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Figure 1

Figure 1: Figure 1

Abstract

Full Text

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THE EFFECT OF AN EXTERNAL ELECTRIC FIELD ON THE LUMINESCENCE OF CUPROUS OXIDE

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In 1956 we discovered the quenching effect of an electrolyte on the luminescence of cuprous oxide ([1]). The quenching effect could be increased by applying a negative potential to the cuprous-oxide specimen, i.e., by bringing positive ions closer to the surface. A field of the opposite sign reduced the quenching effect. This phenomenon was explained from the standpoint of the influence of the ion field on the near-surface bending of the bands in the semiconductor.

In the present work, the influence of an external electric field, perpendicular to the surface of the semiconductor, on the infrared luminescence of cuprous oxide has been found. To our knowledge, such an effect is observed for the first time.

A Cu_2O specimen was glued with polystyrene adhesive to a mica plate about 50 μ thick; a semitransparent platinum electrode was deposited on the mica from above by cathodic sputtering. A voltage from 500 to 3500 V was applied between this electrode and the cuprous oxide. The luminescence was excited by monochromatic light. The specimen was illuminated through the semitransparent electrode. In recording the luminescence, the crossed-filters method was used.

Fig. 1. Dependence of the relative change in luminescence intensity on the field applied to the surface of the semiconductor. The sign of the voltage corresponds to the potential of the cuprous oxide. **1** —wavelength of the exciting light $\lambda = 435.8$ mμ; **2** —$\lambda = 491.6$ mμ.

For the study, specimens of three types were taken: those having a considerable near-surface barrier bending of the bands, those having a weak barrier bending of the bands, and those having no noticeable bending. The character of the band curvature was determined from the sign of the condenser photoresponse ([2]). As shown in ([3]), annealing Cu_2O specimens in forevacuum (of the order of 10^{-3} mm Hg) leads to a decrease in the barrier bending of the bands and to the appearance of an antibarrier bending. Specimens with weak barrier curvature of the bands were obtained by annealing cuprous oxide in forevacuum.

Figure 2

Figure 2: Figure 2

The measurements were carried out in the following sequence. The luminescence intensity was measured without switching on the field (i_{lo}), the luminescence intensity with the field (i_l), and the relative change in luminescence was determined ($\Delta i_l/i_{\text{lo}} = (i_l - i_{\text{lo}})/i_{\text{lo}}$) upon switching on the field. It was found that the sign of the effect depends on the sign of the applied potential. With a negative potential on cuprous oxide, quenching of the luminescence is observed; a field of the opposite sign increases the luminescence. The action of the field on the luminescence varies from sample to sample within rather wide limits (for annealed samples, from 15 to 60% at a voltage of 3500 V). Figure 1 presents the dependence of $\Delta i_l/i_{\text{lo}}$ on the magnitude and sign of the external field. Curve 1 was obtained upon excitation of the Cu_2O luminescence by the blue line of a mercury lamp ($\lambda = 435.8$ mμ). When the luminescence was excited by light of greater wavelength ($\lambda = 491.6$ mμ), the field altered the luminescence more weakly. This is natural, since light of shorter wavelength is absorbed closer to the surface, and a change in its state has a stronger effect on the luminescence.

Fig. 2. Change of the field action on luminescence with time. When the field is switched on, cuprous oxide is charged: *a*—positively; *b*—negatively.

A change with time of the action of the field on luminescence was found. The character of this change depends on the sign of the field applied to the surface. Figure 2 shows the time course of the effect when switching on and switching off negative (a) and positive (b) voltage (the indicated sign of the voltage corresponds to the sign of the potential on the semiconductor). With positive voltage, after the field is switched on the magnitude of the effect is established instantaneously and practically does not change with time. When a field of the other sign is switched on, the change in luminescence at the first moment amounts to 49%, then decreases over 150 sec. and reaches a stationary value (14.2%). The time required for establishment and the magnitude of the stationary value of the luminescence depend on the intensity of the exciting light.

The surface of cuprous-oxide samples that had not been annealed in vacuum was etched with concentrated or 30% nitric acid and washed in ammonia. Samples etched in 30% HNO_3 had a considerable barrier bending of the bands. When etched with concentrated nitric acid, the samples did not exhibit band bending. The action of the field on the luminescence of such samples was much smaller (from fractions of a percent to 10% at a voltage of 3500 V). The effect changed strongly with time, decreasing to zero over a time of the order of 20 sec. for both signs of the applied voltage.

The data obtained confirm our assumption that an external field applied to the surface exerts a substantial influence on the luminescence ([1]). The measurement results can be explained by assuming, as we did in work ([1]), that an increase

in the barrier bending of the bands at the surface under a negative potential on Cu_2O leads to a decrease in the number of uncharged acceptors in the near-surface region and, consequently, to quenching of the luminescence ([4]). A field of the other sign, by reducing the barrier bending of the bands, increases the number of uncharged acceptors at the surface, which

leads to a flare-up of luminescence. The observed change in the action of the field with time is apparently connected with a change in the filling of surface states on cuprous oxide. The fact that the change in luminescence with the field on unannealed etched specimens is much smaller is probably connected both with the presence of considerable initial band bending and with the large number of surface states on the etched surface of cuprous oxide. It may be assumed that the difference in the kinetics of the effect for these two different types of specimens is connected with the latter circumstance.

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REFERENCES

[1] Yu. I. Karkhanin, G. P. Peka, *Photoelectric and Optical Phenomena in Semiconductors*, Publishing House of the Academy of Sciences of the Ukrainian SSR, 1959, p. 173.
[2] V. E. Kozhevin, V. E. Lashkarev, *Radio Engineering and Electronics*, **2**, No. 3 (1957).
[3] Yu. I. Karkhanin, V. E. Kozhevin, G. P. Peka, *Ukrainian Journal of Physics*, No. 6 (1960).
[4] Yu. I. Karkhanin, V. E. Lashkarev, *Reports of the Academy of Sciences*, **97**, No. 6 (1954).

Note: Figure translations are in progress. See original paper for figures.