

# OBSERVATION OF ELECTROLUMINESCENCE IN A HETEROSTRUCTURE WITH AN INSULATOR THROUGH WHICH A SPACE-CHARGE-LIMITED CURRENT FLOWS

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Submitted 13 February 1973

ZhETF Pis. Red. 17, No. 6, 309 - 312 (20 March 1973)

A low-voltage electroluminescence due to injection into the luminor of minority carriers from an insulator, in which these carriers are produced by space-charge-limited current, has been observed in a metal-insulator-luminor system at room and nitrogen temperatures. The luminors used were semiconducting compounds of the  $A_2B_6$  type.

It follows from arguments advanced in [1] that it is possible to observe, in a metal-insulator-luminor system, electroluminescence excited by injection of minority carriers into the luminor from an insulator in which these carriers are produced by space-charge-limited current. Such a method of electroluminescence excitation is important, in particular, because production of emission in the visible region of the spectrum at room temperature calls for the use of semiconductors with sufficiently broad bands, for which it is frequently impossible to choose minority-carrier emitters with even broader bands. Insofar as we know, however, this idea has not been confirmed experimentally so far.

We have succeeded, apparently for the first time, in producing a heterostructure in which such a mechanism of electroluminescence excitation is experimentally realized.

Our analysis of the requirements imposed on the physical parameters of the materials used in such structures (primarily on the electron affinity and the widths of the forbidden bands) has made it possible to select a number of systems in which one can expect realization of the considered minority-carrier injection mechanism. The luminors used were broad-band superconductors on the  $A_2B_6$  group.

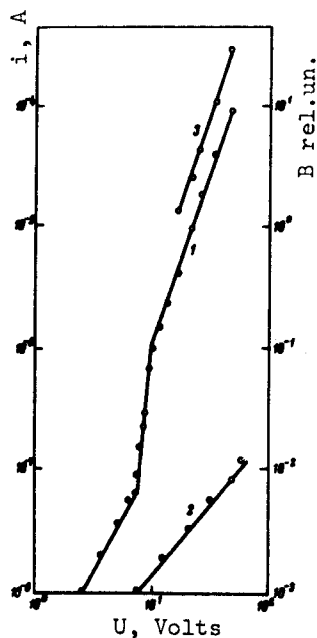
One such system is the heterostructure  $Pt-La_2O_3-CdS-In$ , the current-voltage characteristics of which are shown in the figure. The main features of these characteristics, which allow us to assess the electroluminescence mechanism in these structures, are the following:

1) They are unipolar. When a positive potential is applied to the platinum electrode (curve 1), the current flowing through the system (forward current) is much larger than for a negative potential of the same magnitude (curve 2).

2) The presence of one or two sections with a power-law relation  $i \sim U^n$  with  $n = 2 - 3$ . In the case of two sections, they are usually separated by a region with a stronger increase of the current.

3) The flash-like character of the relaxation of the forward current after increasing the voltage.

4) The dependence of the forward current on the thickness  $d$  of the  $La_2O_3$  layer,  $i \sim d^{-(2-3)}$  at



Current-voltage (curves 1, 2) and voltage-brightness (curve 3) characteristics of the system  $Pt-La_2O_3-CdS-In$  at  $T = 300^\circ K$ .

$U = \text{const}$  (in the experiments,  $d$  was equal to  $1000 - 3000 \text{ \AA}$ ).

5) Equality of the forward branch of the current-voltage characteristic of the system  $\text{Pe-La}_2\text{O}_3\text{-Pt}$ , in which the current was independent of the polarity of the applied voltage.

The foregoing features indicate that the forward current in the investigated system is due to monopolar injection of holes from the platinum electrodes into the  $\text{La}_2\text{O}_3$ .

Indeed, it follows from items (4) and (5) that the behavior of the forward branch of the current-voltage relations is determined by processes occurring in the insulator layer; the features (2), (3), and (4) are typical of a space-charge-limited current [2]; the facts indicated in (5) and (1) allow us to assume the current flowing through the  $\text{La}_2\text{O}_3$ , which is limited by space charge, is due to injection of holes into the  $\text{La}_2\text{O}_3$  from the platinum electrode.

This is precisely the reason why luminescence is observed in the investigated systems at rather low voltages ( $U \approx 10 - 30 \text{ V}$ ), particularly in the visible region of the spectrum ( $510 - 700 \text{ nm}$ ). The brightness of this luminescence increases in proportion to the current flow into the sample (see curves 1 and 3 in the figure). It is important that the electroluminescence was observed at  $T = 300^\circ\text{K}$  when the luminor was cadmium sulfide, in which, as is well known, the green and orange photoluminescence are strongly quenched at this temperature. On going to nitrogen temperature, the intensity of the registered visible electroluminescence increases appreciably (by as much as  $10^3$  times).

The results give grounds for hoping that the method realized by us for injecting minority carriers is promising for the development of effective sources of visible light on the basis of a broad class of luminors. We see particular advantages in this method when broad-band semiconductors of the  $\text{A}_2\text{B}_6$  are used, since these are known for their effective photoluminescence in the visible region of the spectrum.

[1] A.G. Fischer, J. Electrochem. Soc. 118, 139c (1971).

[2] A. Rose, Concepts in Photoconductivity and Allied Problems, Interscience, 1963.