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# ФОТО ЭЛЕКТРОНИКА

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The results of theoretical and experimental studies in problems of optoelectronics, solar power and semiconductor material science for photoconductive materials are adduced in this collection. The prospective directions for optoelectronics are observed.

For lecturers, scientists, post-graduates and students.

У збірнику наведені результати теоретичних і експериментальних досліджень з питань оптоелектроніки, сонячної енергетики і напівпровідникового матеріалознавства фотопровідних матеріалів. Розглянуто перспективні напрямки розвитку фотоелектроніки.

Для викладачів, наукових працівників, аспірантів, студентів.

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<sup>1</sup> Odessa I. I. Mechnikov National University, Odessa, Ukraine<sup>2</sup> Opole State University, Opole, PolandPREPARATION OF THE  $\text{Li}_x\text{Ni}_{1-x}\text{O}$ -SOLUTION FOR GAS SENSORS

The properties of metal-oxides, which are used as sensitive elements for gases are discussed. The systems of metals with variable valence have been got on the base of the given metals acetates and acetates of metal of 1A group are shown.

Now the complex materials of different metal-oxides are used as the primary sensitive elements to gases ( $\text{CO}$ ,  $\text{CH}_4$ ,  $\text{C}_2\text{H}_2$ ,  $\text{NO}_x$ ,  $\text{NH}_3$ ). These materials used more often than pure ones because of their high sensitive qualities. The most effective materials are the solid solution of oxides of variable valence metals which have the general formula  $\text{Me}_x^I\text{Me}_{1-x}^II\text{O}$ , where  $\text{Me}_x^I$  — is the first group metal of the periodic system and the  $\text{Me}_{1-x}^II\text{O}$  — is variable valence metal. These systems have stable electrophysical characteristics owing the oxygen balance establishment between volume, surface and gas phase at high temperatures. At the same time these systems are very sensitive to adsorption of small gas portions. This quality is their main trait.

We have got the systems on the base of metals with variable valence. The systems have been got on the base of given metals acetates and the acetates of metals of 1A group by decomposition in air during 5 hours by temperature 6000 °C. So we have got the oxides mixtures with the content of 1A group metals — 10, 20, 30, 40 and 50 per cent. These mixtures were the initial material for the obtained systems, by the treatment by different temperatures — 700, 800, 900, 1000 and 1200 °C.

We determined the number of «holes», corresponding to the quantity of inclusion metal of 1A group, The change of crystal lattice constant, electrical conductivity depends on the conditions to form of such systems. Fig. 1 shows the dependence of

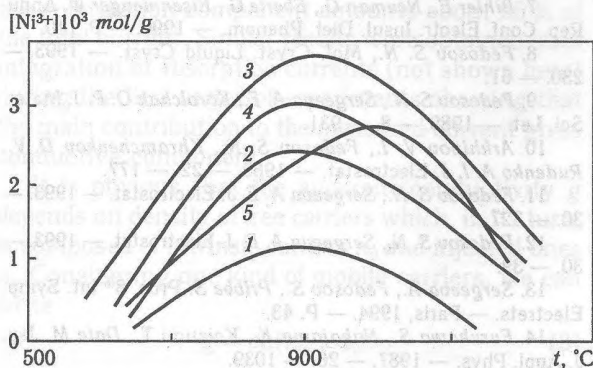


Fig. 1. Solid-solution concentration — temperature dependence. The content of 1A group metals: 1 — 10, 2 — 20, 3 — 30, 4 — 40, 5 — 50%

solid solution concentration on temperature of its formation. Fig. 2 shows the dependence of «hole»

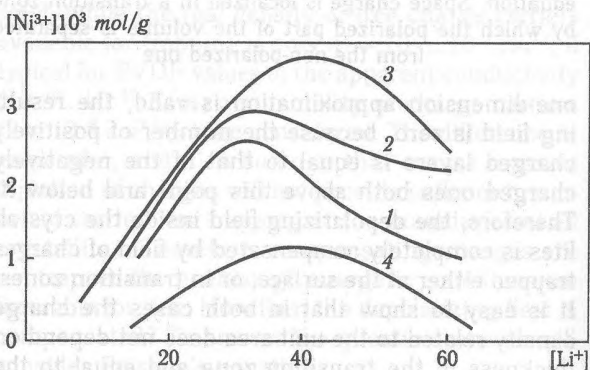


Fig. 2. «Hole» concentration — lithium concentration dependence. The temperature formation:

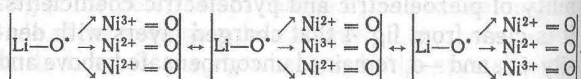
1 — 700, 2 — 800, 3 — 100, 4 — 1200 °C

concentration on the initial concentration of 1A group metal (lithium).

The quantitative determination of «holes» by chemical method in solid solution consists of determination of trivalent nickel in the system. When solid solution  $\text{Li}_x\text{Ni}_{1-x}\text{O}$  is dissolving in the hydrochloric acid owing to oxidizing-reduction process between trivalent nickel and ion of chlorine, the uncombined chlorine is reducing. The chlorine is determined by the iodometrical method. The quantity of lithium is increasing when the initial concentration is increasing.

This formula is right for all temperatures to form of solid solution. Fig. 2 shows that the curves go through the maximum (the initial concentration of lithium — at 30%) and then fall down. We have got the region where inclusion more lithium even by the way of another treatment of solid solution was impossible. The inclusion of lithium is desirable because sensor sensitivity depends on the quantity of «holes» in the system.

