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EFFECT OF RADIATION EXPOSURE ON PbS PHOTOSENSITIVE FILMS

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Abstract: This article investigates the critical role of surface adsorption of acceptor or donor atoms in the formation of photosensitive thin films, with a focus on sensitized PbS films. While the influence of surface interactions on film properties has been well established, the presence of multiple effective boundaries in multiphase systems like PbS complicates the understanding of dark resistance (Rto) and photoconductivity. The study explores how thermal and radiation effects influence the kinetic parameters of these films, particularly addressing the contribution of oxygen to the sensitization process. Through this examination, the article provides deeper insights into the mechanisms driving the photosensitivity of PbS films, paving the way for improved understanding and application of these materials in optoelectronic devices.

Keywords: Adsorption, Acceptor atoms, Donor atoms, Photosensitive thin films, PbS films, Sensitization, Dark resistance (Rto), Photoconductivity, Multiphase systems, Thermal effects, Radiation effects, Kinetic parameters, Oxygen, Surface interactions, Optoelectronic devices.

Introduction

The important role of adsorption of acceptor or donor atoms on the surface in the mechanism of formation of photosensitive thin films has now been reliably established [1,2]. However, for multiphase systems, such as sensitized PbS films, the situation is complicated by the presence of several effective boundaries in the system, which determine the change in dark resistance (Rto) and photoconductivity [3]. One of the ways to determine the role of oxygen in the sensitization of PbS films is to study the influence of thermal and radiation effects on their kinetic parameters.

We have conducted studies of the properties of PbS films under radiation and thermal influence. The studied samples were conditionally divided into three types:

a) Low-resistance photosensitive (Rto < 0.3 Mohm, Us > 1000 μV),

b) High-resistance photosensitive (Rto > 0.3 Mohm, Us > 1000 μV),

c) Insensitive, non-photosensitive (low-resistance).

The studies were carried out in succession in several cycles of irradiation and annealing in air. The most characteristic changes in dark resistance (Rт) and photosensitivity (Uc) for a) series of samples during electron irradiation and reduction in air are shown in Fig. 1.

For some samples of series a) and b) it is necessary to note the effect of a significant decrease (Rт) after irradiation in comparison with the initial one.

One of the factors confirming the predominant role of the surface layer in the conductivity mechanism is the presence of a characteristic maximum of dark resistance in the process of electron irradiation of sensitized PbS layers.

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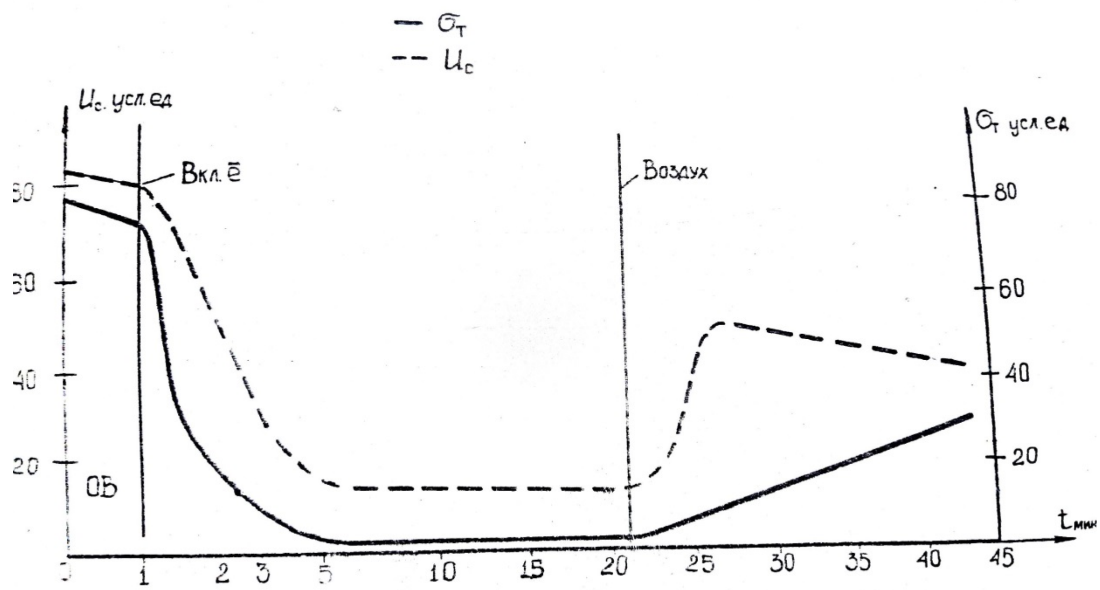

Fig. 1. R_T=0.27Mohm, Uc=6400μV. Changes in R_T and Uc during irradiation with 30 keV electrons and annealing in air at room temperature.

On a real semiconductor surface, the density of surface states is significantly (by two to three orders of magnitude) less than on an atomically pure surface containing Tamm levels. Surface electron states can act as recombination and capture centers depending on the number of carriers, the electron and hole capture cross-section, the concentration of surface states, their type and energy position, etc. [4]. The energy structure of impurities and defects in crystallites, as well as the density of surface electron states at the boundaries of crystallites, depend on the details of the process of obtaining a polycrystal. Just as in single crystals, defects in crystallites play a significant role.

Under normal conditions, the surface of a crystal is always covered with one or more monolayers of adsorbed atoms and molecules. There are structural defects on the surface of a crystal: these include empty nodes and a group of empty nodes, dislocations coming to the surface, mosaic angles, microblocks, etc. All of the listed surface defects correspond to local surface states of electrons, the energy levels of which, as a rule, fall into the forbidden zone of the general energy spectrum of the crystal.

Surface levels are charged because there is an exchange of carriers between surface electron states and zones on the surface. The total charge of surface states is called the surface charge Qs=Qss+Qsc. Under the influence of external influences, it changes to $\Delta Q_s=\Delta Q_{ss}+\Delta Q_{sc}$.

When irradiated, adsorbed oxygen molecules are knocked out from the surface of the sample as a whole and from the surface of the crystallites, therefore, as a result, the surface potential decreases. Measurement of dark resistance during irradiation for most samples gave characteristic bell-shaped curves with a maximum at intermediate irradiation times, when the population of the adsorbed layer is still different from zero. The irradiation time at which the resistance reaches its maximum is determined by the intensity of the electron beam and the features of the adsorbent surface. Further irradiation led to complete depletion of the adsorbed layer, while the resistance dropped approximately to the original value and an inversion of the conduction type occurred.

The energy of radiation is transferred to the lattice through fast electrons excited by radiation, which will lead to the displacement of atoms with the formation of point defects [5].Along with the generation of point defects, the effect of radiation leads to radiation-stimulated diffusion of atoms [6]. Radiation-stimulated diffusion is an athermic process, and the "stimulator" of diffusion is the energy of non-equilibrium electron-hole pairs excited by radiation. The energy obtained by the atoms of the impurity increases the probability of interatomic jumps, i.e. accelerates diffusion. In films, under the influence of radiation, both the diffusion of impurities localized in the volume of crystallites and impurities adsorbed at the crystallite boundaries can be stimulated, as indicated by the results obtained.

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