

OLVASGÉPÍRMI FELDANYI

TK 155.128

KFKI-1980-01

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PHOTOELECTRICAL INVESTIGATION OF
 $\text{CaSe-Sb}_2\text{Se}_3$ HETEROJUNCTIONS

Hungarian Academy of Sciences

CENTRAL
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BUDAPEST

187

KFKI-1980-01

PHOTOELECTRICAL INVESTIGATION OF
 $\text{CdSe-Sb}_2\text{Se}_3$ HETEROJUNCTIONS

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HU ISSN 0368 5330
ISBN 963 371 620 9

ABSTRACT

The preparation is described of CdSe-Sb₂Se₃ heterojunctions and details are given of measurements on their photoelectric properties. Both amorphous and polycrystalline CdSe layers were investigated and the problems of their different sensitivities are contrasted. The possible application of these heterojunctions as photodiodes or solar cells is considered.

АННОТАЦИЯ

В данной работе описаны подготовка и фотоэлектрические свойства CdSe-Sb₂Se₃ гетеропереходов. Как аморфные так и поликристаллические CdSe пленки были изучены и проблемы различной фоточувствительности были показаны. Возможность применения этих гетеропереходов с целью фотодиодов или солнечных батарей была выдвинута.

KIVONAT

Jelen cikk a CdSe-Sb₂Se₃ heteroátmenetek előállítását és fotoelektromos tulajdonságainak mérését írja le. Mind az amorf, mind a polikristályos CdSe réteggel készült minták vizsgálatra kerültek összehasonlítva különböző érzékenységüket. A cikk utal arra, hogy napelem célokra való esetleges felhasználáskor milyen paraméterek további optimalizálása szükséges.

INTRODUCTION

In this paper the photoelectrical properties of CdSe-Sb₂Se₃ heterojunctions are investigated. There is some possibility of using these heterojunctions as electrooptical transformers (especially to obtain electrical energy from the optical radiation of the sun). Recently, the main problem to be considered is the low efficiency resulting from the low conductivity and photoconductivity of these devices.

Some of the electrical properties of the heterojunctions under consideration have already been determined by other authors [1,2,3,4]. Using these p-n junctions as solar cells the most important parameters are: the values of photoconductivity and photocurrent, the ratio between forward and reverse currents in the p-n junction, the value of photovoltage and of course the dependence of photocurrent and photovoltage on the applied wavelength. These parameters are investigated on annealed and non-annealed CdSe-Sb₂Se₃ heterojunctions in this paper.

EXPERIMENTAL

The samples had sandwich-like structure (Fig. 1). The active areas of samples were 3.14 mm² (dots with a diameter of 2 mm). First a transparent In₂O₃ layer was deposited on the silica substrate. Then a CdSe layer was vacuum evaporated to a thickness of 0.8-4 μm. From the measurements the films of about 2.5 μm thickness proved to be the most sensitive.