We can show the inner group of solid solution in mobile conduction as:



So, sensor sensitivity is the cause of the mobility. The possibility of getting the solution by the cheap well-known methods permits the possibility of gas primary making with the help of industry. The developing ideas about «hole complex» allow us to select sensors without using the method of «tests and mistakes». The goal of this work is to research the dependence of system sensitivity  $Me-MeO$  ( $Me-Li, K, Na, Cs; MeO-NiO$ ) on CO adsorption from atmosphere, draining air and nitrogen.

The films of  $Me^I_x Me^{II}_{1-x}O$  which is on quartz plate with platinum contacts were used as sensitive substrate. The research of these pellicles shows that there is no any charges in the process of marking of solid solutions. The crystals sizes ( $3...10 \mu m$ ) are rather the same. We carried our the experiment in gas flow containing CO (2 volume percent,  $T = 573 K$ ). There is no any sharp increasing of electrical conductivity. This preparation brings to nearly full reversibility. We researched the kinetic curve of electrical conductivity  $\Delta\sigma/\sigma_0 = f(t)$  and the de-

pending of response upon the structure of solid solution and temperature of its preparation (fig. 3).

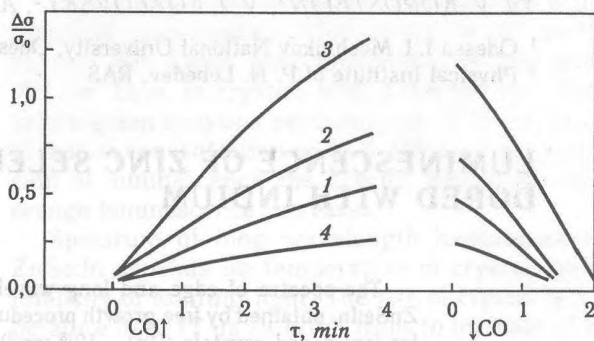


Fig. 3. Kinetic of electroconductivity. The temperature of preparation:

1 — 700, 2 — 800, 3 — 1000, 4 — 1200

The received facts are explained in terms of «hole complex».

not gas mixture was stationary values in all processes and made about 0.00 KHz. More detailed description for the technique to obtain the crystals is contained in works [3, 4]. The concentration of indium in crystals was determined through the atomic emission analysis and varied from  $10^{-2}$  up to  $10^{-6}$  atoms per unit of the number of metal ions. The spectra of photoluminescence were measured by spectrophotometer SP-01 within temperature range 77...400 K. As an excitation source, the helium-cadmium laser LGN-403K emitting on a wavelength  $\lambda = 441.6 nm$  was used. The spectra of long wavelength luminescence were represented with allowance for spectral sensitivity of the measuring equipment (see also in detail about the measuring method in [5]).

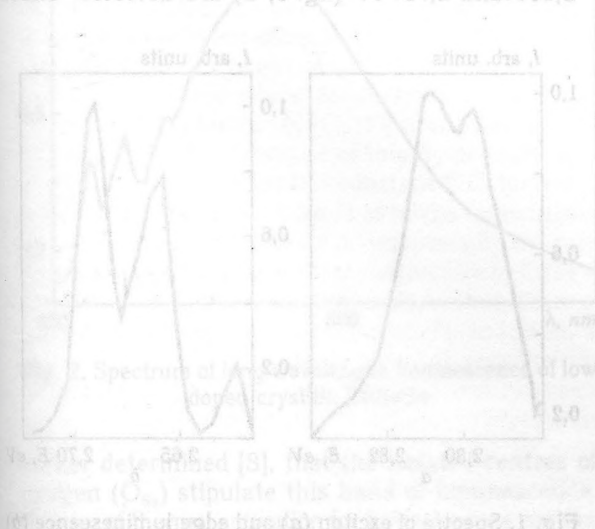


Fig. 4. Spectra of excitation (a) and photoluminescence (b).  
 © Yu. F. Vekman, Yu. A. Milyuk, Yu. N. Purov, S. A. Izrael'skiy, Yu. V. Korotkiy, V. I. Korotkiy, A. S. Nazarov, P. V. Shekita, 2001

The zinc selenide of a wide energy gap ( $E_g = 2.68 eV$ ) semiconductor of  $A^2B^6$  group. Due to its straight zone structure it has high efficiency of blue light-emitting diodes. Now the production of blue light-emitting diodes on the basis of single ZnSe crystals is prospective [1, 2]. However, instability of the emitting characteristics of such diodes is not sufficient for their production in this connection, the production and investigation of the crystals with perfect structure, low dislocation density and high conductivity is the very important problem. During last years the technique of free growth was designed (it consists in growing of crystals of  $A^2B^6$  group from a vapour phase in conditions excluded their constant growth towards the obtained crystals had the perfect structure and low (less  $10^{-2} cm^{-2}$ ) dislocation density. In subsequent, the doping of ZnSe crystals with indium during their growth by means of this technique was realized [4]. The high conductivity crystals ( $\rho = 2 \cdot 10^{-2} \Omega \cdot cm$ ) were obtained as the result of subsequent annealing ZnSe in the hydrogen flow [5].

In this paper the luminescence of ZnSe in single crystals, obtained by method of free growth, is investigated. The purpose of such investigations is to clarify the mechanisms of emitting recombination and the role of luminescence centres in crystals ZnSe, doped with indium.

The investigated zinc selenide crystals were obtained by method of free growth in two crystallographic directions (111) and (100). The growth in both directions was installed in the furnace with inhomogeneous temperature gradient. The seed, contained within the furnace, was placed in the furnace with inhomogeneous temperature gradient. The temperature of vapour source was 1450...1470 K. Temperature difference between

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