between the strips of the contact grid; W is the length of the strip of the contact grid; r $_s$ is the distance from the contact strip to the point at which the potentials created by carriers flowing in the direction of the contact strip and strips of the contact grid, equal to; n - the number of strips of the contact grid; R $_1$, R $_3$ - resistance of the contact strip and strips of the contact grid, respectively; R $_2$ - resistance between the contact strip and the heavily alloyed oxide layer; d is the thickness of the TeO $_2$ oxide layer . An important parameter for calculating the spreading resistance is r $_s$. The value of r $_s$ with other geometric parameters of the upper heavily doped oxide layer S and W is in a very complex analytical relationship [1, 765-775]].

$$\left(\frac{2r_S}{S}\right)^2 = \frac{2W}{r_S} - 1 - 2(-W\ /\ rs - 1)^2 \ln\left[{}^{W}\!/_{W} - r_S\right] \qquad (4)$$

$$\text{f (k)} = \left(\frac{2r_S}{S}\right)^2 \qquad (5)$$

and

$$\text{f (z)} = \frac{2W}{r_S} - 1 - 2\left(\frac{W}{r_S} - 1\right)^2 x \ln\left[\frac{W}{W - r_S}\right] \qquad (6)$$

The values of these resistances were calculated using expressions (2) and (3), which = 18.37 Om and 5.13 Om. Accordingly, at ρ≅ 2 • 10 $^{-3}$ Om.cm of the heavily doped oxide layer SnO $_2$. Further, the spreading resistance was measured. Thus, the final estimate made according to (6) gives n $_s$ ≅ 2.05 Om. As noted above, another important component of series resistance is base resistance, especially when the original semiconductor material is high resistance. In all structures under study, pCdTe is used as the base material.

Films of cadmium telluride with a high diffusion length of minority carriers L_n≅10÷15 μm. [3] have ρ≅ 10 ^{2} ÷ 10 ^{3} Om.cm. Therefore, the contribution of the resistance of the base semiconductor material to R $_n$ can be significant. For example, the resistance of the layers of cadmium telluride P - type R $_b$ ≅ 1.59 Om at values ρ $_{CdTe}$ ≅ 5 • 10 Om.cm. and l ≅ 50 μm.

Typically, the series impedance of the PCs is nested from:

$$R_n = R_s + R_b + R_1 + R_6 + R_7, \qquad (7)$$

Where R $_6$ is the resistance between the base and the rear contact:

R $_7$ is the resistance of the rear contact.

By means of measurements, it was found that the resistances R $_6$ and R $_7$ $_{are}$ equal to R $_6$ ≅ 0.8 Om and R $_7$ ≅ 0.09 Om, respectively.

So, the calculation according to (7) gives for R $_n$ ≅ 4.53 Ohm. Next, you should determine the optimal dimensions of the contact grid and the distance between them. This is necessary in order to obtain the maximum power per unit surface area of the photocell [2, 1356-1359]:

$$P_{yg} = \frac{JU}{S} \qquad (8)$$

$$U = \frac{AkT}{q} \ln \left[\frac{J_{\iota}(S - S_K)}{i_S S} \right] - R_P I \qquad (9)$$

S $_k$ - contact area.

$$\frac{I}{J_{\phi}} = \frac{I}{J_S(S - S_K)} = m \qquad (10)$$

Then the expression for the power taking into account (10) can be written in the form

$$P_{yg} = i_{\Phi m} \left(1 - \frac{S_K}{S}\right) \left\{ \frac{AkT}{q} \ln \left[\frac{i_{cp}(1 - m)\left(1 - \frac{S_K}{S}\right)}{i_S} \right] + 1 \right\} - R_{pm} i_{\phi} \left(1 - \frac{S_K}{S}\right)$$

(11)

