Luminescence and Reflection Spectra of $Sn_2P_2Se_6$ Semiconductors-Ferroelectrics at Low Temperatures

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Abstract

We present the luminescence and reflection spectra of semiconductor-ferroelectric $Sn_2P_2S_6$ crystals obtained at T=2K. It is found that the photo-excited luminescence has, most probably, exciton origin. The shape of the luminescence band indicates that the luminescence is presumably related to existence of excitons confined by inhomogeneous local field.

Keywords: $Sn_2P_2S_6$ crystals, luminescence spectrum, reflection spectrum, exciton, semiconductor, ferroelectrics

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Introduction

In comparison with bulk materials, the structures with superlattices manifest a number of advantages, when being applied in optoelectronics and nonlinear optics (see, e.g., [1]). There are the quantum well structures, periodically poled ferroelectric crystals, photonic crystals, etc. In particular, the electro-absorption coefficients of multiple quantum-well structures are approximately 50 times larger than those peculiar for the bulk semiconductors [2], owing to the quantum confinement Stark effect [3]. The corresponding modulation rate rises up to 20Gbit/s and the increased bandwidth reaches GHz range [4-6]. However, a serious problem of practical applications of quantum size effects is difficulties that appear when the quantum well structures are prepared with the standard techniques of molecular beam epitaxy or metal-organic chemical vapour deposition [7]. Besides of these artificial structures, requiring high-level technology, incommensurate phases occurring in ferroelectric crystals attract a strong interest, because their periodicity is "spontaneous" and the period amounts typically to tens of the lattice periods. In our recent paper [8], we have shown theoretically that the incommensurate superstructure has fundamentally different parameters of the electron spectrum (or the density of electron states), when compare with the basic uniform structures. It has also been found that the positions of electron levels are sensitive to the ratio of periods for the crystal field and the perturbation potential, as well as the crystal bandgap value and its changes due to variations of the spatial modulation period [9]. Below we report the experimental study of the exciton luminescence on the example of ferroelectric-semiconductor $Sn_2P_2Se_6$. This is achieved by means of photoluminescence spectroscopic technique.

Experimental

In their paraelectric phase, $Sn_2P_2Se_6$ crystals belong to the point group *2/m*. They undergo a phase transition at T_c=193K into the ferroelectric phase exhibiting the *m* symmetry. Between the ferroelectric and paraelectric phases, a spatially-modulated incommensurate phase appears in the temperature region of T_c=193 K < T < T_i = 221 K (see, e.g., [10]). "Lock-in" phase transition at T_c is of the first order, whereas the transition from the paraelectric phase at T_i is the second-order one. According to the results of X-ray diffraction studies, the wave vector of the modulated structure is temperature dependent and varies from k=1.5×10^{-2}A^{-1} at T_i to k=1.25×10^{-2}A^{-1} at T_c [11]. $Sn_2P_2Se_6$ crystals may be considered as semiconductors, owing to their relatively narrow bandgap (E_g=1.7 eV at T=293K [12]).

The photoluminescence in these crystals was excited with the ion Ar laser (λ=514.5nm) and studied at the liquid-helium temperature. The spectra were recorded with the aid of grating spectrometer MDR-3 equipped with a cooled FEU-62 photomultiplier tube. The reflection spectrum was obtained with the same experimental setup, using a tungsten lamp as a light source.

Results and discussion

The photoluminescence spectrum of $Sn_2P_2Se_6$ crystals is displayed in Fig. 1. It is clearly seen that the spectrum consists of a single luminescence band, which is rather intense, slightly asymmetric and has its centre at the wavelength of λ=765nm.

The light reflection spectrum is presented in Fig. 2. One can see that the peak at λ=765nm exists in the reflection spectrum, too. We have also observed a weak reflection anomaly at λ = 550nm, which does not manifest itself in the luminescence.

Both the high intensity and the shape of the luminescence band are quite similar to those of the spectrum characteristic for excitons confined by inhomogeneous local field [13]. In the case of ferroelectric crystals, such the inhomogeneities can be naturally connected with spatial variations of the spontaneous polarization occurring in the vicinity of domain walls.

