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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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A NEW EFFECT OF ELECTROLUMINESCENCE OF BLACK CARBORUNDUM

PHYSICS

1. O. V. Losev discovered and described (1) two types of electroluminescence of black carborundum: glow II and "an analogue of glow I." For glow II to arise, it is necessary that, on hole-conducting black carborundum, there be an electron-conducting, "sensitive" (according to Losev) layer; under the action of current in the forward direction, a glow arises at the electron-hole junction which, owing to the presence on the surface of a particularly well conducting layer, often covers in the region of the electron-hole junction an area of the order of tens of square millimeters.

Fig. 1. Specimen No. 20 of black carborundum in a direct-current circuit. Dependence of the glow intensity on the voltage across the specimen.

Since the work of Lehovec and co-workers (2), glow II has been regarded as recombinational, occurring by injection of carriers through an electron-hole junction. Glow II is comparatively weak on the principal plane of a carborundum single crystal and brighter on the side faces and on the narrow strip of the principal plane adjoining them. On the stepped layers characteristic of carborundum it often assumes bizarre forms. Glow II may be of various colors: from dark brown to light yellow-orange and almost white; green glow is often encountered, which may have blue shades up to the color of aquamarine; regions of other coloration occur more rarely.

The "analogue of glow I," which for brevity we shall call in the present paper glow I, is obtained at the same electrode at which glow II was observed, after commutation of the current; it consists of individual luminous points or of a chain of such luminous points, both being situated along the periphery of the region in which glow II was observed. Rüker proposed the name point glow for this glow (3). Glow I, according to Ivey' s definition (4), is glow by acceleration and impact.

O. V. Losev and later investigators studied glow II of carborundum in considerably greater detail than glow I, which in direct-current circuits is 1-2 orders of magnitude weaker than glow II. Figure 1 gives the intensities of glow I and glow II of specimen No. 20, measured with an electron photomultiplier, as functions of the magnitude of the direct voltage. At 22 V, glow I was approximately 100 times weaker than glow II.

2. Crystals of black carborundum from the Zaporozhye Abrasive Products Plant were subjected to rectangular voltage pulses.

For the article by A. G. Goldman, p. 1108

Fig. 4. Microphotographs of the luminescence of specimen No. 20 (dimensions 1—2 mm^2) under the action of rectangular pulses. Pulse duration 10 μsec; amplitude 60 V; repetition rate 10,000 Hz. Exposure 20 min each. *a*—luminescence *II*; *b*—luminescence *I*+ luminescence *III*.

For the article by I. D. Zkus and A. L. Yurevich, p. 1215

Fig. 2. Electron-microscopic photographs. *a*—specimen No. 3/7; I degree of decomposition of volcanic glass; weakly altered ash particles predominate. *b*—specimen No. 3/5; II degree of decomposition of volcanic glass; montmorillonite predominates. *c*—specimen No. 4/7; III degree of decomposition of volcanic glass; the ash material is completely decomposed.

with a duration of 10 μsec and a repetition rate up to 10000 Hz. Photometric, oscillographic, and microscopic observations were carried out. The photocurrent caused by the luminescence, from an FEU-19M photomultiplier, was sent either to a galvanometer or to an oscillograph. The measurements were made at room temperature.

When luminescence II was excited, the oscillogram showed that the light pulse fell to one half in approximately 15 μsec.; 50 μsec. after the cessation of the voltage pulse the light pulse had practically disappeared; its amplitude and shape did not change appreciably when the repetition rate was varied from 1000 to 10000 Hz. Therefore the total light pulse per unit time was the product of the magnitude of a single pulse and the repetition rate, and the photomultiplier current increased linearly with the repetition rate of the pulses (Fig. 3, II).

