PHYSICS

V. F. PISARENKO

1957

SovietRxiv

Abstract

Full Text

PHYSICS

V. F. PISARENKO

CHANGE IN THE CONDUCTIVITY OF KBr IN STRONG FIELDS IN THE TEMPERATURE RANGE 300–450°

(Presented by Academician A. N. Terenin, December 17, 1956)

It is known (1) that, during electrolysis of heated alkali-halide salts, under certain conditions an increase in the conductivity of crystals is possible when they become colored; in this case the dielectric is transformed into an impurity semiconductor. The impurities that increase the conductivity are F-centers. Coloring of the crystals occurs only in the case in which the electrons entering the crystal displace the halide ions.

We succeeded in observing a sharp increase in the conductivity (by a factor of 100–1000) of heated single-crystal KBr specimens in comparatively strong fields (1000–10 000 V/cm) without coloration; moreover, no dendrites formed in the specimen.

The research method used was that described in the article (2), with the difference that, during electrolysis, a "ballast" resistance of about 10^5 ohms was connected in series with the specimen, protecting the specimen from breakdown. The temperature range in which an increase in conductivity can be observed lies approximately between 300 and 450°. At lower temperatures dendrites grow in the specimens; at temperatures above 450° the specimens become colored.

Figure 1 presents the change in conductivity of a specimen with time at constant temperature and voltage across the specimen and the ballast resistance. It is seen from the figure that for a certain time (the size of the interval depends on the field strength and on the quality of the cathode-specimen contact) the conductivity remains constant, and then increases rather rapidly with time by a factor of 100–1000. If the direction of the field is changed, the conductivity very sharply (within 1 sec) decreases to the initial value; when the old direction is restored the conductivity again rises rapidly. If the direction of the field is changed for a long time, the conductivity, after decreasing at first, increases after some time, and after this a return to the original field direction leads to a decrease in the conductivity. Control experiments showed that the increase in conductivity is caused neither by heating of the specimens nor by growth of dendrites.

The passage of current through a crystal in such an "altered" state leads to destruction of the anode, while the cathode is not eaten away (aluminum plates usually served as electrodes); in ordinary electrolysis, however, only the cathode plate is destroyed.

The current-voltage characteristic for a crystal with increased conductivity is a loop-shaped curve that is not reproduced when the voltage-variation cycle is repeated. The dependence of conductivity on temperature at constant voltage is also ambiguous. From these measurements the activation energy can be roughly estimated as about 0.6 eV (in the normal state, about 3 eV).

A crystal with increased conductivity, when rapidly cooled to room temperature, has properties different from those of

of the initial crystal. The near-cathode region of the specimen after such treatment is colored in a thin layer (10 μ). Its absorption spectrum contains the F-, M-, U- and V-bands. The concentration of F-centers, estimated from the optical density, is of the order of 10^{18}–10^{19} cm^{-3}. The near-anode part of the crystal is usually destroyed, but not colored. The volume of the crystal is not colored; its absorption spectrum has no noticeable changes in comparison with the initial one. Nevertheless, the specimen proves to be photoconducting; its integral photosensitivity is comparable with the photosensitivity of x-rayed specimens with an F-center concentration of the order of 10^{16} cm^{-3}. Figure 2 gives the spectral distribution of the photoconductivity of a specimen in the changed state and for an x-rayed specimen. It is clearly seen that the spectral region of photosensitivity of the first specimen is considerably broader than that of the second. On cooling the specimen to −183°, the photoconductivity disappears. The dark conductivity of such crystals at room temperature is 2–3 orders of magnitude above normal.

Annealed at a temperature of 400–500°, the changed specimens return to the normal state within several minutes.

The observed phenomenon can be explained on the basis of the electrolysis mechanism proposed by M. S. Kosman (2), assuming that when electrons, owing to the lowered boundary barrier due to potassium deposited at the cathode, enter the specimen and neutralize the near-electrode space charge, forming a layer with increased conductivity, sufficiently strong fields are not created in the crystal, because of the comparatively low temperature, to carry the Br^- ions to the anode, so that the electrons pass in the conduction band through the whole crystal, accumulating in the near-anode layer. The field produced by this charge ruptures the lattice, liberating Br at the anode. Only a very small fraction of the electrons proves to be captured by defects present inside the crystal. These acceptors probably release electrons, when excited by light, to a metastable level, from which thermal fluctuations throw the electrons into the conduction band. Since the absorption of the specimen does not change noticeably on transition to the changed state, the number of defects apparently does not exceed 10^{13} cm^{-3}. Such a small number of defects probably determines the increased mobility of the electrons in the specimen. It should be noted, however, that we cannot yet

Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

explain all the details of the phenomenon.

Fig. 1. Change in the conductivity of a KBr specimen in strong fields at 400°. $E_{\text{initial}} = 1200$ V/cm

Fig. 2. 1 –Spectral distribution of the photoconductivity of a KBr specimen in the changed state; 2 –photosensitivity of an x-rayed KBr specimen.

A sharp unipolar change of conductivity in strong fields at high temperatures was previously observed by N. I. Shefer (3) in barium titanate.

In conclusion, the author considers it his duty to express gratitude to Prof. M. S. Kosman for supervising the work.

Leningrad State
Pedagogical Institute
named after A. I. Herzen

Received
19 XI 1956

REFERENCES

1. P. S. Tartakovskii, *Internal Photoeffect in Dielectrics*, Moscow-Leningrad, 1940; H. Mott, R. Gurney, *Electronic Processes in Ionic Dielectrics*, IL, 1950; R. W. Pohl, *Phys. Zs.*, 39, 36 (1938).
2. M. S. Kosman, V. F. Trarenko, DAN, 115, No. 4 (1957).
3. N. I. Shefer, Author' s abstract of dissertation, Leningrad, 1953.

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

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.