Transport properties and photoconductivity of PbSe films with variable microstructure

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Lead salt materials are of high interest for infrared optoelectronics. PbSe is a narrow gap semiconductor with a direct energy gap of 165 meV at zero temperature. In present work, photoelectric and transport properties are studied for as-grown and oxidized nanocrystalline PbSe films. Charge transport mechanisms of nanocrystalline films depend on properties of grains as well as properties of grain boundaries and processes which occur on grain surfaces. Contribution to conductivity from different elements of the structure may vary depending on the grain size, oxidation, doping and external factors [1,2]. The purpose of this work was to determine the effect of microstructure and oxidation on the conduction mechanisms of films of different thickness. Photoconductivity and Hall effect in PbSe films in darkness and under illumination were measured in the temperature range 4.2 - 300 K.

The films were deposited on polyimide substrates by Physical Vapor Deposition using an electron gun. The film thickness d was varied from 150 nm to 1500 nm. Some of the as-grown films were annealed in an oxygen atmosphere (2-3 Torr of O_2) under the following conditions: 1 h at $T_{ann} = 400$ °C.

Increase of thickness of the as-grown films is accompanied by qualitative change of conductivity from p- to n-type. In the thinnest films at high temperatures an activation region $\rho \sim \exp(E_a/kT)$ is observed, where E_a is 10 meV. In the films with $d \geq 500$ nm, the temperature dependence of resistivity has metallic character. Oxidation of the films leads to inversion of the conductivity type from electron to hole and gives rise to persistent photoconductivity at low temperatures $T < 50$ K. In p-type films, inversion channels at the grain surface and boundaries are responsible for the charge transport. In n-type films, the grain bulk is responsible for charge transport and photosensitivity. Analysis of the experimental data showed that the film thickness and oxidation substantially affect the grain surface contributions to conductivity and the photosensitivity of the films.

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[2] M. I. Kamchatka, Yu. M. Chashchinov, D. B. Chesnokova, Effect of Oxidation Conditions on the Phase Composition, Structure, and Properties of Photosensitive Lead Sulfide Layers, pp 910-914, INORGANIC MATERIALS, Vol.37, No.9 (2001).