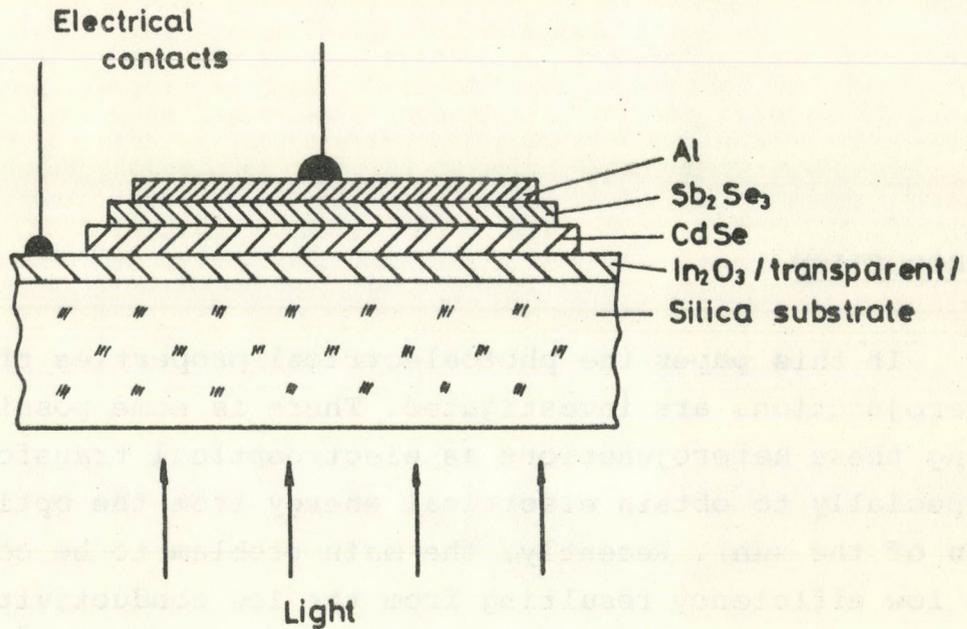


Fig. 1. Structure of samples

After preparation some of the samples were annealed. During the heat treatment, which lasted several hours at a temperature of 400 C, the CdSe layer became polycrystalline. The results of the measurements showed unambiguously that the annealed samples are for more sensitive to light and they have higher conductivity values (for the purpose of solar cells) than the non-annealed ones. Both the annealed and the non-annealed CdSe samples proved to be n-type.

A p-type Sb_2Se_3 layer was then deposited on these CdSe layers. The optimum thickness of this film was 1.8 μm . Finally a 1 μm thick Al layer was vacuum evaporated to form the upper electrode.

The samples were irradiated from the side of the silica substrate, i.e. from the side of the CdSe layers. In some samples the position of CdSe and Sb_2Se_3 layers was inverted, but in this case the photoelectrical properties were poor. This fact indicated

too, that in our experiment the CdSe layer was more photosensitive than the Sb_2Se_3 layer.

RESULTS

During the investigation of the samples with non-annealed CdSe films a space charge layer resulted when we applied a voltage between the two electrodes. This space charge layer was indicated by the hysteresis in the voltage-current curves; the currents at the same voltages were quite different (in some cases the differences reached some orders of magnitude) depending on the sign of the voltage change and the immediate prehistory. The time needed for charge relaxation in some cases reached 30 minutes. After that time the space charge dispersed and the current came to the same value both for increasing and decreasing voltages.

In the case of annealed (polycrystalline) CdSe layers such space charge effects did not occur.

Figure 2 shows the voltage-current characteristics of samples with annealed CdSe layers in the dark state and under light irradiation. The light source was a tungsten filament microscope lamp. The light intensity on the surface of the samples was 390 lux.

From the curves it is obvious that in the dark state a significant difference exists between the forward and reverse currents of the diodes. The rectifying ratio at $U = 2 \text{ V}$ is $I_+/I_- = 1.1 \cdot 10^{-6} \text{ A} / 3.25 \cdot 10^{-9} \text{ A} = 340$, i.e. a difference of 2.5 orders of magnitude. It is well observable too, that in the reverse position the photocurrents at a light intensity of 390 lux significantly differ from the dark current values (at $U = 2 \text{ V}$ the photocurrent is $1.6 \cdot 10^{-7} \text{ A}$ and the dark current is $3.25 \cdot 10^{-9} \text{ A}$). The diode-like behaviour is shown by the reverse dark current following the $I \sim V^{0.8}$ law and simultaneously the