After switching off the pulse, luminescence I arose, considerably weaker than luminescence II (for example, 20 times weaker), and up to a certain value of the repetition rate it increased approximately in proportion to the repetition rate; at higher repetition rates a superlinear increase of the luminescence began. For example, in specimen No. 20, at a pulse amplitude of 40 V and with the repetition rate increasing from 8000 Hz to 10000 Hz, the luminescence increased by a factor of 4.5. The transition to rapid growth occurred at the lower repetition rate, the larger the pulse amplitude: in the same specimen the transition to superlinearity occurred at 50 V at about 7000 Hz; at 60 V at about 5000 Hz; at 70 V at about 4000 Hz (Fig. 2). At 30 V, up to 10000 Hz, the growth was approximately linear. The superlinear amplification of the luminescence with increasing pulse frequency indicated the appearance of a new source of luminescence. It was detected in microscopic observations.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Fig. 2. Specimen No. 20. Excitation by rectangular pulses from a 26-I generator. Pulse duration 10 μsec. The intensity of luminescence I is given as a function of the amplitude and repetition rate of the pulses. 1—40 V, 2—50 V, 3—60 V, 4—70 V

Fig. 3. Specimen No. 20. Excitation by rectangular pulses. Pulse duration 10 μsec.; pulse amplitude 60 V. Luminescence intensity as a function of the pulse repetition rate

3. Observations were made with an MBS-2 stereoscopic microscope at magnifications of the order of 50×. Under the action of pulses at a repetition rate not exceeding 2000 Hz, the usual picture of luminescence I was observed—individual luminous points and a row of points. Beginning at a certain repetition rate, different for different crystals, the entire figure that had been visible under luminescence II began to glow. In specimen No. 20 this occurred at repetition rates between 2500 and 3000 Hz; in specimen No. 39, between 5000 and 6000 Hz; at approximately the same repetition rates in these crystals the superlinear enhancement of luminosity began. With increasing repetition rate, the brightness of the luminous figure increased, and at 10000 Hz it was, in some crystals, only slightly weaker …

less than the brightness of luminescence II (Fig. 3). However, with this polarity the color of the glow of the figure is different than in luminescence II; in the new glow, warm, brown tones are present to a greater degree; in specimen No. 36, under luminescence II the face glowed with a greenish-blue light, whereas in the present case it glowed with a brown light, etc.

The new type of luminescence, substantially different from luminescence I and producing a considerable enhancement of the glow, we shall for brevity call luminescence III. Figure 4 gives microphotographs of luminescence II and of luminescence I + III for specimen No. 20. Luminescence I is visible as a chain of luminous points at the top of Fig. 4b. The difference in intensity and in the colors of luminescences II and III appears in the different distribution of light in Figs. 4a and 4b. The photographs in Figs. 4a and 4b were taken under otherwise identical conditions, with the exception of the direction of the pulse.

4. The superlinear increase of the luminescence with increasing repetition rate supports the supposition that the increase in the frequency of the pulses leads to a greater accumulation of the products of the action of the

> pulses, which subsequently lead to the formation of luminescence. The phenomenon occurs, like luminescence I, for the blocking direction of the current, i.e., when the free electrons in the electron semiconductor and the free holes in the hole semiconductor are driven by the external field away from the boundary of the electron-hole junction and enter a comparatively weak field. It may be supposed that they become fixed at adhesion levels near the outer boundaries of the space-charge regions remaining after their removal, and that their concentration increases with the increase in the frequency of the pulses. From the moment when the pulse disappears, the internal field of the space charges draws the released electrons and holes back, and conditions are created for recombination and luminescence different from those of luminescence II, as indicated by the different color of the glow.

In oscillographic observations of luminescence I below the critical repetition rate, the light pulse retained its shape; at a higher repetition rate the picture changed radically: luminescence was observed also beyond the limits of the initial pulse of luminescence I throughout the whole interval between two voltage pulses. The study of these effects in different crystals is continuing.

Luminescence III is a new type of luminescence in carborundum; its energy is taken from the energy of the electric pulses; therefore, regardless of the details of its mechanism, luminescence III is electroluminescence. Luminescence III arises after the passage of current through the electron-hole junction in the direction that produces luminescence I; the figure of luminescence III is similar to the figure of luminescence II, i.e., it occurs in the region of the electron-hole junction, whereas luminescence I occurs at the periphery of this region; the difference between the color of luminescence III and the color of luminescence II indicates a different character of excitation of the luminescence; a further difference consists in the fact that the rise of luminescence II occurs during the action of the voltage pulse, while luminescence III occurs after the voltage pulse has ceased. Adding to luminescence I, luminescence III can considerably enhance it.

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