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Electrical and Optical Properties of Thin-Film Wide-Gap Metal Oxides Sno $_2$, In $_2$ O $_3$, Ito , Cdo , Moo $_3$

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ANNOTATION: The electrical properties of the created doped and undoped wide-gap layers of metal oxides SnO $_2$, In $_2$ O $_3$, ITO , CdO , MoO $_3$ were studied. Depending on technological factors. The optimal growth conditions for these semiconductor materials have been determined. The study of the electro physical and optical properties of the resulting oxide films confirmed the stability of the operational parameters of oxide materials SnO $_2$, In $_2$ O $_3$, ITO , CdO , MoO $_3$. The AFM method showed, along with the oxides SnO $_2$, In $_2$ O $_3$, ITO , CdO , the oxide of pure MoO_3 has The highest transmittance is in the visible region of the spectrum , where the absorption edge shifts toward higher wavelengths.

KEYWORDS: Metal oxide, spectrum, transmission, mobility, wide-gap semiconductors, doping.

INTRODUCTION

Remarkable classes of compounds of transparent conducting metal oxides of indium, tin and zinc, molybdenum form an n-type semiconductor. These materials provide a rare combination of high electrical conductivity with optical transparency in the visible wavelength region of the solar spectrum. The position of the conduction band of such oxides E_c is favorable for easy electron transport.

Transparent conductive oxides have a high optical transmittance and at the same time high electrical conductivity. They have been intensively studied for use in devices that require electrical contact and optical access, such as flat panel displays (FPDs), light emitting diodes (LEDs), photovoltaic cells. The most commonly used TCO material is indium oxide doped with tin. It has n-type conductivity with a band gap between 3.5 and 4.3 eV depending on the doping concentration and the maximum charge carrier concentration of the order of 10 cm- ^{3} [1,2,7].

Oxides are transparent in the visible range and near-infrared light, have low electrical conductivity, high brightness transmittance, high infrared emissivity, good electrical conductivity, excellent adhesion to the substrate, solid and chemical inertness. The band gap E_g, depending on the deposition parameters, ranges from 2.75 to 3.75 eV, with transparency from the visible to near-infrared range, ≥80%.The purpose of this work is to develop a technology for producing oxide materials of various types with a mobility of more than μ≈100 cm ^{2} / V. Multi component metal oxides have properties suitable for use in microelectronics and solar cell cells [3, 8].

METHODOLOGY AND EXPERIMENT

Structure of SnO_2 Tin oxide SnO_2 is characterized by high chemical and mechanical strength, high abundance and low raw material and processing costs. Prolifically deposited tin oxide SnO $_2$ doped with fluorine F is used for low dielectric constant coatings, which constitutes the largest application of deposited optically transparent electrically conductive oxides transparent

conductive oxides - TCO. Tin oxide is also used as a catalyst, either alone or on a metal support, and is a key material in solid-state gas sensors. The thickness d and resistance R of the films depend on the substrate temperature T_p, deposition time T , and vapor pressure P of the initial tin layers. SnO_2 films 600 thick $\overset{0}{A}$ had a maximum transmittance equal to 80%; such films were obtained at a substrate temperature of 450 ^{0}C for 6 minutes. C film resistance SnO_2 obtained by pyrolysis method depends mainly on the thickness of the SnO_2 layer.

Below in Table.1 the electrophysical characteristics of films obtained by spraying at various temperatures are presented. As can be seen from the table, the electrical characteristics of the films improve significantly as the deposition temperature increases and the minimum resistivity value is obtained at T = 350 $^{o.}$

In Table.1 the dependence of the layer resistance on the thickness of SnO_2 films is shown at different contents of the Sb dopant. As can be seen from Table .1 the lowest resistance at small thicknesses of SnO_2 with a content of $SbCl_3$ ~ 6% in the source material. At thicknesses of 0.4 ÷ 0.8 μm, the resistance slightly depends on the antimony content Sb, transmission increases to the highest value equal to 88%, while the thickness of the SnO_2 layer is ~ 0.5 ÷ 0.7 μm

