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THE OPTIMIZATION METHODS FOR THE ELECTROOPTIC PARAMETERS OF THE ZnS TRANSDUCERS

The results of investigations in the influence of additional technological processing of electrooptical converters on their current—voltage and volt-brightness characteristics are presented in this paper. Is was stated that annealing in He gave the results close to the data for structures formed electrically.

Introduction

The forming processes in the electrical-to-optic transducers were investigated. Such transducers' basis is the barrier structure of metal-dielectric-semiconductor type, produced by means of silicium oxide thin film deposition on the ZnS film surface. The aluminium, deposited in vacuum served as the upper electrode.

The active layer of the electric-to-optic transducers is the semiconductor zinc sulphide film, produced by the electro-hydro-dynamic sputtering (EHDS) and pyrolisis of metal-organic compounds (MOC) method. All the obtained structures required the additional treatment — the forming of radiative parameters. The transducers' parametres became stable only after the preliminary keeping of them under the electric field action.

The processes of the electric field energy to optic radiation transformation take place in the active zinc sulphide layer. Before silicon oxide deposition, the additional technological treatments of the layers were fulfilled: annealing in the air, in He vapours and in vacuum. The annealing in vacuum and in the open air did not change the parameters of the transducers produced, and the forming procedure was needed as previously.

The most interesting behaviour had the structures obtained on the ZnS layers, annealed in He vapours. The transducers' radiative characteristics compared with those, where the active layer was not annealed, makes it possible to conclude about the possibility for the substitution of the electric forming procedure by the active layer annealing in vapours. Besides that the volt-brightness slope was noticed for the layers annealed in He which are the main electroluminescent cells' parameters.

Among the devices for optical representation of information, the thin film electrooptical transducers are widely used. Having enough level of brightness, low operating voltage, they provide high resolving power. The active layer of such transducers is fulfilled using the wide zone A^2B^6 semiconductors, particularly ZnS doped by Mn [1, 2].

The advantages of the thin films sources of light: the low operating voltage with enough level of brightness, high resolving power, the plane type construction, the wide possibility in choosing dimensions, packaging density and the shapes of the illuminating signs.

The goal of the work: investigation of the additional technological processing influence on the electrophysical and luminescent properties of the electrooptical transducers.

The ZnS layers deposition was fulfilled on the glass substrates, coated by the transparent conductive SnO_2 layer. Using this production technology, the two different methods were applied: method of electrohydrodynamic sputtering (EHDS), which was previously used for the production of other A^2B^6 compounds [3], and now applied for the zinc sulphide; the modified method of chemical deposition of the vapour phase of metallorganic compound. The overheated water vapour was used as a transforming gas. The thickness of the films obtained for the period of 60...180 *min* was 1,5...2 μm.

For the improvement of the illuminating characteristics of layers investigated, the additional heat treatment was carried out. The types of annealing: in vacuum, in the air, in the atmosphere of helium.

Experimental results and interpretation

The structures based on the initial layers were investigated as follows: the volt—current dependence measurements; the volt—brightness dependence measurements.

The structures investigated did not show the radiation at the initial application of the electric field in the range of 0...8 *V* (fig. 1). The luminescent glow was registered after the samples were treated at the voltage of 8...10 *V* for 20 *min* and only after the electric current achieved the critical value of 20... 25 μA. Just after the glow was registered the current decreased sharply ten times of the order. The electroluminescent brightness was notably increased. The further voltage increase lead to the super-

linear U—I dependence and to the electroluminescent brightness growth.

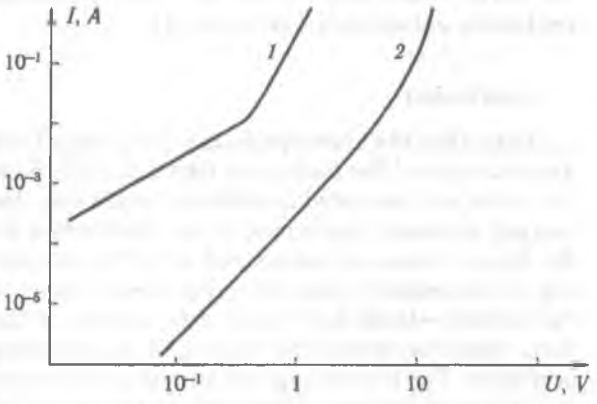

Fig. 1. The *VC* dependence of the samples:
1 — initial films; *2* — after the electric treatment

So the conclusion was made that the electric treatment was necessary for the electroluminescense appearance.

At the recurrent U—I dependencies measurements (curve *2*), the volt—current dependence had two superlinear sections: in the region of low voltages ($U < 10$ *V*), where the current—voltage dependence was described by the law $I \sim U^{1,4}$. The EL glow appeared at this section when $U = 8$ *V*. When the voltage achieves 10 *V* the mentioned dependence changes for the sharp current growth.

As the structural analysis showed, the investigated ZnS layers were the closely packed crystallites, the average size of each was 0,1 μ*m*. At the same time, in the separate regions where three or more crystallites join, one may notice the little crystals presence, the linear dimensions of each is 0,01 μ*m* or less. The mentioned regions may be connected with the ZnO phase inclusion. Their presence is supported by the X-ray analysis, or with the possible segregation of different impurities. Besides that they may be little crystallites of ZnS suppressed at the process of growth by the bigger crystallites.