It is necessary to find, for such dimensions, the contact section and at what value of m the specific power of the photocell is maximum. For this, we differentiate expressions (11) with respect to m and equate the derivative to zero. In this case, we obtain the optimal value of m. If we neglect the term S $_k$ / S in comparison with unity and the voltage drop across the heavily doped surface oxide layer (SnO $_2$), then we get the following analytical expression:

$$f(m) = \frac{m}{f - m} - \ln(1 - m) = \ln \frac{i_{\phi}}{i_S} \qquad (12)$$

Having built a graph of the function f (m) from "m", one can find the optimal value "m", which corresponds to the expected value of lg • i $_\Phi$ / i $_s$. For example, from the experiment taken with the value of I $_\Phi$ = 12 mA / cm ^{2} and i $_s$ = 8 • 10 $^{-8}$ A / cm ^{2} we obtain m = 0.908. Further, assuming that the area of the contact mesh strip is small compared to the total area of the element, we obtain an expression for the distance between these

$$l_1 = \sqrt[3]{t \frac{AkT}{q}} \ln \left[\frac{i_{cp}(1 - m)}{i_S} + 1 \Big/ \frac{2}{3} \frac{P}{d} m^2 i_{cp} \right] \qquad (13)$$

Whence follows; to remove the maximum power per unit area, photoconverters with a structure, about 15% of its surface must be covered with current-collecting contacts.

The experimental values of series resistance were determined by the Handy method [1,765-775]. For this, the load characteristic (Fig. 1) was changed at different light intensities. Then, on each curve, a point was marked that differed by ΔJ from the short-circuit current (in our case, ΔJ = 4 mA). The marked points were connected by a straight line. If this is a straight line not parallel to the axis of the currents, then the voltage change is proportional to the value of R $_n$.

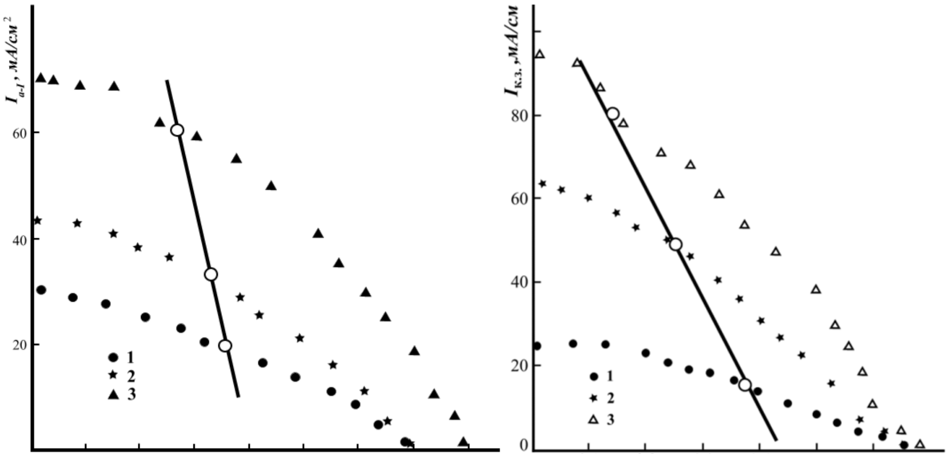

Fig. 1. Load characteristic at different light intensities . Light density: 1 - 60 mW / cm^2; 2-180 mW / cm^2; and 3-280 mW / cm^2.

In this case, the main requirement is that the value of the series resistance is not modeled.

$$L_1 = \sqrt[3]{t\frac{AkT}{q}}\ln\left[\frac{i_{cp}(1-m)}{i_S} + 1\Big/\frac{2}{3}\frac{P}{d}m^2 i_{cp}\right] \tag{14}$$

The performed estimate gives for $L_1 = 3.74.10^{-10}$ cm with a change in the light intensity. Thus, a certain value of resistance $R_n = 6.8$ Om and almost 2 Om more than its calculated value. The calculation cannot take into account the resistance of the dielectric layer between the layer of SnO_2 and pCdTe. In this case, it was assumed that it is thin, transparent for minority photo carriers, and also creates an additional potential barrier for major current carriers.

However, the photosensitive structure of SnO_2 / pCdTe is formed quite at high temperatures of 350 ÷ 400 ^{0}C, therefore the dielectric layer of TeO_2 [5,211; 6,73-78] is formed with a considerable thickness. This is evidenced by capacitance measurements (d = 1000 Å), as well as a low value of the short-circuit density in these structures. Therefore, the difference between R_{nexp} and R_{ncalc}, apparently, can be explained by not taking into account the resistance of the dielectric layer when calculating the series resistance for this structure.

