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Birefringence of $CuGa_xAl_{1-x}Se_2$ crystals

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Abstract
Excitonic reflection spectra of $CuAlSe_2$ crystals were studied at 10 K. The spectral dependences of refractive indices n_o and n_e were calculated. The isotropic wavelength (the point of intersection of n_o and n_e) in the excitonic region was determined. The spectral dependence of $\Delta n = n_o - n_e$ was studied on the long-wavelength and short-wavelength sides of the isotropic wavelength of $CuGa_xAl_{1-x}Se_2$ crystals. Up to 15 narrow transmission (absorption) lines were revealed in the interference spectra of thin crystals, which can be used for the development of comb filters.

Keywords: polaritons, absorption and reflection spectra, semiconductors, optical constants, birefringence

(Some figures in this article are in colour only in the electronic version)

1. Introduction

$CuGaSe_2$ and $CuAlSe_2$ compounds as well as their solid solutions that belong to $I–III–VI_2$ group semiconductors crystallize into a chalcopyrite structure with the space group I^4_{2d}–D^{12}_{2d}. Optoelectronic devices and solar cells are developed on the basis of these materials [1–4]. Photoluminescence properties of $CuAlSe_2$ crystals doped with Er^{3+} ions [3] and photoelectrical properties of surface barrier structures based on $CuAlSe_2$ crystals have been previously investigated [4–6]. These compounds possess a strong anisotropy of optical properties both in the visible and infrared spectral range. Some optical and transport measurements were carried out on $CuGaSe_2$ thin films and single crystals [7–18], and values of the fundamental gap and its temperature dependence, the crystal field and spin–orbit valence band splitting, as well as phonon and exciton parameters and the defect level schema were reported. The energy band structure of I–III–VI compounds has been calculated as the nearest zinc blende analogue [19, 20].

I–III–VI_2 chalcopyrite crystals possess anisotropy of the transmission (absorption) spectra at the fundamental absorption edge. Absorption spectra measured in $E \parallel c$ and $E \perp c$ polarizations demonstrate different spectral characteristics due to different spectral characteristics of the ordinary refractive index n_o for $E \parallel c$ polarization and the extraordinary refractive index n_e for $E \perp c$ polarization. The spectral characteristics of the refractive indices intersect at a certain wavelength λ_0. There is no anisotropy at this wavelength [21–23]. The following isotropic wavelengths have been determined: $\lambda_0 = 536$ nm for $CuAlSe_2$ crystals, $\lambda_0 = 642$ nm for $CuGaS_2$ crystals [23], $\lambda_0 = 811$ nm for $AgGaSe_2$ crystals and $\lambda_0 = 810$ nm for $CuGaSe_2$ crystals [23, 24]. The transmission spectra of such crystals, measured with cross-oriented polarizers and the optical axis of the crystal oriented parallel to the polarization of one of the polarizers, are characterized by a narrow transmission band localized at the wavelength of the isotropic point (IP) (i.e. the system works as a band-pass-mode filter) [25–32]. In contrast, a thin absorption line is observed in the same spectral range with parallel-oriented polarizers (band elimination filter).

2. Experimental details

Plate-like $CuAl_{1-x}Ga_xSe_2$ crystals with 2.5×1.0 cm^2 mirror surfaces and 15–600 μm thickness have been grown by vapor phase transport. The surfaces of some platelets were parallel to the C axis. The optical transmission and reflectivity spectra were measured with a double spectrometer SDL-1 (figure 1). The light from a halogen lamp was focused on a system of parallel-oriented or crossed cross-oriented Glan–Thompson polarizers. An anisotropic crystal was placed between the polarizers. The samples were mounted on the cold station of