Table 1: Electrophysical parameters of SnO_2 films

Deposition temperature , C ^{0}	Carrier concentration N , cm $^{-3}$	Mobility μ -, cm $^{-3}$/V sec.	ρ , Ohm, cm	Content $SbCl_3$, mol , %
220	3.4.10	2.4	7.6.10 $^{-2}$	6
240	2.4.10	6.2	3.6.10 $^{-2}$	6
260	1,2.10	14	3.7.14 $^{-3}$	6
280	4. 10 ^{20}	23.5	6.6. 10 $^{-4}$	6
300	3.4. 10	26	7.1. 10 $^{-4}$	6
350	4.2. 10	27.3	5.4. 10 $^{-4}$	6

It turned out that the transmittance of SnO_2 layers obtained by spraying is higher (88%) than those obtained by pyrolysis (80%). The maximum concentration of tin in the In + Sn alloy was determined to be 6%.

Compounds based on indium, cadmium and tin oxides have been studied and used, which is primarily due to their electrical characteristics (Table.2). All these oxides have an electronic type of conductivity and their electrical properties strongly depend on the degree of oxidation (oxygen stoichiometry). The electrical resistivity, depending on the synthesis conditions, lies in the range of 10 $^{-2}$ ÷2 10 ^{4} Ohm cm for indium oxide films In_2O_3, 10 ^{2} ÷ 10 $^{-3}$ Ohm·cm for cadmium oxide C d O and 10 $^{-1}$ ÷ 4·10 $^{-4}$ Ohm·cm for tin dioxide SnO_2 .

Under certain production conditions, thin-film wide-gap semiconductors are direct-gap and degenerate with $E_g > 3$ eV. The main reason for the high conductivity of wide-gap semiconductors is their deviation from stoichiometry [4,3].

Table 2: Electrical characteristics of oxide semiconductors[3]

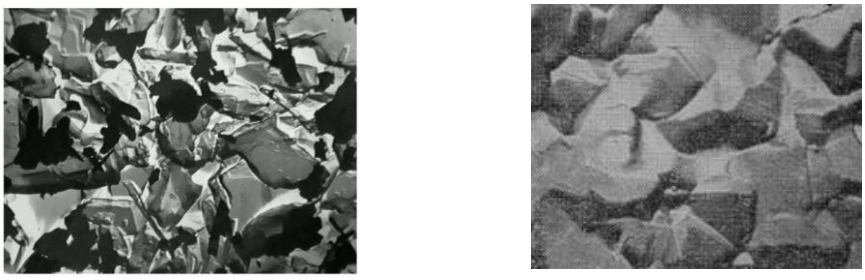
Material	Band gap E_g at 300 K , eV	Conductivity, σ , Ohm/cm $^{-1}$	Electron concentration, N, cm $^{-3}$	Mobility, μ,cm^2/V cm	Lattice parameters, nm
In_2O_3	2.7 ÷3.75	10000	>10 ^{21}	35	a: 1.01 8
CdO	3.3 ÷3.75	8000	>10 ^{21}	20	a:0.32 8 c: 0.52 16
SnO_2	3.6	5000	>10 ^{20}	15	a: 0.47 9 c: 0.3 2

The studies carried out show that with increasing discharge power the deposition rate increases, however, the oxygen pressure in the working volume of the reactor leads to a decrease in the deposition rate. When oxygen makes up 75% of the working volume, the deposition rate is 6 $\overset{0}{A}$ /sec with a specific power of 12 W/cm^2 , which is almost 14 times less than in the

absence of oxygen. The presence of oxygen in TeO_2 system leads to oxidation of the target, as a result of which the evaporation of compounds decreases, and the deposition rate also decreases.

