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STUDY OF CATHODE-ANODE SPRAYING IN A GAS DISCHARGE LIGHT-SENSITIVE SYSTEM BASED ON CdTe-SnO_2

Sharifa B. Utamuradova[1], Kakhramon M. Fayzullaev[1], Bunyodbek Z. Khaydarov[2]
[1]Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan named after Mirzo Ulugbek, 100057, Yangi Almazar St., 20, Tashkent, Uzbekistan
[2]Fergana State Technical University, Uzbekistan
**Corresponding Author e-mail: qahramonfayzullayev8@gmail.com*
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This paper investigates the physical phenomena occurring in a gas discharge photosensitive system that uses cathode-anode sputtering. This system consists of a single-crystal cadmium telluride and a glass plate coated with SnO_2, separated by a gas gap. The thickness of the gas gap is 100 µm. The materials under study are sputtered onto the glass plate's surface in a vacuum chamber. Changes in the optical density of bismuth, tellurium, aluminum, and tin under the action of gas discharge are examined. It has been demonstrated that decreasing bismuth thickness results in a sharp increase in the 'current' sensitivity of the gas discharge cell, reaching a value of $q_m = 10^{-4}$ C/cm^2 at an optical density of $D = 0.5$.
Keywords: *Gas discharge photosensitive system; Cadmium telluride photodetector; Sputtered metal layers; Cathode-anode sputtering; Optical density*
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INTRODUCTION

Ultra-thin (4–10 mm thick) gas discharge light-sensitive systems based on various semiconductors and dielectrics in combination with other elements are currently attracting the attention of many researchers [1–9]. These systems consist of a photodetector (photocathode), a counter electrode (anode) and a gas gap. When the electric field strength between the semiconductor photocathode and the counter electrode is sufficiently high, the gas gap breaks down and the photodetector controls the current density. The uniformity of the glow and the intensity of the discharge across the cross-sectional area of the gas gap depend on the thickness of the gas gap, the gas pressure and the specific resistance of the photosensitive semiconductor.

Experimental results in [10] showed that only an ideal isotropic semiconductor with a specific resistance greater than 10^7 Ω·cm can produce uniform gas discharge luminescence with a gas gap thickness between 10 and 100 µm. The upper limit of the semiconductor's specific resistance has not yet been determined.

In [11], the properties of gas discharge in a photosensitive system with a gas gap thickness greater than 100 µm were studied. The gas gap thickness was d = 0.3÷1.5 mm and the gas pressure were p = 100÷400 Torr. The spatial state of the discharge was achieved using semi-insulating gallium arsenide at room temperature and below. Under these conditions, unstable dissipative structures of various shapes were observed in the gas discharge.

In [12], the properties of the gas gap were studied in various configurations: The semiconductor was in a normal state (i.e., the input surface had translucent ohmic contact and the inner surface facing the discharge had a smooth, polished appearance); a thin layer of nickel was applied to the inner surface of the semiconductor; and point layers of nickel in the form of a raster were applied to the inner surface of the semiconductor. The authors found that only variant 1 result in uniform luminescence across the screen area. In option 2, a single bright gas discharge cord is observed. In variant 3, gas discharge luminescence is observed in the form of cords at the site of the dotted nickel layer.

Despite considerable research, the physical mechanisms of processes in gas discharge photosensitive systems remain unclear. Therefore, it is advisable to study the physical phenomena in such a system with regard to cathode-anode spraying of recording medium materials onto a counter electrode. This is the subject of the present study.

EXPERIMENTAL METHODOLOGY

This work uses a gas discharge photosensitive system based on CdTe-SnO_2, the basic electrical connection diagram of which to the current source is shown in Fig. 1. Research into the physical properties of the gas discharge photosensitive system was carried out in an ionization chamber [13]. A Helios 44-2 lens projects visible light through an optical wedge (1) onto the receiving surface of a 2 mm thick, 30 mm diameter semiconductor plate (2). In this study, single-crystal, semi-insulating cadmium telluride (CdTe) with a specific resistance of $6\cdot10^7$ Ω·cm at room temperature and in the absence of illumination was employed as a photocathode. In the figure, a nickel translucent contact was applied to the CdTe receiving surface in a VUP-5M vacuum post. The optical wedge was made by spraying a nickel layer with different optical densities onto a 25 mm diameter mica plate. Fig. 1 shows the installation of the optical wedge on the surface of the CdTe photodetector.

