ABOUT THE EDGE LUMINESCENCE OF CADMIUM SULPHIDE THIN LAYERS GROWN ON MOLYBDENUM

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SUMMARY

CdS layers on to molybdenum were synthesized from separate elements in an open flowing hydrogen set. The surface micromorphology and some electrical and photoluminescent properties were investigated. The nature of layers edge photoluminescence peaks are discussed in the frames of the excitated exciton model.

1.INTRODUCTION

CdS thin layers were synthesised onto molybdenum from elementary components in the hydrogen flow. The optimum technological conditions for layers deposition were determined. The surface morphology, electrical properties at 300 K and photoluminescence spectra at 77 K were investigated. The luminescence spectra are discussed in the frames of the mechanism of hot photoluminescence with the consideration of a whole spectrum of rotating and oscillating exciton.

2.EXPERIMENTAL

The layers were deposited from separated components in an open hydrogen flow system. Cadmium and sulphur of semiconductor purity were used as sources. Molybdenum foil with the thickness 0,1 mm was used as a substrate. The layers were grown in a horizontal reactor with the separate openings for sources. High quality CdS layers were obtained at $P_{Cd} > P_S$ at $P_S \approx 50...500\ Pa$ at substrate temperatures in the region of 800...1000 K. P_{Cd} and P_S are partial pressure of cadmium saturated vapors and summary pressure of sulphur saturated vapors in the evaporation region. It was established that layers quality enhances, if directly before the beginning of the growing process the vapor-gas etching of the substrates was carried out during 2-3 min at the growth temperature and the H_2S concentration in the hydrogen approximately 0,1 mol.%. More details about the used technology are described in Ref. /1, 2/.

The layers surface morphology was examined by using optical microscope ММР-2Р. Monochromator МДР-23У was used for the investigation of photoluminescence spectra. The photoluminescence excitation was realised by using N_2 -laser ($\lambda = 0.3371\ \mu m$) with the pulse power

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3 kW, at pulse duration 10 ns. The radiation signal was recorded by ФЭУ-51 photomultiplyer conected to standard set of synchronous detecting.

3.RESULTS AND DISCUSSION

The surface micromorphology of the layers obtained in a single experiment but at different growth temperatures is given in Fig.1. The layers are polycrystalline and fine-grained and the growth mechanism is island-like. The grain dimensions are increasing with the growth temperature increase and the structure becomes more perfect. The grains are faceted crystals without any determined orientation to one another. Layers with the thickness up to 50 μm were obtained. The layers electrical parameters vary depending on growth temperature. When the growth temperature increases from 860 to 960 K, the conductivity, mobility and carrier concentration vary in the limits 5,7...0,38 $Ohm^{-1}cm^{-1}$, 30...220 $cm^2/(V \cdot s)$ and $1{,}3.10^{18}...1{,}3.10^{16} cm^{-3}$ respectively.

The photoluminescence spectra are given in Fig.2. CdS layers onto molybdenum are distinguished by wery high intensity of edge recombination radiation, which covers the region 2,30...2,54 eV. The similar results were obtained for CdS layers grown onto silicon by using analogical technology. Six peaks were revealed in the photoluminescence spectra, the origin of which is partialy discussed in Ref. /2/. The predominant radiation in the spectrum corresponds to I_1 (2,54eV) peak, related to the annihilation of the exciton which is thermodissotiated from impurity complex of interstitial cadmium. I_2 (2,52eV) peak was also revealed in the cadmium sulphide spectrum /3/ but its origin was not firmly revealed. I_4 (2,375eV) usualy was attributed to donor-acceptor recombination. The peaks I_5 (2,348eV) and I_6 (2,304eV) are attributed to the radiation in which only longitudinal optical phonons take part. For more clear interpretation of cadmium sulphide layers radiation peaks it is of interest to discuss the photoluminescence spectra by using the single energetical model of two-centred structures /4/. According to this model the whole energetical spectrum of oscillating and rotating exciton is described by the equation:

$$E = E_g - G/n^2 + \hbar\,\omega_{on}(\nu+1/2) + Q_n\,\lambda(\lambda+1)$$

where E_g - band gap value; G - Rydberg constant; n - principal quantum number of exciton spectrum; ν, λ - oscillatory and rotatory quantum numbers; ω_{on} - frequency of exciton oscillations in the state n; Q_n - rotation constant. It was shown in Ref. /4/, that for CdS the energy which corresponds to ω_{01}, ω_{02} and Q_1 are 150, 40 and 9 meV, respectively. By taking into account these results the I_2 peak can be considered as the transition from excited exciton state from the level with n=2 with the emission of energy quantum Q_1 = 9 meV accompanied by LO phonon with the

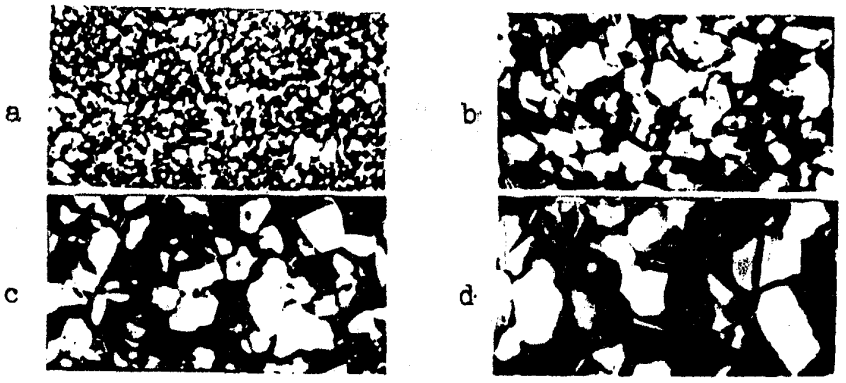


Fig.1.Micromorphology of CdS layers on to molybdenum synthesized from separate elements at different deposition temperatures, K: a - 873; b - 913; c - 933; d - 943. x600.