Conclusion

As a result of the present study, one can conclude that $Sn_2P_2S_6$ crystals manifest photo-exited luminescence at T=2K which, most probably, could be explained as the excitons luminescence. Following from the shape of the luminescence band, we assume that it is associated with the existence of excitons confined by inhomogeneous local field. In the case of ferroelectric crystals, this inhomogeneous field may arise from the changes in the spontaneous polarization that happen in the vicinity of domain walls.

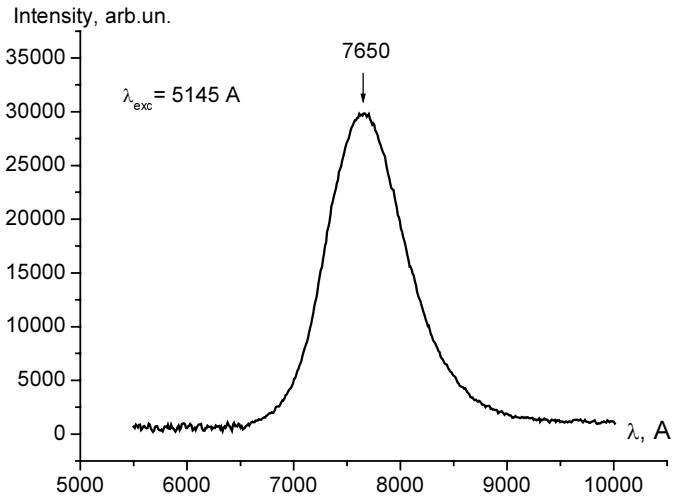

Fig. 1. Photoluminescence spectrum of $Sn_2P_2Se_6$ crystals at T=2K.

Fig. 2. Reflection spectrum of $Sn_2P_2Se_6$ crystals at T=2K.

The subsequent results on the subject will be reported in a forthcoming paper.

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References

1. Hunsperger R.G. Integrated optics: Theory and technology. Springer Verlag 5th Ed. 2002.
2. Chemia D.S., Damen T.C., Miller D.A.B., Gossard A.C. and Wiegmann W. Appl. Phys. Lett. **42** (1983) 864.
3. Miller D.A.B., Chemia D.S., Damen T.C., Gossard A.C., Wiegmann W., Wood T.H. and Burrus L.A. Phys. Rev. Lett. **53** (1984) 2173.
4. Chao P.S., Mahgerefteh D. and Coldhar J. IEEE Photonics Tech. Lett. **11** (1999) 1662.
5. Kuri T., Kotaka I., Stohr A. and Ogawa Y. IEEE J. Lightwave Tech. **17** 799 (1999).
6. Ajisawa A., Fujiware M., Shimizu J., Sugimoto M., Uchida M. and Ohta Y. Electron. Lett. **23** (1987) 1121.
7. Goldstein C., Stark C., Emory J., Gaberit F., Bonnevie D., Poingt F. and Lambert M. J. Cryst. Growth **120** (1992) 157.
8. Vlokh R., Vlokh O. and Lukiyanets B. Ukr. J. Phys. Opt. **5** (2004) 46.
9. Lukiyanets B.A. Ukr. J. Phys. Opt. **5** (2004) 147.
10. Slyvka V.Yu. and Vysochanskii Yu.M. Ferroelectrics of $Sn_2P_2S_6$ family. Properties around the Lifshitz point. Uzhgorod "Zakarpattya" (1994) 264p. (in Russian).
11. Barsamian T.K., Khasanor S.S. and Shekhtman V.Sh. Ferroelectrics **138** (1993) 63.
12. Slivka O., Gerzanych E., Shusta V. and Guranich P. Izv. Vuzov Russ. Akad. Nauk, Ser. Fiz. **9** (1999) 23 (in Russian).
13. Rashba E.I. and Sturge M.D. Excitons "North Holland Company" 1982.