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A standardized glass plate measuring 24×36×3 mm and coated with a transparent conductive SnO_2 layer (5) was used as the counterelectrode in the gas-discharge photosensitive system. The material under investigation (the current-recording film) was applied to the front surface of the glass plate (i.e., the gas discharge side). The optical density of the optical wedge and the current-recording film after exposure to charged particles from the gas discharge was measured using a CP-25M densitometer with computer software. A plate made of dielectric material (100 μm thick mica) with a 25 mm diameter round cutout in the center (3) was used to form the gas gap. Electrical contact to the glass plate (5) was made by a pressure electrode with a round cut-out in the center, having a diameter of 25 mm. The pressure electrode was made of Textolite with a single layer of metal foil.

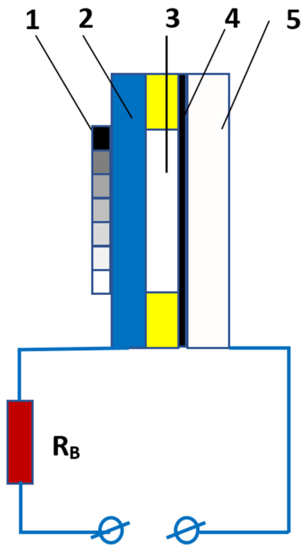

Figure 1. Basic electrical circuit diagram of connecting a gas-discharge cell to a current source:
1 – optical wedge, 2 – photoelectrode (cathode), 3 – gas-discharge gap, 4 – current-registering film, 5 – anode (glass) with conductive coatings made of SnO_2, R_B – ballast resistance.

The photodetector was illuminated by an OI-24 type light source. To measure the illumination intensity, a silicon photodiode of the FD-17K type was installed in place of the semiconductor photosensitive plate. The ionization chamber was sealed by screwing the rear cover through a vacuum rubber gasket. The residual air pressure in the working volume of the ionization chamber was adjusted using a four-vacuum pump. The residual air pressure in the ionization chamber was kept constant at p = 200 Tor. The gas discharge photosensitive system was powered by a high-voltage unit that we developed based on a TVS-P1 transformer, specifically for these studies. The unit is equipped with a time relay that provides electrical exposure times in the following ranges: 0.1÷1 s at 0.1-second intervals and 1÷10 s at 1-second intervals. The power supply unit provided a DC voltage of up to 3 kV and a maximum current of up to 10 mA.

The following calculation of the optical wedge was performed. The quantities measured in the experiment were the dark current (I_d), the total current under illumination ($I_f = I_d + I_{ph}$), the total light intensity (J_f) and the applied voltage (U). It is necessary to find the dark current density (J_d) and the photocurrent density (J_{ph}) in each separate field of the wedge. The optical densities of each wedge field (D_i) and the areas of these fields (S_i) were measured in advance.

The ratio of the light intensity passing through each wedge field (J_i) to the total light intensity (J_f) was denoted by η_i, where

$$\eta_i = \frac{J_i}{J_f} = 10^{-D_i}. \tag{1}$$

In a gas discharge cell, the current density of each wedge field (j_i) is proportional to the light intensity of each wedge field (J_i), and the total current density (j_f) is proportional to the total light intensity (J_f)

$$j_i = aJ_i,\ j_f = aJ_f, \tag{2}$$

where a is the proportionality coefficient. Using equations (1) and (2), we can write

$$\eta_i = \frac{J_i}{J_f} = \frac{j_i}{j_f}, \tag{3}$$

from which it follows that

$$j_i = j_f \eta_i. \tag{4}$$

The total photocurrent I_{ph} consists of the photocurrents of individual wedge fields I_i:

$$I_{ph} = \sum_{i=1}^{n} I_i, \quad (5)$$

where

$$I_i = j_i S_i. \quad (6)$$

Using formulas (4) and (6), we can rewrite formula (5) as

$$I_{ph} = j_f \sum_{i=1}^{n} \eta_i S_i. \quad (7)$$

It is known that $I_{ph} = I_f - I_d$, so using (7), we can find the value of

$$j_f = (I_f - I_d)/(\sum_{i=1}^{n} \eta_i S_i). \quad (8)$$

Using formulas (4) and (8), we can find the current density of each wedge field:

$$j_i = \eta_i (I_f - I_d)/(\sum_{i=1}^{n} \eta_i S_{i)}. \quad (9)$$

Using formula (9), we can calculate the amount of electricity corresponding to each wedge field q_i that reaches the material under investigation:

$$q_i = j_i S_i \Delta t = \eta_i S_i \Delta t (I_f - I_d)/(\sum_{i=1}^{n} \eta_i S_i). \quad (10)$$

After measuring the optical density of each wedge field (D_i), we calculate the value of (η_i) using formula (1). The values of the total If and dark Id currents are measured experimentally. Therefore, in order to construct the sensitometry characteristics of a gas discharge photosensitive system, there is no need to measure the total light intensity J_f or the light intensity for each wedge field J_i. Furthermore, it is impossible to measure the photocurrent I_{ph} experimentally, so this procedure is also eliminated.

The table shows the results of calculations based on optical wedge parameters:

No. wedge stripes	D	S_i	η_i	$\eta_i S_i$	$\sum_{i=1}^{n} \eta_i S_i$
1	0	0,18	1,00	0,18	0,55
2	0,10	0,20	0,83	0,166	
3	0,30	0,20	0,50	0,100	
4	0,53	0,20	0,30	0,06	
5	0,85	0,20	0,14	0,028	
6	1,28	0,20	0,052	0,0104	
7	1,6	0,20	0,025	0,005	

Figure 2 shows the resulting pattern of changes in optical density in the metal layers on the counter electrode's surface. The optical wedge installed on the input surface of the photocathode is shaped in the same way. The optical density of each wedge field (D_i) is proportional to the illumination intensity (J_i), the current density (J_i) and the amount of electricity (q_i) arriving at each wedge field (calculated using formula (10)).

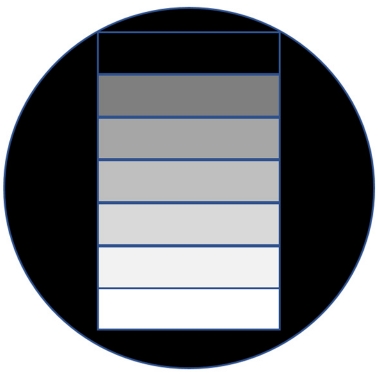

Figure 2. Picture of changes in the optical density of metal layers on the surface of the counter electrode

EXPERIMENTAL RESULTS

In a gas discharge photosensitive system, the material under study is subjected to a positive potential. Under these conditions, negatively charged gas discharge particles act on its surface. In this study, sputtered films of bismuth, tellurium and aluminum were used. Figure 3 shows the dependence of optical density on "current exposure" – $D(q_m)$ for the Bi, Te and Al materials. As can be seen from the obtained results, "current exposure q_m" correlates well with the cathode sputtering coefficient [14].

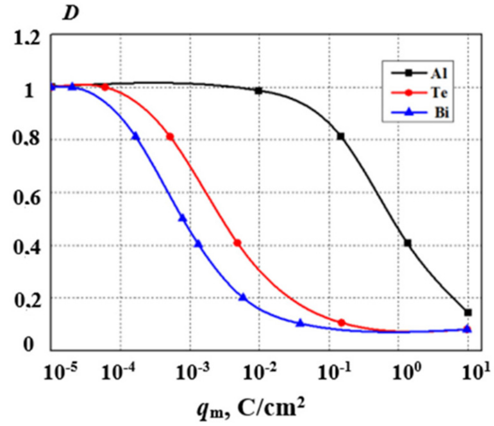

Figure 3. Dependence of the change in optical density *D* on the amount of electricity *q* for Bi, Te and Al films. The initial optical density of the film is 1.