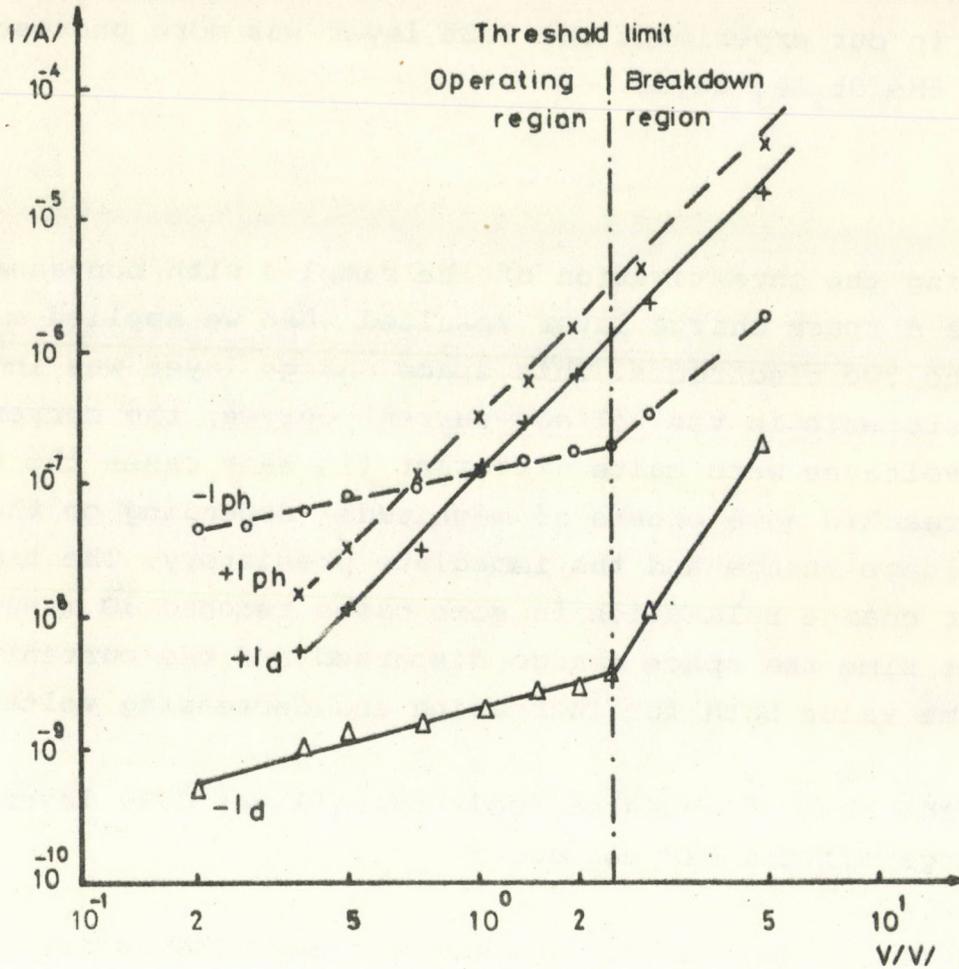


Fig. 2. Current-voltage characteristics in the dark state and under irradiation $-I_d$ = reverse dark current; $+I_d$ = forward dark current; $-I_{ph}$ = reverse photocurrent; $+I_{ph}$ = forward photocurrent (light intensity = 390 lux)

forward dark current obeying the $I \sim V^{3.3}$ law. In the reverse direction above 2.5 V, space charge effects occur both in the dark and in the irradiated case. In the forward position up to 10 V such effects were not observable.

In Fig. 3 the reverse photocurrent versus light intensity is shown at room temperature and at a voltage of 1 V. The photocurrent depends on the light intensity as $I_{photo} \sim F^{0.68}$. The exponent 0.68 refers to a continuous distribution of trap states in the gap of the photosensitive material [5].

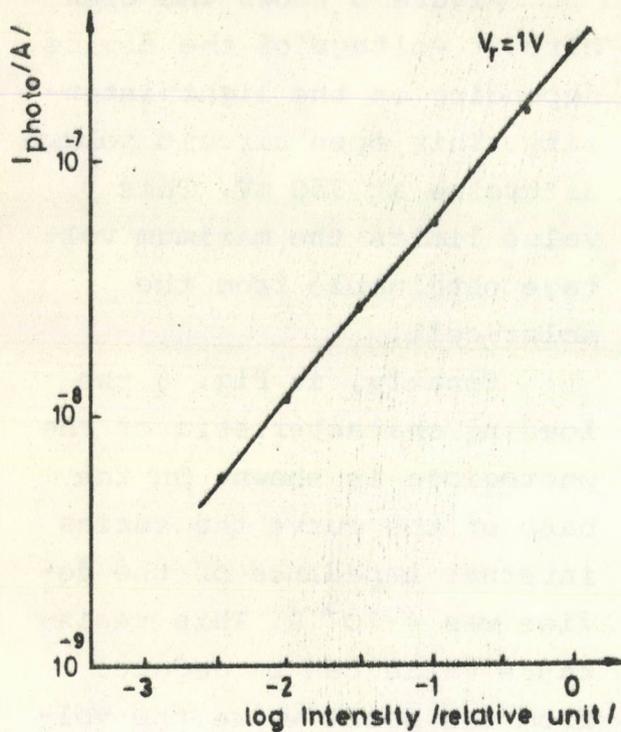


Fig. 3. Photocurrent versus light intensity ($V_{\text{reverse}} = 1 V$; $\log \text{intensity } 0 \equiv 390 \text{ lux}$)

