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Excitonic and band parameters in SnSe crystals

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1. Introduction

Tin selenide (SnSe) is a layered semiconductor material of IV-VI group. The material attracts an attention due to potential applications and interesting physical properties. The high availability of SnSe components in nature, for economic reasons, has attracted interest and attention for development in the field of photoelectronic instrumentation and solar energy. Switching, memory, photoelectric and light-emitting devices (LEDs) and holographic information recording systems are developed on the base of SnSe [1–3]. Recently, about development of solar cells based on CdS/SnSe heterojunctions has been reported [2]. In the development and manufacturing of memory devices [2–5] SnSe has played a vital role due to its low crystallization and high melting point under certain conditions. Recently, about changes in the behavior of SnSe–SnSe₂ phase in multilayer films have been reported [6–9].

The properties of SnSe crystals have been studied in a number of works, the results of which are very contradictory. There are works on the edge absorption spectra and the temperature dependence of the optical properties of thin SnSe films obtained by different methods [7–12]. The nature of electronic transitions (direct, indirect) in the minimum band gap has not been established. The minimum band gap varies from 0.58 eV [12,14] to 2.8 eV [15–17]. The band structure calculations of different authors also give contradicting and ambiguous results [10,18,19].

In the present work, absorption, reflection and wavelength modulated transmission spectra in wide temperature range 300–10 K in regions of the band gap minimum and of transitions to the excitonic band were studied. The exciton binding energy (Rydberg constant)

0.077–0.086 eV was calculated. The value of the background dielectric constant $\epsilon_b = 8$ and the translational mass of exciton $M = 4m_0$ were determined. The value of the reduced effective mass ($\mu^* = 0.89m_0$), the effective masses of electrons in the bottom conduction band ($m_{c1}^* = 1.3m_0$), and the effective mass of holes in the upper valence band ($m_{v1} = 2.4m_0$) were estimated.

2. Experimental methods

The SnSe crystals grown in the ampoules by the gas transport method were single-crystal blocks 1.5–0.8–0.5 cm in size that could be easily chipped along the soldered plane. The samples with mirrored faces $\sim 7 \times 9$ mm and thicknesses around 70 μm were received by splintering. The thin layers (500–1500 nm) were received by exfoliation with help of adhesive tape. Tin (Sn) and selenium (Se) components in stoichiometric proportion were deposited into a quartz ampoule. The ampoules with compound were evacuated down to $10^{-5} - 10^{-6}$ Torr. The sealed ampoules were deposited into a furnace with two zones (source and growth) with temperature gradient. The first zone where evaporation of source components take place was heated up to 973 K and another end of ampoule, growth zone of crystals, was heated to 923 K. The velocity of ampoule hating was ~ 24 K/h. The ampoule deposited at this temperature range during 80 h for SnSe single crystals growth. Due to temperature gradient the material transport from the source zone into the growth zone takes place. The grown crystals quality was controlled by XRD measurements. Fig. 1 illustrates XRD pattern of a sample and insert shows images of investigated SnSe crystals.

Reflection spectra at room temperature on spectrophotometer Specord-M40 were measured. Transmission, and wavelength modulated

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