AC ELECTROLUMINESCENCE IN ZnS(Mn,Cu,Cl) THIN FILMS

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The ac electroluminescence of ZnS (Mn, Cu, Cl) thin films was studied. Vacuum evaporated films 0.7 to 1.7 μm thick were fed with sinusoidal voltages of 80–120 V, and up to 2 kc/s and gave the luminance response which satisfies Alfrey-Taylor's relation. Thus, the electroluminescence model suggested by these authors for ZnS monocrystals can be applied also for ZnS thin films.

1. Introduction

Electroluminescence phenomena can be observed in semiconductors with a wide energetic gap, containing a certain amount of admixtures. These later form electroluminescence centers. One of these semiconductors is zinc sulphide with Cu, Cl, Mn and Ag admixtures. The reason to study the properties of ZnS (Mn, Cu, Cl) thin films that show an electroluminescence effect is because of their wide application in optoelectronics.

In numerous studies on the subject of electroluminescence [1–8], little attention was given to the electroluminescence of thin films, particularly in alternating fields.

This paper is a study of the electroluminescence of ZnS(Mn, Cu, Cl) thin films during excitation with ac voltage. The results agree with the model suggested by Alfrey and Taylor for monocrystals [9]. According to these authors, for electroluminescence excited with sinusoidal voltage, the instantaneous value of the light flux can be described as:

$$B_t \sim \gamma \exp(-\gamma t) \exp\left[-\frac{\alpha}{\sqrt{U_0 \sin 2\pi f t}}\right], \tag{1}$$

where, γ is a temperature dependent constant at an ordinary temperature equal to 940 s^{-1}, α — a parameter that depends on the value of the critical intensity of the electric field that causes the ionization of the luminescence center, f — frequency, U_0 — voltage amplitude, t — time, and the total light flux per cycle can be given as:

$$B = B_0 \exp\left(-\frac{A}{f}\right) \exp\left(-\frac{\alpha}{\sqrt{U_0}}\right), \tag{2}$$

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where, B_0 is a constant that depends on the units in which luminance, B, is expressed, A — a parameter that depends both on the technological conditions of preparing the samples and on the temperature.

2. *Experimental results*

ZnS thin films were produced by vacuum evaporation on a Corning 7059 glass substrate. Before this a photoconducting layer of In_2O_3(Sn) was produced on the glass surface by cathode sputtering.

The material used for evaporation was powdered ZnS with Mn, Cu and Cl admixtures added. These admixtures were introduced by heating the mixed powders of ZnS, $MnCl_2$ and $CuCl_2$ at 1000°C in an H_2S atmosphere. The contents of the admixtures were as follows: Mn — 2.5×10^{-2} g/gZnS, Cu — 3.2×10^{-2} g/gZnS and Cl — 3.6×10^{-2} g/gZnS. The material produced in this way was then evaporated in a vacuum of 5×10^{-6} Tr from an alundum crucible heated to 950°–1050°C on the substrate. This was placed 8 cm away from the source and heated to 200°C. The processing time was varied from 50 to 120 minutes and this resulted in layer thicknesses varying from 0.7 to 1.7 μm. The ZnS films so obtained were then recrystallized in a vacuum for 30 minutes at about 350°C. Finally, the aluminium electrodes were evaporated on the resulting ZnS film (Fig. 1). The active surface of this arrangement was 0.28 cm².

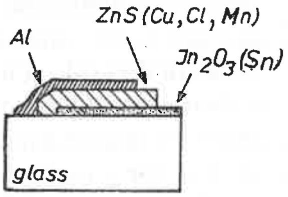

Fig. 1. Thin film electroluminescence capacitor

For the measurement of light emission a photomultiplier with a spectrum range of sensibility from 3500 to 6500 Å was used.

