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Fig. 1. Dependence of dark electrical conductivity (across the crystal) in air on temperature

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Abstract

Full Text

PHYSICS

V. A. IZVOZCHIKOV and G. A. BORDOVSKII

PHOTOCONDUCTING SINGLE CRYSTALS OF LEAD OXIDE

(Presented by Academician A. N. Terenin, 5 IV 1962)

The photoelectric properties of lead oxide have been studied on powders, thin films, and pressed specimens ([1–9]). The internal photoeffect in single crystals of yellow PbO has been reported only in the work ([10]), devoted to the investigation of the energy of formation of free current carriers under the influence of x-rays.

The authors obtained fairly large PbO single crystals possessing appreciable photoelectric sensitivity in the visible part of the spectrum. The crystals precipitated during slow cooling of a solution of PbO in concentrated alkali. Depending on the ratio of the components of the solution, crystals of three types were formed: 1) thin yellow needles up to 2 mm long; 2) small crystals (approximately $1 \times 1 \times 1$ mm^3) of red color; 3) yellow crystals in the form of plates (thickness ~ 0.1 mm, width 1 mm, length 6–8 mm). Most of the crystals of the last group acquired a red coloration after several days. Photoelectric sensitivity was found only in crystals of red color.

The crystals studied had a dark resistance of the order of 10^{10}–10^{12} Ω at an average electric-field strength of $5 \cdot 10^2$–10^3 V/cm. In light (an incandescent lamp with a tungsten filament, $L = 7.5 \times 10^2$ lux) the resistance decreased by more than an order of magnitude, and in individual crystals by two orders of magnitude.

Fig. 1. Dependence of dark electrical conductivity (across the crystal) in air on temperature

The dependence of the dark electrical conductivity on temperature in the range 0 –350° is characterized by “hysteresis,”indicating a rearrangement of the structure and sorption processes (Fig. 1). On the curve $\ln \sigma = f(1/T)$ one can distinguish approximately rectilinear sections, the slope of which varies somewhat from specimen to specimen and corresponds to a thermal activation energy $\Delta E_t \approx$

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Figure 2

Figure 2: Figure 2

1.25–1.5 eV (sections AB and $A'B'$) and 0.58–0.71 eV (section CD), if the activation energy is estimated from the formula $\sigma = \sigma_0 \exp(-\Delta E/kT)$.

The optical properties of the photoconducting crystals are characterized by an absorption band with a long-wavelength edge near 630 mμ, which corresponds to an optical activation energy $\Delta E_{\text{opt}} = 1.96 \pm 0.06$ eV (Fig. 2). The same value of ΔE_{opt} was obtained by one of the authors ([9]) for powders of red lead oxide.

From the character of the dependence of the photocurrent on illumination, the crystals belong to nonlinear photoresistances, i.e. $\Delta I \sim L^x$. The exponent of nonlinearity x is equal to 0.6–0.7 (from 1 to $4 \cdot 10^2$ lux) and 0.35 (from $4 \cdot 10^2$ to 10^3 lux), if the lux-ampere characteristic is recorded starting from low illumination. If, however, beginning with a high value of illumination (10^3 lux), the latter is gradually decreased, then x assumes the value 0.35 even at low illumination. Without taking this circumstance into account, the form of the spectral-

Fig. 2. Optical characteristics of crystals in air at room temperature: D –spectral distribution of optical density (D' –at increased sensitivity of the instrument); T and T' –transmission; R –diffuse reflection. Curves D, D', T, and R were recorded on an SF-2M, curve T' on an SF-4.

Comparison of the spectral distribution of the photoelectric sensitivity (Fig. 3) and the optical density (Fig. 2) of the crystals indicates that absorption of light in the band from 400 to ~ 650 mμ is photoactive. The maximum photocurrent is observed near 610 mμ. The value of the activation energy, determined from the red edge of the internal photoeffect, $\Delta E_{\text{phot}} \simeq 1.9$ eV, is close to the value of the optical activation energy.

The authors express their gratitude to Academician A. N. Terenin for his attention and interest in the work.

The form of the spectral distribution of the photocurrent depends sharply on the direction in which the spectrum is recorded (Fig. 3, curves 1 and 2). The position of the photocurrent maxima does not depend on the direction of recording of the spectrum, if the change in the exponent x is taken into account (Fig. 3, curves 1 and 3). However, when the spectrum is recorded from long wavelengths to short wavelengths, a relative increase of the photocurrent in the short-wavelength part of the spectrum is observed.

One of the reasons determining the dependence of the lux-ampere characteristic and the spectral sensitivity on the conditions of the initial illumination is sorption processes. Thus, for example, illumination of PbO leads to desorption of H_2O vapor*, which in turn is accompanied by an increase in the photoelectric activity of the specimens [9].

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Figure 3

Figure 3: Figure 3

Fig. 3. Spectral distribution of the photoelectric sensitivity of crystals in air at room temperature

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* The desorption of water vapor upon illumination of PbO, apparently of thermal origin, was discovered by Yu. P. Solonitsyn, to whom the authors are sincerely grateful for carrying out the experiment at their request.

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

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