From the analysis of the load characteristics, taken at densities integral intensity of 60 - 280 mW / cm ^{2}, it follows that in the structure of PCs SnO_2 / pCdTe fill factor has low values θ = 0,35 ÷ 0,4. Such a low value of θ, in turn, convincingly shows that θ in such phase transitions is very significant. To lower the values of the series resistance, it is necessary to optimize the parameters of the PCs . To do this, first of all, it is necessary to lower the resistance of the base semiconductor material (pCdTe) and reduce the thickness of the dielectric layer to such a thickness that it becomes transparent to minority current carriers.

PCs with the ITO / pCdTe structure. The photosensitive structure ITO / pCdTe was obtained by magnetron sputtering of highly regressed ITO oxide [4]. The calculation performed for the spreading resistance of the heavily doped ITO oxide layer gave an insignificant value (~ 0.90 Om), and the total series resistance for this structure turned out to be only $R_n = 1.76$ Om. Note that when calculating R_n, the following parameter values were used:

$R_S = 0, 102$ cm; W = 0.5; S = 0.17 cm; $\rho_{JTO} = 2.6.10^{-4}$ Om cm;

$R_I = 0.003$ Om; $R_2 = 0.007$ Om; $R_3 = 0.6$ Om; $R_5 = 1$ Om; $R_6 = 0.6$ Om ; $R_7 = 0.07$ Om

These values were determined in the same manner as for the PCs with the structure of SnO_2 / pCdTe. The experimental values of the series resistance were found for this structure also by the Handy method [1, 765-775]. For this, the load characteristic was taken at three values of light density: 60 mW / cm ^{2}; 180 mW / cm ^{2}; and 280 mW / sm ^{2}; then a point was marked on each curve that differed from the short-circuit current by 10 mA. Further, connecting these points, the value of R_P was determined from the slope of the straight line . in this way, the determined value of the series resistance $R_P = 1.86$ Om. Note that the experimental value of the sequential structure for ITO / pCdTe is also relatively small. This is due primarily those factors which were listed above, namely, slight spreading resistance value R_S, and the dielectric layer (TeO_2), and relatively small value pCdTe base resistance ($\rho = 10^2$ Om. sm). For photo converters with the ITO / pCdTe structure, the calculated experimental value of the fill factor is Q = 0.4. This experimental fact also indicates a significant series resistance in photosensitive ITO / pCdTe structures, at which a significant fraction of the generated photo voltage drops.

PCs with In_2O_3 / pCdTe structure. The geometrical dimensions of the strip of the contact grid of the contact strip are the same as those of the PCs with the ITO / pCdTe structure. The oxide layers In_2O_3 were homogeneous and had $\rho = 5.4.10^{-4}$ Om. cm. The calculated value of the series resistance for this structure turned out to be = 3.26 Om. The results of the measurements show that the values of the resistances that add up the series resistance are almost the same as those of the PCs with the ITO / pCdTe structure, except for the resistance of the base conductor. The series resistance values for this structure are of the order of = 2 Om. Also noteworthy is the increased resistance value (~ 0.85 Om) of the transition layer between the pCdTe film and the rear contact - Mo. As for the experimental value of the series resistance, it turned out to be $_{Rnexp} = 3.75$ Om by the Handy method. In this photosensitive structure, the maximum efficiency is also not achieved because of the significant series resistance. Indeed, the depth of intrinsic absorption of light in cadmium telluride is d ~ $\left(\frac{1}{\alpha}\right)$ of the order of 10 μm. Consequently, it is possible to reduce the thickness of the ρ-type cadmium telluride film to 10–15 μm, but at the same time it is necessary to preserve its previous electro physical properties and obtain a rear omic contact with low resistance. The difference in the values of R_{ncalc} and $_{Rnexp}$ is explained, first of all, by a change in the resistance of the base during the fabrication of structures.