The optimal target-substrate distance d when depositing In_2O_3 and ITO layers is d = 60 mm. In this case, the deposition rate was equal to Voc = 42 A °/sec, discharge power M = 9 W/cm ^{2}

MoO_3 Films MoO_3 thin films have attracted much attention due to their interesting structural, chemical, electrical and optical properties [2 5, 6,]. MoO_3. The layers have found widespread use in batteries and electro chromic devices, solar cells, gas sensors, optoelectronic devices. Due to its wide band gap E_g, MoO_3 oxide is capable of absorbing only the short-wavelength part of the solar spectrum, which limits it photovoltaic and photoelectrochemical applications [9]. Along with these oxides, molybdenum oxide MoO_3 also has a wide band gap from 2.8 to 3.2 eV. Molybdenum foil Mo is pre-oxidized in nitric acid HNO_3, then the oxide is removed in hydrofluoric acid HF , followed by washing in distilled water. In addition, the substrate is subjected to gas etching for 30 minutes in a gas deposition reactor chamber at a temperature higher than the deposition temperature in a hydrogen flow H_2. The source temperature T and substrate T_p varied in the range 850÷900 C ^{0} and the cooling rate in the cooling rate range 10 $^{-5}$ deg/min. Structural analysis of the "Mo- MoO_3 substrate" interface was carried out using the X-ray method using a MIM-7 microscope and a Kameka -type micro analyzer. In MoO_3 films, an amorphous structure with a columnar shape is clearly visible (Fig.2)



(a) (в)

Fig.2. Mo foil film without surface treatment; increased (Magnification: 1500) (a); film of MoO_3 oxide on the surface of the Mo substrate (в) (Magnification: 3500).

DISCUSSION

MoO_3 thin films. The decomposition results showed that the sum Mo + 5 in the film was only 3% of the total Mo 3d peak, which indicates that the film is predominantly in the oxidation state Mo +6, i.e. stoichiometric . The AFM method for films of pure MoO_3 showed the highest transmittance is in the visible region of the spectrum, where the absorption edge shifts towards higher wavelengths. The absorption coefficient (α) of the resulting films was determined from the values of the transmission spectrum (T) using the relation

$$T = \exp -\alpha d \qquad (1)$$

Where d is the film thickness. CdTe is a high-absorbency material that has a high optical absorption coefficient (~10 ^{5} cm $^{-1}$) in the visible region of the solar spectrum [6,10] . These results indicate possible applications MoO_3 films with a CdTe compound for efficient light absorption in solar cells. This process in our case occurs in a single technological cycle during the formation of MoO_3 oxide films on a Mo substrate. The mobility values of MoO_3 oxide carriers on Mo are determined depending on temperature (Fig. 3)

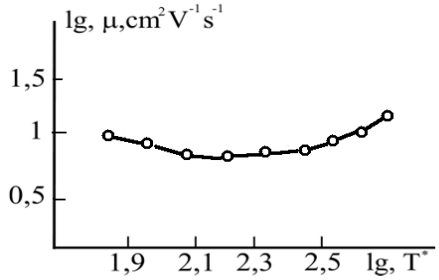


Fig 3. Dependence of film mobility μ MoO3 from temperature logT °

The spectral dependences of the transmittance R on the wavelength λ of MoO_3 oxide films were studied at the substrate temperature T = 550 ° C and at the substrate temperature T = 650 ° C (Fig. 4) .

Fig. 4. of the transmittance R on the wavelength λ of MoO_3 films at a temperature T = 650 C ° has a large transmittance R.

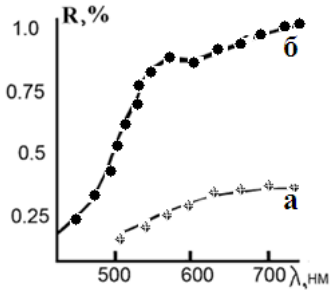


Fig.4. Spectral dependences of the transmittance R on the wavelength λ of MoO_3 films at a temperature T = 550C ° (a) at a temperature T = 650C ° (b).