The luminescence characteristics were obtained for the 0.72 μm thick film fed with sinusoidal voltages of 50, 200 and 500 c/s frequencies (Fig. 2). Here it can be seen that the function $\ln B\left(\frac{1}{\sqrt{U_0}}\right)$ is linear and is independent of the applied frequency. Thus, Alfrey--Taylor's formula (2) is fulfilled for all voltages used. The luminance characteristics were obtained at room temperature, so parameter, A, was constant for a given sample. On the basis of the measurements performed the mean values of A and α were calculated. For a 0.72 μm thick sample they equal 238 s^{-1} and 16.13 $V^{1/2}$, respectively.

When feeding the sample with a sinusoidal voltage of constant amplitude, the characteristic $\ln B\left(\frac{1}{f}\right)$ should be, according to formula (2), a straight line with a slope independent

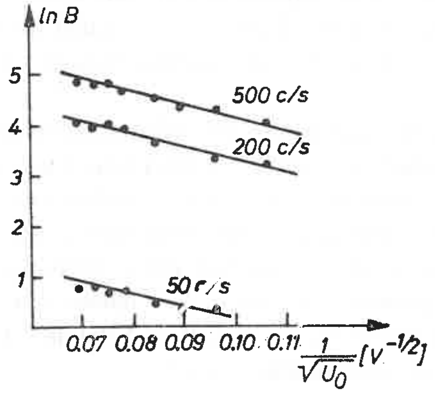

Fig. 2. Luminance characteristics for ZnS (Mn, Cu, Cl) thin films at various frequencies

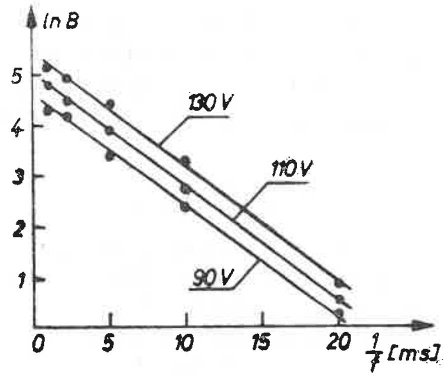

Fig. 3. Plot of $\ln B(1/f)$ for a 0.72 μm thick ZnS (Mn, Cu, Cl) film

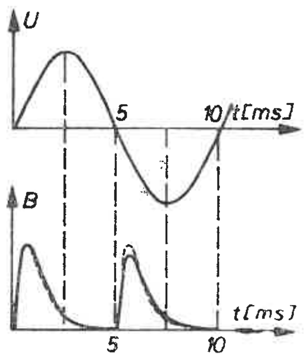

Fig. 4. Luminance intensity vs. time over a voltage cycle. The frequency is 100 c/s, and the amplitude is 120 V. Continuous line — experimental results, dashed line — theoretical values

of the applied voltage and which depends only on the value of A. The plots presented in Fig. 3 indicate that all the measured points are situated on straight lines whose slopes are the same and are independent of the applied voltage. The Alfrey-Taylor's relation is thus fulfilled.

The luminance vs. time for a single cycle of applied voltage at 100 c/s frequency was observed for the film studied (Fig. 4). The $B(t)$ function was estimated from formula (1) for the earlier calculated parameter, A, and for the amplitude of applied voltage $U_0 = 120$ V. Pulses obtained from the oscillograph and those numerically calculated were similar in shape and the maximum of the luminance pulse appeared after a relaxation time of $\tau = 1.02$ ms from the beginning of the pulse. This agrees with the numerically calculated maximum value and thus confirms the validity of formula (1) used by Alfrey and Taylor for their model describing electroluminescence.

3. *Summary*

It follows from this study that for vacuum evaporated ZnS (Mn, Cu, Cl) thin films 0.7 to 1.7 μm thick, fed with sinusoidal alternating voltages of amplitudes of 80–120 V and frequencies up to 2 kc/s, the Alfrey-Taylor's relation agrees well with the experimental results. Accordingly, the theoretical model of electroluminescence suggested by Alfrey and Taylor for ZnS monocrystals can be applied also for ZnS thin films.

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