In order to obtain the maximum power per unit surface, the sizes of the contact area in the last two structures were also calculated for their given electro physical and geometric parameters. In this case, the calculation of the contact area is reduced to determining the distance between the strips of the contact grid, since the thickness of the contact grid is insignificant in comparison with their length.

Thus, the calculated [7; 8, 71-76.] value of the distance between the strips of the contact grid $l_i = 4.5.10^{-1}$ cm for a phase transition with the ITO / pCdTe structure and $l_i = 3.75.10^{-1}$ cm for a phase transition with the In_2O_3 / pCdTe structure is beyond doubt. Next, we calculate the effective area of the strips of contact meshes. Adding the W-shaped area of the collecting contact strip, we find the total surface of the current-collecting contacts.

III. SUMMARY

The values of the photocurrent, open-circuit voltage, and limiting efficiency of the photosensitive structures SnO_2 / pCdTe, ITO / pCdTe, and In_2O_3 / pCdTe are calculated. The maximum specific power is obtained for a PC with the ITO / pCdTe and In_2O_3 / pCdTe structures when 10–15% of the surface is covered with current-collecting contacts. The calculations performed for these structures are: efficiency 21.6% for the ITO / pCdTe and In_2O_3 / pCdTe structures, 19% for the SnO_2 / pCdTe structures. PCs manufactured with $\eta = 5 - 6\%$ ITO / pCdTe and In_2O_3 / pCdTe, with c $\eta = 3 - 5\%$ SnO_2 / pCdTe. The theoretical and experimental values of the series resistance of the photosensitive structures SnO_2 / pCdTe, ITO / pCdTe and In_2O_3 / pCdTe, as well as their optimal sizes, have been determined. It is shown that series resistance is mainly determined by the resistances of the base thickness, the back contact Mo **-** pCdTe, as well as the resistance of the dielectric layer TeO_2

REFERENCES

[1]. Xandy RT “Theoretical analysis of the series resistance of a solar cell” sol st. electron N 8, pp 765-775., **1967** .

[2]. Bardina N.M., Zaitseva A.K. The choice of the optimal size and load of a silicon photocell for various versions of down conductors Radio engineering and electronics**, 1965**. vol.10 v.7 pp. 1356-1359.

[3]. Labrets J., Domincuez E., Lora Yamayo E., Arjona F. Thin oxide silicon dioxide - silicon MIS solar cells. Photovoltaic solar energy conf. proc. 3 rd inst. Conf. Cannes 1980.

[4]. Muzafarova S.A. Investigation of photosensitive SIS structures based on cadmium telluride. PhD thesis **1983,** Tashkent.

[5]. Aliev A.A., Mirsagatov Sh.A., Muzafarova S.A., Abduvayitov A.A. Investigation of the impurity composition of the chemical state of synthesized films of cadmium telluride on molybdenum substrates from the vapor phase by the EOS method. Fundamental and applied problems of physics, Tashkent, **2004**.-P.211.

[6]. Kutiniy D.V., Kutiniy V.E., Rybka A.V., Shlyakhov I.N., Zakharchenko A.A., Kutiniy K.V., Verevkin A.A. Modeling the voltage-current characteristics of X-ray and gamma-radiation detectors based on structures Me - CdZnTe - Me. // Bulletin of Kharkov University, **2007,** No. 777, issue 2 (34). - S73-78.

[7]. Vasiliev A.M. Landsman A.P. Semiconductor photoconverters M, Sov. radio **1970**

[8]. 8. Sh.B. Utamuradova, S.A. Muzafarova. Influence of dose γ- irradiation on the current transfer mechanism of photodetectors with SIS structure pCdTe-TeO2-n SnO2. Euroasian Journal of Semiconductors Science and Engineering **2019**, Vol. 1, Issue 6 pp. 71-76.

Utamuradova Sharifa Bekmuradovna, et. al. "Analysis of Serial Resistance of Film Photoconverters with Sis Structure Based On Polycrystalline Cadmium Telluride.”*American Journal of Engineering Research (AJER)*, vol. 11(01), 2022, pp. 32-35.