Figure 4 shows the dependence of "current sensitivity (q_m)" on the initial thickness of the bismuth layer, as determined by a 5% change in transparency from the initial optical density.

Figure 5 shows the $D(q_m)$ characteristics of two tin (Sn) layers deposited by vacuum evaporation on a glass surface with a conductive tin dioxide (SnO_2) coating, with different initial optical densities (D_1 = 0.45 and D_2 = 0.9). When the 'exposed' layers were developed in a weak sulfuric acid solution (0.5% concentration), the Sn layer was slowly and evenly etched away. Current-registering tin layers produce unusual changes in optical density; in areas where plasma was applied, the solubility of the film in a weak sulfuric acid solution decrease compared to other areas.

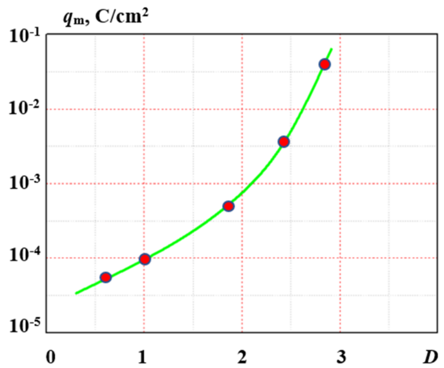

Figure 4. Dependence of the minimum amount of electricity on the initial optical density of the bismuth layer

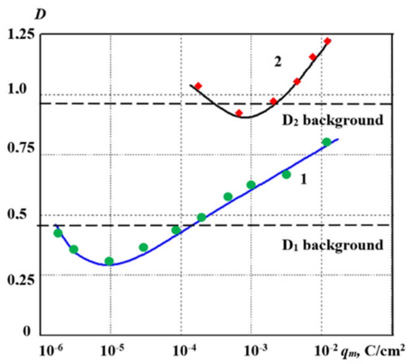

Figure 5. Dependence of optical density *D* on the amount of electricity *q* (on the "current" exposure) for Sn films with different initial optical density

DISCUSSION OF RESULTS AND CONCLUSIONS

The study of the effect of charged gas discharge particles on thin layers of bismuth, tellurium and aluminum revealed no new physical phenomena when these materials were sprayed under the action of charged discharge particles.

The dependencies studied showed that the sensitivity of bismuth layers to the Coulomb effect decreases with decreasing initial optical density (and therefore decreasing metal layer thickness). With decreasing bismuth layer thickness, the 'current' sensitivity in the gas discharge cell increases sharply, reaching $q_m = 10^{-4}$ C/cm^2 at an optical density of $D = 0.5$.

Sn current-registering films undergo negative transformation under the action of gas discharge and subsequent acid etching. Negative transformation occurs at an initial optical density of $D = 0.9$ at 10^{-3} C/cm^2 and at an initial optical density of $D = 0.45$ at 10^{-5} C/cm². At high initial optical densities ($D > 1$), negative transformation with high optical density ($D = 1–2$) can apparently be observed with virtually no background (zero optical density). This property of plasma-sensitive material based on Sn films could be used in a number of photo technical processes. The Al and Sn layers on the anode of the gas discharge cell are the most resistant to the action of gas discharge plasma (q_m greater than 0.1 C/cm^2).

Studies investigating changes in the optical density of metal layers on the surface of the counter electrode of a CdTe-SnO_2-based gas discharge photosensitive system under the influence of a gas discharge expand our understanding of the physical processes occurring in the latter.