The photocurrent vs light wavelength curve in Fig. 4 shows a maximum sensitivity sharply decreases; at shorter wavelengths the decrease is slow. The decrease at shorter wavelengths is probably due to the high density of recombination centres in the CdSe layer: this means that the electron-hole pairs produced by photons of short wavelengths (near the surface of the CdSe layer and far from the p-n junction) recombine before reaching the junction and so cannot produce a current in the external circuit [6].

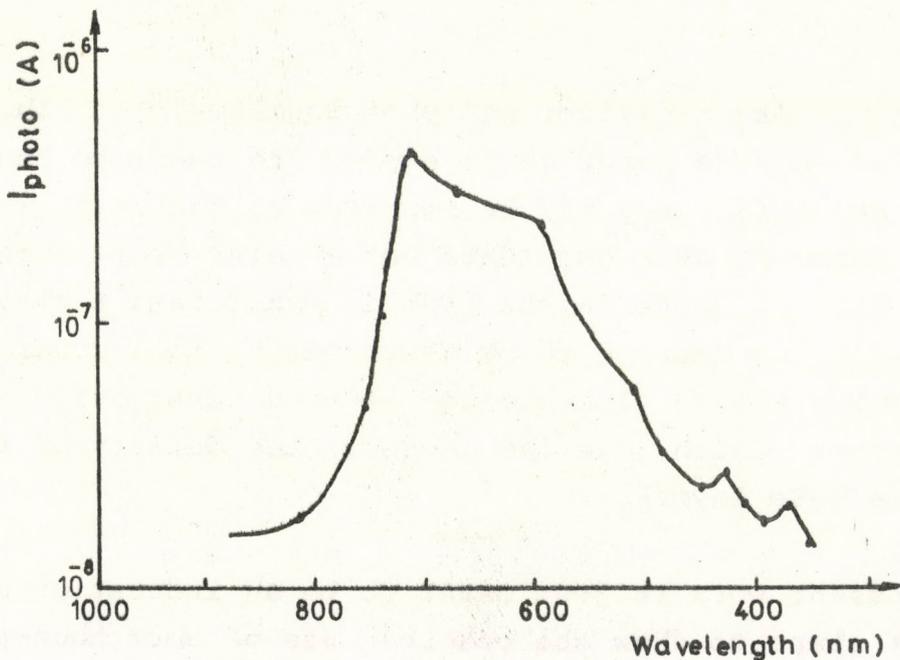


Fig. 4. Photocurrent-wavelength characteristic ($V_{\text{reverse}} = 1 V$)

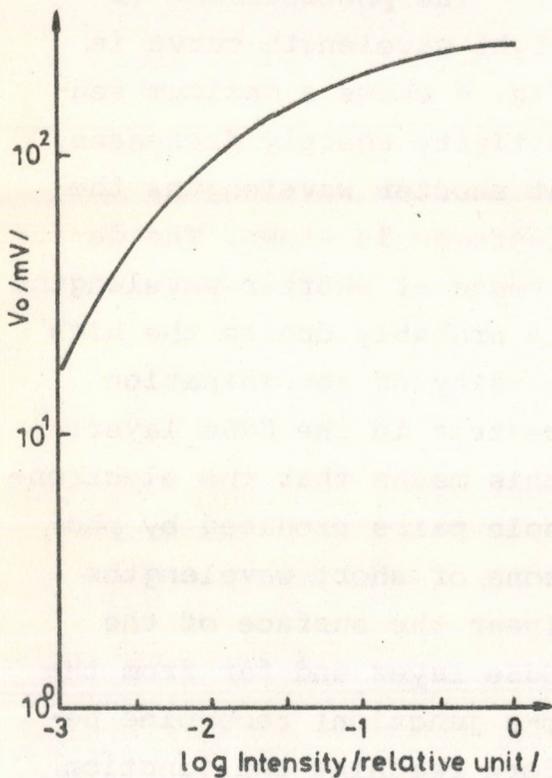


Fig. 5. Dependence of open-circuit voltage on light intensity (log intensity 0 = 390 lux)

Figure 5 shows the open circuit voltage of the device depending on the light intensity. This open circuit voltage saturates at 350 mV. This value limits the maximum voltage obtainable from the solar cell.