Taking into consideration the X-ray analysis results, the treatment process may be explained as the following: in the structures initially prepared, the current flows along the channels which are formed by the intercrystallites inclusions, which have a great amount of defects and, hence, are lower ohmic than the matrix film. When some critical heat power is emitted within these channels they may be irreversibly switched off the current transport when the voltage is increased. When the following measurements were made on the structures the current flows along the chains made of big crystallites of zinc sulphide. As the films thickness was 1,5...2 μ*m*, then 15...20 intercrystallite barriers appeared to be switched to the current channel. The linear section of the I—U dependence in the region of low voltages may be explained in the frames of the polycrystalline layer Farenbruch—Bube model for the event when a great amount of intercrystallite barriers form the current channel [4]. The superlinear volt—current dependence may be connected with the space charge limited currents (SCLC) regime for the intercrystallite interlayers, or with the high electric field tensions in the regions of the reversed biased barriers of the intercrystallite interlayers [5]. The volt—current characteristic of the structure formed, which had the superlinear character as in the region of low voltages and in the region of higher voltages, may also be explained by the SCLC regime in the zinc sulphide layer.

Influence of the thermoprocessing on the structures' parameters. The annealing of the films in the open air and in vacuum did not change their volt—current dependencies. The radiation in such structures appeared only after they were preliminary treated in the electric field. It may be supposed that the current transport mechanisms did not change after said annealing. The structures based on the films annealed in helium atmosphere had specific characteristics. When the structure was switched on reversed polarity at low ($U < 1$) voltages then U—I had the linear dependence, i. e. $I \sim U$ (fig. 2). While

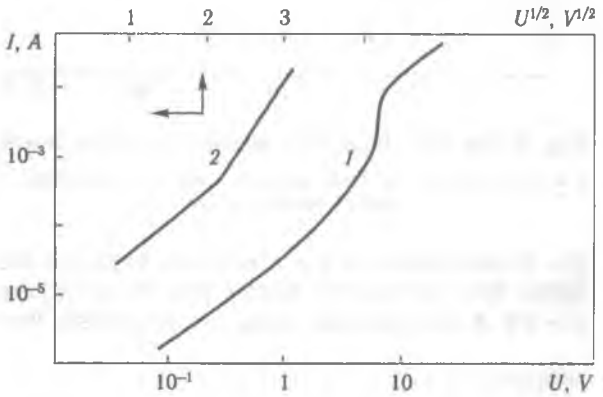

Fig. 2. The *VC* dependence of the films after annealing in the atmosphere of He

the voltage increases, the linear dependence changes for the exponential law $I \sim \exp(\text{const}\ U^{1/2})$. This part of the U—I curve is plotted in $\ln I \sim U^{1/2}$ coordinates (curve *2*). In this figure one may notice two linear parts with different slope coefficients: from 1 *V* to 5 *V* $I \sim \exp(2{,}7U^{1/2})$, and from 5 *V* to 10 *V* $I \sim \exp(3{,}8U^{1/2})$. The rectification of U—I curve at the reversed voltage polarity in $\ln I$—$U^{1/2}$ coordinates, witnesses that the current transport mechanism in the structure is the above-barrier Shottky emission [6]. The part of saturation which is registered on the I—U dependencies is connected with the charge polarisation effects.

Comparing I—U dependencies of the initial films after the processing (fig. 1, curve *2*) and of the films annealed in helium atmosphere (fig. 2) one may notice the following specific features: the U—I dependencies for the annealed structures has exponential law $I \sim \exp(\gamma U^x)$. Such dependencies are specific for the Shottky emission through the reverse biased metal-semiconductor barrier and also for the

intercrystallite potential barriers. The γ coefficient in the given dependence is defined by the ionised donors' density. The electric field processing followed by the helium annealing resulted in the increase of the samples' resistance, Thid differs from the initial lower ohmic samples (fig. *1*, curve *1*). It seriously contributes to the current transfer. The resistance increase of the layers after they were annealed in helium might be connected with the ionised donors density change.

The fig. 3 presents the volt-brightness luminescence characteristic of the structures discussed. The

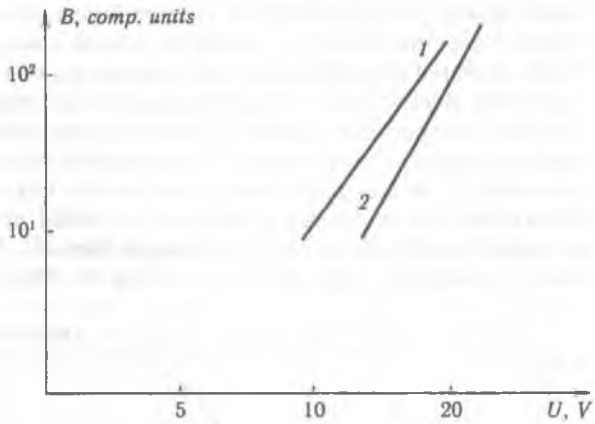

Fig. 3. The volt—brightness dependence of the layers: *1* — after the electric treatment; *2* — after the annealing in the atmosphere of He

U—B dependence of the structures based on the initial films follows the degree law $B \sim U^n$ where $n = 3{,}8...4$. The threshold voltage at the reversed bias was ~10 *V*. But for the structures based on the annealed in helium films, n was 5,5, i. e. the slope of the curve, which was one of main electroluminescent cell's parameters, increased [1].

Conclusion

Thus, after the investigations of I—U and U—B dependencies of the structures based on ZnS films, the initial and annealed in different conditions, the current transport mechanisms are established for the layers measured before and after the processing (or annealing) procedure. The mechanisms of Farenbruch—Bube and SCLC are realised for the films measured before the electric field processing procedure. The processing and annealing are resulted in the exclusion of the little crystallites out of the current channel and the current flows as the above-barrier Shottky emission. The results obtained, allow to conclude about the possibility to change the electric field processing for the annealing in the He vapours for the ZnS electrooptical structures.

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