ORCID

Sharifa B. Utamuradova, https://orcid.org/0000-0002-1718-1122
Kakhramon M. Fayzullaev, https://orcid.org/0000-0001-7362-1439
Bunyodbek Z. Khaydarov, https://orcid.org/0009-0008-2652-4220

REFERENCES

[1] P.R. Blaszuk, US Patent 3-743-881 (1973).
[2] L.G. Paritskii, and Sh.S. Kasymov, USSR Patents 19460/18-10 and 197820/18-10 (1973).
[3] G. Gottardi, and E. Galli, Natural Zeolites (Springer, Berlin, 1985).
[4] C. Jovalekic, M. Pavlovic, P. Osmokrovic, and M. Zdujic, IEEE Trans. Electr. Insul. **2**, 409 (1995). https://doi.org/10.1109/94.395429
[5] I. Tiscornia, S. Irusta, P. Pradanos, C. Teller, I. Coronos, and J. Santamaria, J. Phys. Chem. C, **111**, 4702 (2007). https://doi.org/10.1021/jp070044v
[6] Zh. Ji, M.N. Ismail, D.M. Callahan, E. Pandowo, Z. Cai, T.L. Coordrich, K.S. Ziemer, *et al*., Appl. Catal. B: Environ. **102**, 323 (2011). https://doi.org/10.1016/j.apcatb.2010.12.021
[7] Q. Xiong, Z. Yang, and P.J. Bruggeman, J. Phys. D, 48, 424008 (2015). https://doi.org/10.1088/0022-3727/48/42/424008
[8] B.G. Salamov and H. Hilal Kurt, JOM, Vol. 72, No. 2, 644 (2020) https://doi.org/10.1007/s11837-019-03955-1
[9] Sh.B Utamuradova, Z. Khaydarov, and B.Z. Khaydarov, UNEC Journal of Engineering and Applied Sciences, **4**(2), 55 (2024) https://doi.org/10.61640/ujeas.2024.1206
[10] L.G. Paritskii, Z. Khaidarov, O. Mukhamadiev, and O. Dadabaev, Phys. Technol. Semicond. **27**(11-12), 2020 (1993).
[11] Yu.A. Astrov, A.N. Lodygin, L.M. Portsel, and E.V. Beregulin, Phys. Rev. E, **95**, 043206-7 (2017). https://doi.org/10.1103/PhysRevE.95.043206
[12] N.N. Lebedeva, V.I. Orbukh, and B.G. Salamov, J. Phys. III 6, 797 (1996). https://doi.org/10.1051/jp3:1996155
[13] Z. Khaydarov, K.Z. Khaydarova, and Kh.T. Yuldashev, Applied Physics, Russia, (1), 65 (2017).
[14] A.N. Gorlyak, I.A. Khramsovsky, and V.M Solonukha, Scientific and Technical Bulletin of Information Technologies, Mechanics of Optics, **15**(3), 378 (2015). https://doi.org/10.17586/2226-1494-2015-15-3-378-386

ДОСЛІДЖЕННЯ КАТОДНО-АНОДНОГО РОЗПИЛЕННЯ В ГАЗОРОЗРІДНІЙ СВІТЛОЧУТЛИВІЙ СИСТЕМІ НА ОСНОВІ $CdTe-SnO_2$

Шаріфа Б. Утамурадова[1], Кахрамон М. Файзуллаєв[1], Буньодбек З. Хайдаров[2]
[1]Інститут фізики напівпровідників та мікроелектроніки Національного університету Узбекистану імені Мірзо Улугбека, 100057, вул. Янги Алмазара, 20, Ташкент, Узбекистан
[2]Ферганський державний технічний університет, Узбекистан

У цій статті досліджуються фізичні явища, що відбуваються в газорозрядній фоточутливій системі, яка використовує катодно-анодне розпилення. Ця система складається з монокристалічного телуриду кадмію та скляної пластини, покритої SnO_2, розділених газовим зазором. Товщина газового проміжку становить 100 мкм. Досліджувані матеріали напиляються на поверхню скляної пластини у вакуумній камері. Досліджуються зміни оптичної густини вісмуту, телуру, алюмінію та олова під дією газового розряду. Було показано, що зменшення товщини вісмуту призводить до різкого збільшення «струмової» чутливості газорозрядної комірки, досягаючи значення $q_m = 10^{-4}$ Кл/см² при оптичній густині D = 0,5.
Ключові слова: *газорозрядна фоточутлива система; фотодетектор на основі телуриду кадмію; напилені металеві шари; катодно-анодне розпилення; оптична густина*