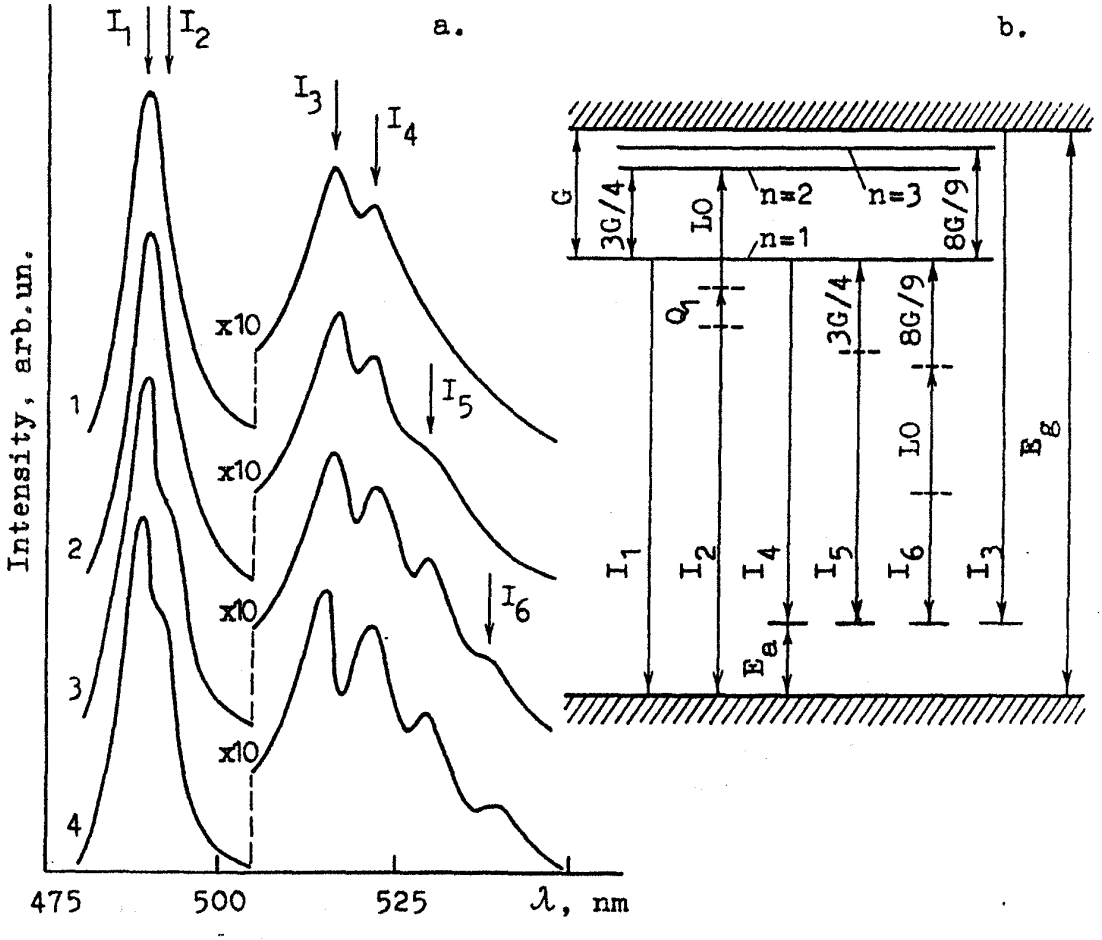


Fig.2. Photoluminescence spectra at 77 K of CdS layers onto molybdenum, obtained at different substrate temperatures, K: 1 - 873; 2 -913; 3 - 933; 4 - 943 (a) and quantum transitions diagram (b), E_g = 2,576eV - CdS band gap; G = 36 meV - exciton binding energy ; n - principal quantum number of the exciton line; LO=38meV - longitudinal optical phonon energy; Q_1 - rotatory constant. The scale is not followed.

energy 38 meV (hot luminescence). Such an interpretation satisfactorily agrees with the results given in Ref. /3/, where it was established that this peak intensity grows as the intensity of excitating radiation is growing. I_4 peak is stipulated by electron transition from exciton level n=1 to the sulphur acceptor level with the energy E_a=160 meV. I_5 peak is stipulated by the electron transition from n=1 level to E_a with the excitation of the exciton in n=2 state and I_6 - by the transition with the emission of a LO phonon and the excitation of the exciton in n=3 quantum state. The energetical model of the transitions is given in Fig.2(b). One can note that the intensity of I_5 and I_6 peaks is low and they were revealed only due to high quality of synthesized layers.

4.CONCLUSION

High quality cadmium sulphide layers on molybdenum substrates were synthesized from separate elements in the flowing hydrogen set at $P_{Cd} > P_S$, P_S approximately 50...500 Pa and substrate temperatures approximately 770...970 K. The layers are fine-grained and polycrystalline. The layers are distinguished by anomalous values of radiative recombination near the fundamental radiation edge. The nature of some radiation peaks is discussed in the frames of the model of the exciton with the oscillatory and rotatory degrees of freedom.

REFERENCES

/1/S.Raevski, A.Simashkevich, L.Gorchac, P.Ketrush, "CdS layers grown from vapor-gaz by zone method", CAS 93 Proceedings, p.345-348, 1993.

/2/ S.Raevski, A.Simashkevich, A.Koval, I.Diaconu, P.Ketrush, "Growth of CdS layers on Si from gaseous phase using separate elements", CAS 94 Proceedings, vol.2, p.651-654, 1994.

/3/ N.N.Zinoviev, N.D.Yaroshetski, "Investigation of radiative recombination in cadmium sulphide under high excitation levels", Physics and Technics of Semiconductors, vol.14, Nr.3, p.464-471, 1980 (in Russian).

/4/ N.V.Starostin, D.N.Starostin, "Quantum-statistics of Excitonic and Bielectronic Bose-gases", Optics and Spectroscopy, vol.75, Nr.4, p.770-782, 1993 (in Russian).