CONCLUSION

The electrical properties of the created doped and undoped wide-gap layers of metal oxides SnO_2, In_2O_3, ITO , CdO , MoO_3 were studies depending on technological factors. The optimal growth conditions for these semiconductor materials have been determined. Shown are the resulting layers of In_2O_3 and ITO with parameters μ = 36 cm^2/V.s, N = 10^{21} cm^{-3}, ρ = 6.10^{-4} Ohm. cm(ITO); μ = 25 cm^2/V.s, N = 10^{20} cm^{-3}, ρ = 2.10^{-3} Ohm. cm (In_2O_3) have a transparency of ≥88%. The electrophysical and optical properties of SnO_2 layers obtained by pyrolysis and spraying were studied. The possibility of obtaining SnO_2 layers uniform in thickness and area with low resistivity ρ = $5.4.10^{-4}$ Ohm has been revealed. S m μ = 27 cm^2/V.s, N = 4.10^{20} cm^{-3}. Obtained transparent wide-gap semiconductor metal oxides SnO_2, In_2O_3, ITO, CdO , MoO_3 create great opportunities for using them in the creation of diode transistor structures for wide use in microelectronics and solar energy.

REFERENCES

1) Muzafarova S. A. Surface states of n ITO-pCdTe structures based on polycrystalline films pCdTe. // Science and education scientific journal, issn 2181-0842. – V. 1. Issue 2 May. – 2020. – P. 57.
2) Sh. B. Utamuradova, S.A Muzafarova. Z.S Kenzhaeva. Study of surface states of in- nITO - pCdTe structures based on large-block polycrystalline films pCdTe IOSR Journal of Applied Physics (IOSR-JAP) Volume 14, Issue 1, and Ser. I (Jan–Feb. 2022), pp. 51-56.
3) Muzafarova S.A. Study of photosensitive PDP structures based on cadmium telluride. // PhD thesis. – 1983. – Tashkent.
4) Sh.B.Utamuradova, S.A. M Uzafarova, A.M. A bdugafurov . And a study of the stability of the operating parameters of SDS photodetectors with the pCdTe-TeO_2-CdO structure and pCdTe-TeO_2-ITO photosensitivity in the spectral region of 0.3-0.4 microns. // Journal l - Electronic Innovation Bulletin No. 6. –2020. – P.7-12.
5) Sh.B.Utamuradova , Muzafarova S.A. Properties of the wide-gap semiconductor compound molybdenum trioxide MoO_3 Bobek international conference. 2023, 26-27 Mayi, pp. 45-47
6) Sh.B.Utamuradova S.A. Muzafarova, Z.M. Khusanov . Photoelectric properties of CdO-pCdTe structure Proceedings of the international conference “Optical and photoelectric phenomena in semiconductor micro- and nanostructures”. Fergana, 2023, Volume 1, pp. 137-138.
7) 7. Kamal C., Chakrabarti A., Ezawa M. // Phys. Rev. B 93, 125428 (2016).
8) 8. Luo W., Xiang H. // Nano Letters < 2015, doi : 10.1021/ acs.nanolett.5b0041.
9) 9.Molina-Mendoza AJ, Lado JI, Island JO, Nino MA, Aballe L., Foerster M., Bruno FY, Lopez-Moreno A., Vaquero- Garzon L., van der Zant HSJ, Rubio-Bollinger G., Agrait N., Perez EM, Fernandez- Rossier J., Castellanos -Gomez A. // Chem. Mater. 2016, 28, 4042-4051, doi : 10.1021/acs.chemmater.6b01505.
10) 10.Johansson M.B., Baldissera G., Valyukh I., Persson C., Arwin H., Niklasson G.A., Osterlund L. // J. Phys.: Condens . Matter 25 (2013) 205502 (11 pp).