Finally, in Fig. 6 the loading characteristic of the photodiode is shown. On the base of the curve the series internal impedance of the device was $4 \cdot 10^5 \Omega$. This resistance value can be deduced from the point where the voltage due to the load drops to half of the open circuit value.

CONCLUSIONS

The diode-like behaviour and photosensitivity of the device described in this paper lends support to the hope that its sensitivity and efficiency may be improved to the point where it could be regarded as a candidate for a solar cell. More research is needed to decrease the high internal resistivity of the device (i.e. to improve the conductivity), to increase the photosensitivity and to eliminate the reduced sensitivity in the short wavelength region (i.e. to decrease the density of trap states in the CdSe layer).

The present work is just meant to be an indication of one of the first steps to show the possible use of amorphous-poly-

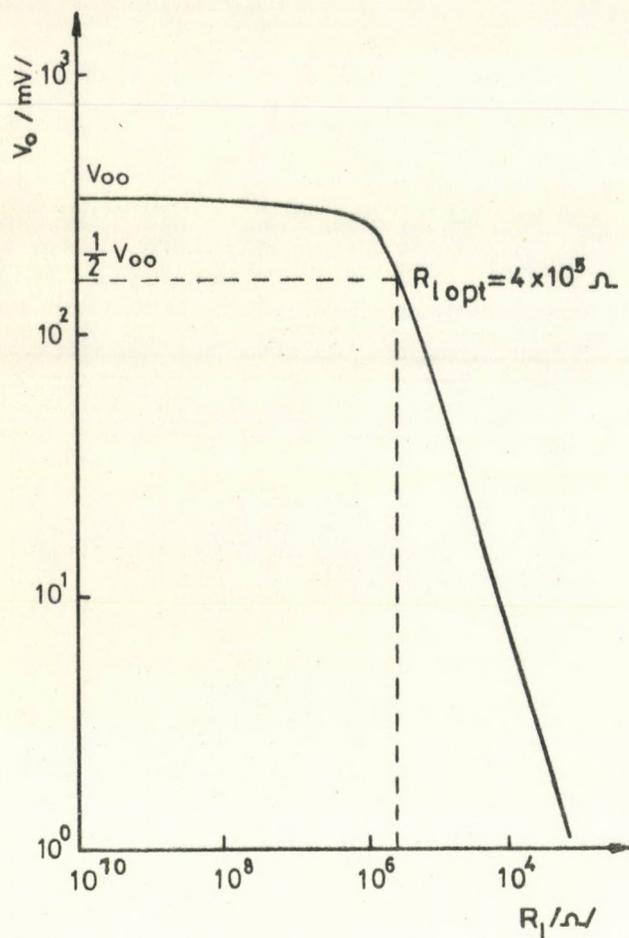


Fig. 6. Loading characteristic (light intensity = 390 lux)

crystalline junctions and/or heterojunctions for the purpose of photodiodes and solar cells.

ACKNOWLEDGEMENT

The author is indebted to Prof. B.T.Kolomiets, Dr. V.M.Lyubin and Dr. M.A. Tagirdzhanov for the provision of samples and for the opportunity to carry out these measurements in the A.F.Ioffe Physical-Technical Institute, Leningrad, USSR.

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STUDYING PROBLEMS

1. Read the problem carefully.

2. Understand what is given and what is to be proved.

3. Think about the conditions of the problem.

4. Try to find a way to solve the problem.

5. Write down the solution.

6. Check your solution.

7. Think about other ways to solve the problem.

8. Write down the final answer.

9. Review the solution.



Figure 1. A trapezoid with height h .

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Kiadja a Központi Fizikai Kutató Intézet
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Nyelvi lektor: Harvey Shenker
Példányszám: 240 Törzsszám: 80-10
Készült a KFKI sokszorosító üzemében
Budapest, 1980. január hó